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DIETARY PATTERNS IN CHILDREN

Associations with ethnicity, socioeconomic position, BMI and body composition

Viyan Rashid

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	dr.ir. E. Corpeleijn
	dr. T.L.S. Visscher

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CHAPTER 1

General introduction

Background

Adequate nutrition in childhood is essential for optimal growth and development in both childhood and later life (1). Unhealthy diets in childhood increase the risk of noncommunicable diseases (e.g. cardiovascular disease, diabetes or musculoskeletal disorders) (2, 3), poorer mental health and lower learning abilities (4). In addition to that, unhealthy diets are also a risk factor for suboptimal weight development (5-7). The prevalence of overweight and obesity is rising in the majority of the countries within the WHO European Region (8). In many high-income countries, prevalence of overweight is higher in children originating from low- and middle-income countries (9-12) or when the parents had a lower socioeconomic position (SEP) (8, 13-16). These differences between groups are already present early in life (11, 17, 18). Obesity in childhood tracks into adolescence (19, 20) and later into adulthood (21, 22) and this process is even more pronounced in children originating from low- and middle-income countries and in groups with a lower socioeconomic position. Concurrently, there is evidence for a growing prevalence of underweight in higher SEP children originated from high-income countries (23-25). Although it is not clear how important this trend is for clinical practice, both underweight and overweight/obesity are a risk factor for health problems at young age and later in life (27-32). Therefore it is important to develop healthy eating habits from early childhood and focus on optimal weight development (33).

Dietary patterns

Intake of foods tends to cluster and therefore studying dietary patterns may better capture the totality of the diet then single foods or nutrients (34, 35). Dutch and other national dietary guidelines made a shift from focusing on intake of single nutrients to a more food-based dietary guideline (36). The current Dutch Dietary Guidelines are translated at the level of foods and food patterns and are in line with dietary patterns that have been associated with health benefits such as Mediterranean diet, the 'Dietary Approaches to Stop Hypertension' (DASH-) diet and a vegetarian diet (37). Overall, these dietary patterns include high intakes of plant-based staple foods such as vegetables, fruit, wholegrain products, nuts, legumes, low-fat dairy products and fish; and low intakes of animal-based foods such as red or processed meat, full-fat dairy products, hard fats, salt or drinks or products with added sugar (37). Despite these recommendations, children consume more often Western dietary patterns that are characterized by high intakes of energy-dense, high-processed foods and low intakes of fruit and vegetables (38-40). And these ultra-processed foods are associated with adverse health outcomes as cardio-metabolic risks (41-43), asthma (42, 44) and increased body fatness (41, 45-47) in children and adolescents. Dietary patterns that are once established in childhood, may track into mid-childhood (48), adolescence (49-53) and adulthood (53, 54). Therefore it is of extra importance to develop healthy dietary patterns from early childhood. By identifying the most relevant determinants of these dietary patterns, public health care professionals will be able to use this information in interventions to possibly target children at risk for unhealthy dietary patterns from early childhood.

Role of ethnicity and socioeconomic position

Although dietary patterns are population specific (55, 56), there is limited evidence about ethnic differences in dietary patterns in young children. Few studies described ethnic differences in dietary patterns in pre-school children and findings are mixed. These studies observed that children originating from low- and middle-income countries consumed unhealthy dietary patterns more often (7, 57), healthy dietary patterns less often (7) but also consumption of both a healthy and a unhealthy dietary pattern are observed (58, 59). In Europe, the Avon Longitudinal Study of Parents and Children (ALSPAC) cohort divided the study population into white and non-white ethnicity and observed that a 'junk' pattern was related to white ethnicity at age 4 and 7 (60) a healthy pattern was related with non-white ethnicity at age 2 (61). However the distinction between ethnic groups as white/non-white does not do justice to the diversity of ethnicities in Europe. Based on earlier food consumption data in the Netherlands and studies among adults, we expect to observe differences in dietary intake between ethnic groups (62-64).

Socioeconomic differences in dietary patterns in children have frequently been described (57, 65-70). A number of studies described that lower maternal education is associated with unhealthy dietary patterns in children (57, 65, 66, 69, 71, 55, 60). Maternal education is an important determinant of children's diet (72-74) and consequently most literature focuses on the role of maternal education as a proxy for SEP. SEP however, is a multidimensional construct (75, 76) and in children, SEP impacts well-being at multiple levels, including individual and neighbourhood level (75, 76). Besides the existing literature about the role of maternal education, there has been less consideration of how other SEP factors influence dietary patterns in young children. On an individual level, paternal education can be linked to dietary patterns through knowledge and attitudes but its role in children's diets may reflect gender roles (72). Additionally, household finance, may be indicative of the potential to purchase a healthy diet (77, 78). At neighbourhood level, there is evidence that individuals living in low-income neighbourhoods are subject to a greater degree of food advertising (79), have greater accessibility to unhealthy food establishments and have lower accessibility to healthy food stores (77, 80). At the same time, there is evidence that the importance of dietary costs for dietary quality differs between ethnic (81) and SEP groups (81, 82).

In recent decades, European populations have become increasingly ethnically diverse (83, 84) and children originating from low- and middle-income countries are often disproportionately represented in lower SEP groups (83, 85). For this reason, ethnicity and SEP cannot be studied separately from each other. The prevalence of childhood obesity is not only unevenly distributed across ethnicity and SEP, it is also unevenly distributed across neighbourhoods (86). This can be related to ethnic and individual socioeconomic factors of residents in the neighbourhood, but also possible related to neighbourhood SES factors which reflect the food environment by the type of foods that are available (79, 87) and advertisements that are present (86). And one may argue to which extent observed ethnic differences in dietary patterns in children are also driven by socioeconomic factors (58). So it is of importance to study the role of both ethnicity and different levels of SEP in dietary patterns, and identify groups at higher risk of unhealthy dietary patterns.

Textbox 1: Terminology of ethnicity

Ethnicity

In this thesis we focus on ethnicity in its role as a cultural determinant of health and dietary patterns. Ethnicity encompasses a broad range of characteristics, including shared origins, cultural traditions, common sense of identity, language or religious tradition and links to a particular geographic region. In this dissertation we have used a number of different terms to designate ethnicity. In Chapters 2, 4 and 6, we have used the terms: ethnic minority groups, non-native groups, non-western origin and non-native ethnicities. In the general introduction and discussion of this thesis we instead used the terms: children originating from low- and middle-income countries, Dutch, African Surinamese, Turkish or Moroccan children, children from Dutch, non-Dutch, African Surinamese, Turkish or Moroccan origin.

Surinamese children

The majority of Surinamese children are of either African or South (East) Asian origin. The African Surinamese group has a mixed African and European ancestry, the South Asian group originated from the Indian sub-continent and the South East Asian group originated from southern Asian countries as for example Indonesia. In this thesis we include Surinamese children of African origin, thus, in Chapter 2 where we include the group 'Surinamese children' we are referring to African Surinamese. In Chapter 4,6, and the general introduction and discussion of this thesis, we chose to identify the group more specific by using the term 'African Surinamese' descent.

Textbox 2: Terminology of socioeconomic position

The term socioeconomic position (SEP) indicates the extent to which a person has access to resources and opportunities, and how this affects living conditions and health. It is usually based on determinants at individual level, such as educational level, income and occupation which relate to different underlying causal mechanisms. In children, SEP impacts well-being at multiple levels, including individual and neighbourhood level. In this thesis, we included maternal education level, paternal education level, and the level of household finance as socioeconomic determinants at individual level. We have also included neighbourhood socioeconomic status (SES) as an determinant at neighbourhood level, which is assessed based on a composite score including educational level, household income and employment status of residents per postal code.

In Chapters 2, 3, 4 and 6, we have used the previously more common term socioeconomic status (SES) instead of the term SEP. SES however describes the position of a person, usually at determinants as educational level, income and occupation, which however can also reflect a value judgment. In the general introduction and discussion of this thesis we used the terms SEP instead of SES.

Dietary patterns and BMI and body composition

A number of studies have observed cross-sectional or longitudinal associations between dietary patterns and Body Mass Index (BMI) or body composition in children in Western European countries (50, 88-95). In general, dietary patterns containing of 'obesogenic foods' (including energy-dense and low-fiber ultra-processed foods, fatty cheeses, sugary drinks, processed foods, fast food, candies, snacks, cakes, animal products, whole milk, and refined grains) were associated with higher risk of becoming overweight in children and adolescents. While dietary patterns containing 'healthy foods' (including low levels of sugar and fat and high levels of fruits, vegetables, whole grains, fish, nuts, legumes, and yogurt) showed the weakest association with the risk of becoming overweight or obese (6, 89, 90, 94, 96). Although it is convincing that there is an association between dietary patterns and weight and weight development in young children, the evidence in the existing literature is not straightforward as illustrated by studies that indicate counterintuitive results (92, 95). Body mass includes both fat mass as well as lean mass and bone mass (97, 98). Increased BMI may be caused by increased fat mass or increased lean mass, or both (99). Given the observed mixed associations, it is essential to gain knowledge about the role of dietary patterns in weight development, and also to study measures of body composition as Fat Mass (FM) and Fat Free Mass (FFM) in this association. Furthermore, it is essential to study if these dietary patterns are relevant for ethnic and SEP subgroups among children.

Aims

Exploring the potential ethnic and socioeconomic differences in dietary patterns in young children and associations with weight development, may provide new and more specific insight for public healthcare professionals to identify groups with unhealthy dietary patterns in order to contribute to the prevention of childhood overweight.

Research questions

The research in this thesis aims to define dietary patterns at age 5 using three different methods. And examine associations with ethnicity, socioeconomic determinants, longitudinal BMI and body composition. The following research questions will be addressed in this thesis (Figure 1.1), using data from the Amsterdam Born Children and their Development (ABCD) study (100):

1. Which dietary patterns can be defined in 5 year old children?
    a. In an a posteriori derived method (Chapter 2)
    b. In an a priori derived method (Chapter 5)
    c. In a hybrid method (Chapter 6)
2. Which ethnic and socioeconomic determinants are associated with the derived dietary patterns? (Chapters 2, 3 and 5)
3. To which extent are the derived dietary patterns associated with longitudinal BMI and measures of body composition? (Chapters 4, 5 and 6)

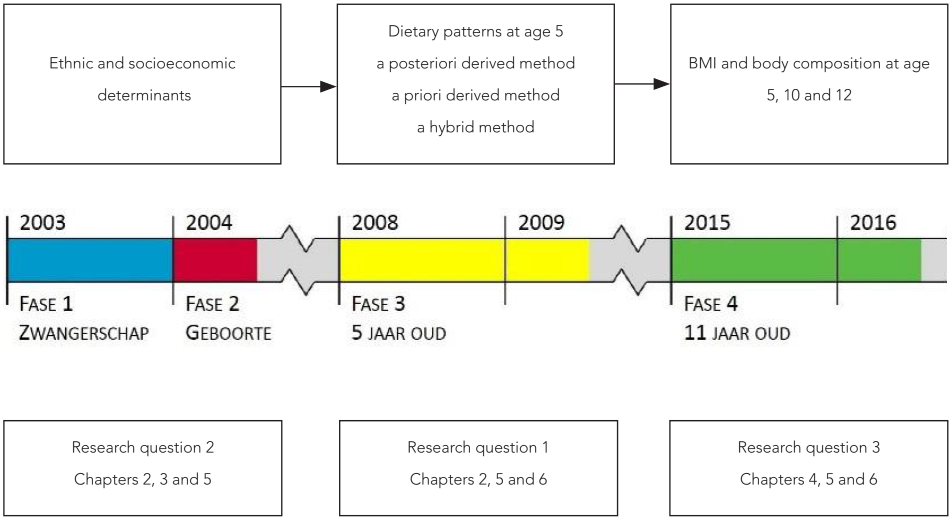

Figure 1.1: The associations investigated in this thesis: In research question 1, dietary patterns are derived using three different methods. Research question 2 addresses the association between ethnicity, socioeconomic determinants and the derived dietary patterns are investigated. In research question 3, the association between the derived dietary patterns and longitudinal BMI and measures of body composition are described.

Chapter 2 of this thesis describes dietary patterns in children using the a posteriori Principal Component Analyses (PCA) and the association with ethnicity and SEP. Chapter 3 focuses on the socioeconomic determinants of the PCA-derived so called snacking pattern. Chapter 4 describes weight development between age 5 and 10 years and its association with all PCA-derived dietary patterns. In Chapter 5, an a priori method (diet quality score) was used to determine diet quality and associations with longitudinal BMI and body composition between age 5 and 10. And finally Chapter 6 describes the use of a hybrid method Reduced Rank Regression (RRR) to derive dietary patterns that are related to BMI and body composition, and the association with longitudinal BMI and body composition.

Methods and design

The Amsterdam born children and their development (ABCD) study

Textbox 3: Study design and population

The ABCD-study is a multi-ethnic population based, prospective, ongoing longitudinal birth cohort (http://www.abcd-study.nl/). The aim of the ABCD-study was to determine early-life factors that might explain differences in health between children from different groups in later life. Between January 2003 and March 2004, all pregnant women living in Amsterdam, the Netherlands, were invited to participate in the ABCD cohort by their obstetric care provider at their first parental care visit. Of the 12,373 women approached, 8,266 women filled out a pregnancy questionnaire. When the children turned 5 years of age, the addresses of 6,161 mothers were retrieved from the Youth Health Care registry of the Public Health Service Amsterdam. A 5-year questionnaire was sent to the woman's home address and 4,488 questionnaires were filled out by the mothers. These woman's received a invitation for a health check of their child which was completed by 3,321 children. Also, a self-administered Food Frequency Questionnaire (FFQ) was send out. A number of 2,851 mothers returned the FFQ. At age 10, an invitation was sent for a regular preventive health check of the child, arranged by the Youth Health Care Department of the Public Health Service Amsterdam, carried out at their primary school. At age 12, an invitation was sent for a another health check of the child within the framework of the ABCD study, which was conducted by a team of trained researchers (Figure 1.2).

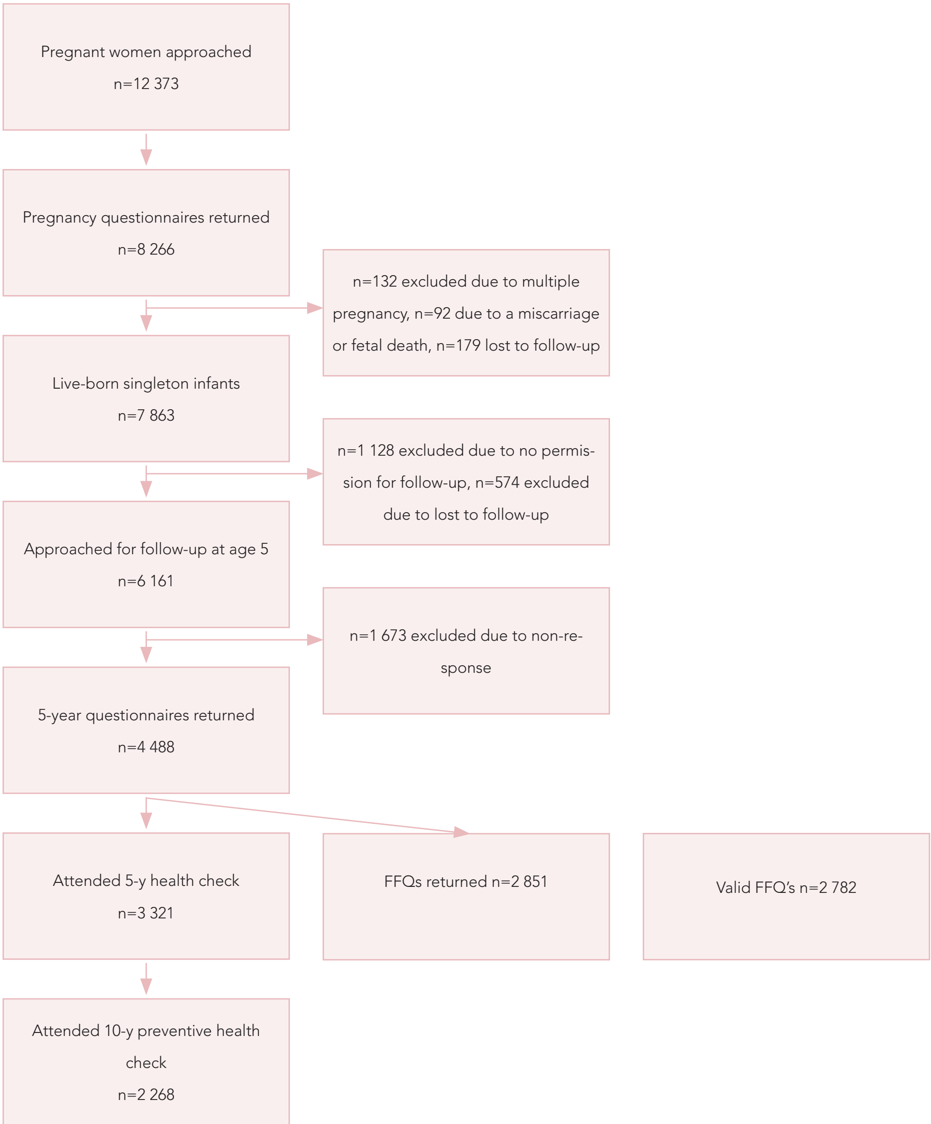

Figure 1.2: Inclusion of the participants in this thesis.

Assessment of dietary patterns

Dietary intake was assessed using a semi-quantitative FFQ which was developed by TNO Food (Zeist, The Netherlands) and was validated for energy intake against the doubly labelled water method (101). This FFQ was filled out by the mother of the child and included questions on food items, frequency of consumption, portion sizes, and type of products consumed, covering the last 4 weeks. Based on the data clearance protocol developed by TNO Food, the returned FFQs were scanned and the data on amounts (g/day) of products consumed and intake of energy was calculated using the Dutch Food Composition Database (NEVO) 2010 (102).

Generally a data-driven method (a posteriori), a hypothesis-driven method (a priori) or a combination with these two methods have been used to describe dietary patterns in children (67). The first method to derive dietary patterns was the a posteriori method PCA. PCA is a data-driven method that derives dietary patterns based on the correlations between consumed food items. PCA tends to explain as much variation in dietary intake as possible, and can therefore represent actual dietary habits in a study population. Food items, including different type of products, were reduced to 41 food groups, based on nutritional value and culinary use. In this thesis, we were interested in the effect of dietary quality independent of its energy content and adjusted for total energy intake using the nutrient residual method (103, 104). Standardized energy adjusted intake (g/d) of the 41 food groups were used in the PCA analysis with varimax rotation. Secondly, we applied the a priori diet quality score. Assessing a diet quality score is an example of a hypothesis-driven method, in which prior knowledge in the form of specific dietary guidelines or recommendations is used to define an individual score that reflects the dietary intake compared to the guideline or recommendation. In this thesis, we applied a previously developed predefined diet quality score for school-age children (105), which quantified adherence to the Dutch Dietary Guidelines for children at age 5 (37). Although PCA derived dietary patterns and a diet score both reflect several advantages, these methods do not include specific health related information of the study population. Therefore Reduced Rank Regression (RRR) was used as a third method to derive dietary patterns. This method is combining both the a posteriori and the a priori method, by deriving dietary patterns in an exploratory way but based on a priori knowledge used in the selection of response variables that are thought to link dietary patterns to disease risk (106). In this thesis, RRR was used to derive dietary patterns for the response variables BMI z-score, FMI, and FFMI at age 5 and this analysis was conducted separately for each maternal education level group. In line with the PCA analyses, the energy adjusted intake (g/d) of 41 composed food groups were used to derive dietary patterns using the RRR method.

Assessment of BMI and measures of body composition

Data on height and weight were measured at age 5 and 12 during the ABCD 'health check' and at age 10 during the preventive Health Check at the children's primary school. At age 5 and 12, they were measured by a team of trained researchers according to standard protocols and at age 10 by a professional of the Youth Health Care Department of the Public Health Service Amsterdam. Height and weight were converted to BMI scores [weight (kg) / height (m)2]. Age- and sex-specific BMI cut-offs from the International Obesity Task Force (32, 107) were used to categorize the BMI scores into underweight, normal weight and overweight/obesity. BMI scores were also converted to age- and sex-specific BMI z-scores (SD scores), by comparison with the 'World Health Organization standards' (108). Additionally, weight development in children is often defined by Body Mass Index (BMI) as an outcome measure. However, especially in young children, the use of general measures like BMI is not an adequate measure of body fatness, as body mass includes both fat mass (FM) as well as fat free mass (FFM) consisting of lean mass and bone mass (97, 98). Increased BMI may be caused by increased FM or increased FFM, or both (99). Therefore, it's important to consider both FM and FFM as additional proxy's for healthy weight development. At age 5 and 12, components of body composition were measured during the ABCD 'health check' were children were measured by a team of trained researchers according to standard protocols. Fat Mass (FM) with arm-to-leg bioelectrical impedance analysis (BIA) was measured (Bodystat 1500 MDD machine (Bodystat Inc, Douglas, UK)), Fat Free Mass (FFM) was measured (weight(kg) - FM) and fat mass index (FMI) (fat mass (kg) / height (m)2) and fat-free mass index (FFMI) (fat-free mass (kg) / height (m)2) were calculated.

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CHAPTER 2

Ethnicity and socioeconomic status are related to dietary patterns at age 5 in the Amsterdam born children and their development (ABCD) cohort

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Abstract

Background

Health inequalities are already present at young age and tend to vary with ethnicity and socioeconomic status (SES). Diet is a major determinant of overweight, and studying dietary patterns as a whole in relation to overweight rather than single nutrients or foods has been suggested. We derived dietary patterns at age 5 and determined whether ethnicity and SES were both related to these dietary patterns.

Methods

We analysed 2769 validated Food Frequency Questionnaires filled in by mothers of children (5.7 ± 0.5y) in the Amsterdam Born Children and their Development (ABCD) cohort. Food items were reduced to 41 food groups. Energy adjusted intake per food group (g/d) was used to derive dietary patterns using Principal Component Analysis and children were given a pattern score for each dietary pattern. We defined 5 ethnic groups (Dutch, Surinamese, Turkish, Moroccan, other ethnicities) and 3 SES groups (low, middle, high, based on maternal education). Multivariate ANOVA, with adjustment for age, gender and maternal age, was used to test potential associations between ethnicity or SES and dietary pattern scores. Post-hoc analyses with Bonferroni adjustment were used to examine differences between groups.

Results

Principal Component Analysis identified 4 dietary patterns: a snacking, full-fat, meat and healthy dietary pattern, explaining 21% of the variation in dietary intake. Ethnicity was related to the dietary pattern scores ($p < 0.01$): non-Dutch children scored high on snacking and healthy pattern, whereas Turkish children scored high on full-fat and Surinamese children on the meat pattern. SES was related to the snacking, full-fat and meat patterns ($p < 0.01$): low SES children scored high on the snacking and meat pattern and low on the full-fat pattern.

Conclusions

This study indicates that both ethnicity and SES are relevant for dietary patterns at age 5 and may enable more specific nutrition education to specific ethnic and low socioeconomic status target groups.

Background

Health inequalities, such as the prevalence of overweight, are already present at a young age and tend to vary on the basis of ethnicity and socioeconomic (SES) status [1–3]. Diet is a major determinant of overweight [4–6], and studying dietary patterns as a whole in relation to overweight rather than single nutrients or foods has been suggested [7–9]. Dietary patterns are population specific and influenced by sociocultural factors and food availability [10, 11]. In recent decades, European populations have become increasingly ethnically diverse and ethnic minority groups are often disproportionate in lower SES groups [12]. The predominant ethnic minority groups, i.e. Turkish, Arabs (North African and Middle Eastern), Berbers and Black Africans (Afro-Caribbean and others by descent), form approximately 3% of the total European population, with the largest numbers in Western European countries [13]. Non-native groups have less often completed higher education than native borns [14] which makes observation of SES differences also of interest. Socioeconomic differences in dietary patterns have been described in adults. In children, SES differences in dietary patterns has been observed in several studies including 4 prospective birth cohorts in 3 countries in Europe, i.e. The Avon Longitudinal Study of Parents and Children (ALSPAC) cohort, the EDEN mother-child cohort, the Norwegian Mother and Child Cohort Study and the Southampton Women's Cohort Survey [15–23]. Data on ethnic differences in dietary patterns among children is limited [24]. To our knowledge, only the ALSPAC cohort identified an association between ethnicity dividing the study population into white and non-white ethnicity [18, 19]. However, the diversity of ethnic groups in Western Europe is more pronounced and we expect to observe differences in dietary intake between ethnic groups [25–27]. Exploring the potential ethnic diversity as well as socioeconomic differences in dietary patterns in children may provide new and more specific insight for public healthcare professionals to identify groups with poor dietary habits.

Therefore, the aim of the present study was to derive dietary patterns at age 5 in the multi-ethnic Amsterdam Born Children and their Development (ABCD) cohort and to examine potential associations with either or both ethnicity and SES.

Methods

Study design and study population Data were used from the ABCD study, a large ongoing community-based birth cohort (http://www.abcdstudy.nl/). The cohort study design has been described previously [28]. Figure 2.1 shows the study procedure and inclusion in the current analysis. In brief, between January 2003 and March 2004, all pregnant women living in Amsterdam were invited to participate in the ABCD study by their obstetric care provider at their first prenatal care visit. Of the 12,373 women approached, 8266 women filled out a pregnancy questionnaire that covered socio-demographic characteristics, obstetric history, family history and lifestyle, which was available in Dutch, English, Turkish and the Arabic language. When the children turned 5 years of age, 4488 received a self-administered Food Frequency Questionnaire (FFQ) by post and a number of 2851 mothers returned the FFQ. Based on a data clearance protocol set by TNO Food (Zeist, The Netherlands), children were excluded from analysis with more than 50% missing per page or per cluster of food items (n = 69). Finally, 13 children were excluded as years of education of the mother was not available in the pregnancy questionnaire, resulting in 2769 children included in the present analysis. Efforts to enhance participation among all women and children, regardless of ethnicity and education were done by using translated questionnaires and information leaflets. Also, women from ethnic minority groups who did not respond within a month were approached by phone by trained students who explained the study in the women's preferred language. Attrition in follow-up number was largely attributable to untraceable changes in address or migration. This study was approved by the institutional review committee of the Academic Medical Center, and the Registration Committee of Amsterdam. All of the participants gave written informed consent for themselves and their children. The present study was conducted according to the guidelines laid down in the Declaration of Helsinki.

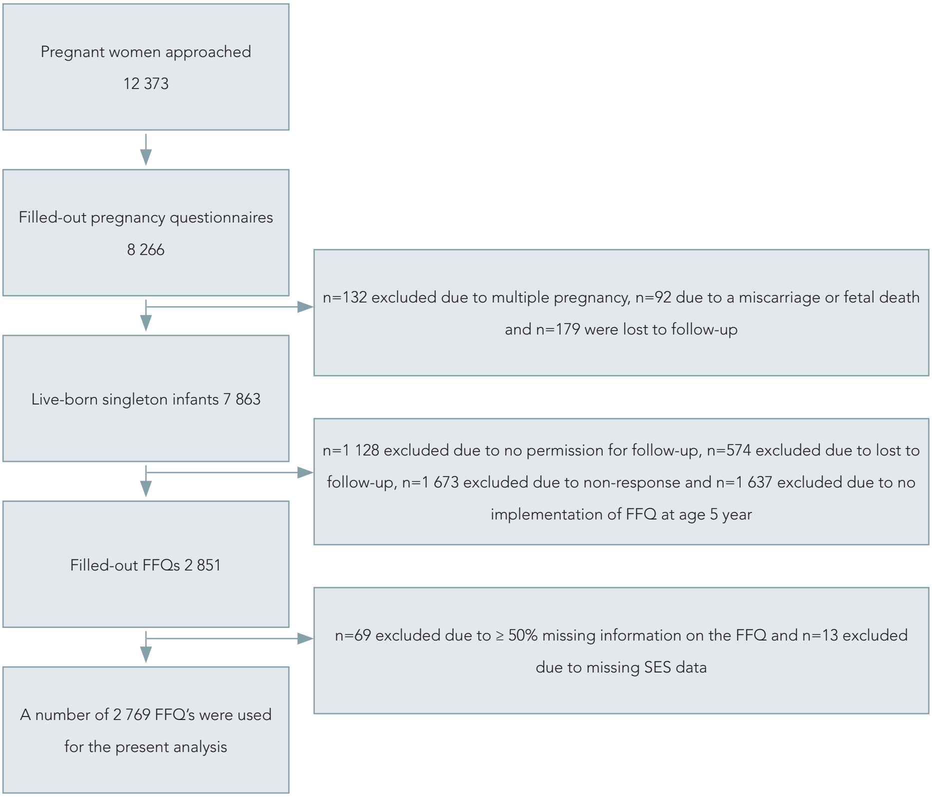

Figure 2.1. Flowchart of the inclusion into the present study.

Dietary assessment

A validated 71-item FFQ, developed by TNO Food (Zeist, The Netherlands) was used [29]. Per food item, consumption frequency, portion size and the type of product consumed over the last 4 weeks was reported by the mother of the child. Frequency options were "never", "less than once a week", "once a week", "2–3 times a week", "4–5 times a week", and "6–7 times a week". Food items were assessed in units (e.g. a piece of fruit and a slice of bread) and in household units (e.g. a glass and a tablespoon). Intake of items such as breakfast cereals, vegetables or pasta were asked in standard tablespoons which could give a reliable idea of the actual eaten portion size for children. Based on the data clearance protocol developed by TNO Food, the returned FFQs were scanned and the data were checked for inconsistencies or extreme values. Impossible values were defined as portion sizes larger than the maximum portion size consumed in the Dutch Food Consumption Survey and were imputed by the mean. For example a maximum of 6 tablespoons of cooked vegetables (180 g) per day was substituted when a higher amount was filled in. Frequencies and portion sizes were converted into weights (g/day) of product consumed and intake of energy was calculated using the Dutch Food Composition Database (NEVO) 2010 [30]. Each food item in the questionnaire was linked with one or more foods from the Dutch Food Composition Database. In total, a number of 308 different NEVO codes were used for analysis. After calculation of the scanned FFQs, inconsistencies in energy intake for those children with the 5% highest and 5% lowest intake of energy were checked with the original FFQ. When the FFQ was filled in correctly, FFQ's of these children were not excluded as we expect that these high or low energy intakes might reflect a realistic intake.

Assessment of ethnicity and socioeconomic status

Data on ethnicity and SES was collected via the pregnancy questionnaire, filled out by the mother during the baseline measurements of the ABCD study. Five ethnic categories were formed: Dutch, Surinamese, Turkish, Moroccan and other ethnicities (mainly non-western origin). We excluded the Surinamese South Asians because of specific body composition and cardiometabolic risk [31]. Ethnicity was based on the country of birth of the pregnant woman and her mother including both first-generation women (born outside the Netherlands) and second generation women (born in the Netherlands but whose mother was born in another country). When the pregnant woman or her mother were born in a country defined as 'none of the given options': the participant's self-registered ethnic origin was used [32]. The pregnant women's education after primary school was defined in years and considered as a proxy for SES. Low SES was defined as a maximum of 5 years post primary education, middle SES as 6–10 years and high SES was defined as more than 10 years of post-primary education [33].

Assessment of dietary patterns

Principal Component Analyses (PCA) with varimax rotation was used to derive dietary patterns. Food items, including different type of products, were reduced to 41 food groups, based on nutritional value and culinary use. The list with food groups and its type of products can be found in Supplemental Table 2.1. Products such as ginger cake and raisins are often given to children as a healthy alternative for biscuits or candy and were therefore assigned to the food group "healthy snacks". Because we were interested in the effect of dietary quality independent of its energy content, we adjusted total energy intake using the nutrient residual method [34, 35]. Standardized energy adjusted intake (g/d) of the 41 food groups were used in the PCA analysis. The number of components (dietary patterns) retained was based on the scree plot [see Supplemental Figure 2.2], eigenvalues >1 and the interpretability of the dietary patterns [36, 37]. Food groups with component loadings ≥0.3 were considered important for interpretability of the dietary patterns. A larger absolute factor loading indicates a higher positive or negative correlation between the food group and a given dietary pattern. The patterns were named after the nature of the food groups with the highest component loadings within each pattern. Individuals were given a pattern score for each pattern as a sum of the 41 standardized food group intakes, each weighted according to their factor loading. Positive pattern scores indicate higher consumption of food groups in that pattern.

Statistical analysis

Statistical analyses were performed in SPSS version 22 for windows. Population characteristics were described in percentages or means with standard deviations (SD), shown for the total population and by ethnicity. Univariate and multivariate ANOVA was used to determine whether ethnicity and/or SES were related to dietary patterns with the individual pattern score of each dietary pattern used as continuous dependent variable and ethnicity or SES used as independent variables (Model 1; crude). The association with ethnicity was additionally adjusted for SES (dummy) and the association with SES was additionally adjusted for ethnicity (dummy) (Model 2). In the fully adjusted model (Model 3) the association with ethnicity was adjusted for child's age (y), gender, maternal age (y) and SES (dummy) and the analysis with SES was adjusted for age (y), gender, maternal age (y) and ethnicity (dummy). Mean ± SE pattern scores were shown for each of the dietary patterns by ethnic and SES group separately. Post-hoc analyses with Bonferroni adjustment was used to examine differences between groups. Additionally, we tested for interaction by SES in the association between ethnicity and dietary pattern scores. $P < 0.01$ was considered significant.

Results

Population characteristics

Characteristics of the study population, divided by ethnicity are shown in Table 2.1. Mean age of the study population was 5.7 ± 0.5 years and 51% of the population was boy. The percentage of children from Dutch origin was 82.4%, followed by Surinamese (4.2%), Moroccan (4.1%), Turkish (2.2%) and other ethnicities (7.1%). The majority of children (53.3%) belonged to the high SES, 35.4% to middle SES and 11.3% to low SES group.

Table 2.1. Population characteristics in the ABCD cohort by ethnicity (n=2 769).

Population characteristics	Total population (n=2 769)	Dutch (n=2 283, 82.4%)	Surinamese (n=116, 4.2%)	Moroccan (n=112, 4.1%)	Turkish (n=61, 2.2%)	Other ethnicities (n=197, 7.1%)
Age, in year (Mean, SD)	5.7, 0.5	5.7, 0.5	5.8, 0.5	6.0, 0.6	5.9, 0.5	5.7, 0.5
Boy, n (%)	1 415 (51.1)	1 166 (51.1)	58 (50.0)	64 (57.1)	34 (55.7)	93 (47.2)
Socioeconomic status, n (%)						
Low	313 (11.3)	145 (6.4)	38 (32.8)	48 (42.9)	33 (54.1)	49 (24.9)
Middle	980 (35.4)	759 (33.2)	57 (49.1)	55 (49.1)	25 (41.0)	84 (42.6)
High	1 476 (53.3)	1 379 (60.4)	21 (18.1)	9 (8.0)	3 (4.9)	64 (32.5)
Maternal age (Mean, SD)	32.3, 4.3	32.8, 3.8	30.6, 5.8	27.9, 4.9	27.1, 6.0	31.5, 4.8

Ethnicity was based on the country of birth of the pregnant woman and her mother including both first-generation women and second generation women. SES was based on maternal educational: low SES (≤ 6y), middle SES (6-10y) and high SES (≥10y) post-primary education.

Dietary patterns

PCA identified 4 dietary patterns in this cohort explaining 20.8% of the variation of dietary intake, according to the Rotated Sums of Squared Loadings. In Table 2.2, an overview of the component loadings from ≥0.3 is shown per dietary pattern. The snacking pattern was mainly characterized by high intakes of savoury snacks and refined breakfast products and low intakes of whole-grain breakfast products. The full-fat pattern was characterized by high intakes of full-fat spreads and pasta dishes and low intakes of low-fat spreads. The meat pattern was characterized by high intakes of low- and high-fat meat, sauces and refined grain products for warm meals. Finally the healthy pattern was characterized by high intakes on the food groups water and tea, vegetables, fish and fruits.

Ethnicity and dietary patterns

Ethnicity was significantly related to dietary pattern scores ($p < 0.01$, Table 2.3). Post-hoc analyses showed that Dutch children had significantly lower (−0.171 ± 0.019, $p < 0.01$) snacking scores compared to the other ethnic groups, whereas Turkish children had significantly higher (1.363 ± 0.118, $p < 0.01$) snacking scores. After adjustment for SES the associations were less pronounced (−0.124 ± 0.019 for Dutch, 0.998 ± 0.117 for Turkish), but still significant for most groups. Further adjustment for age, gender and maternal age did not change the results (Table 2.3). With respect to the full-fat pattern, Turkish children and children from other ethnicities had higher pattern scores compared to Moroccan children (0.283 ± 0.128 and 0.167 ± 0.071 versus −0.247 ± 0.094, $p < 0.01$), whereas Surinamese children scored higher on the meat pattern (0.589 ± 0.092) compared to the other ethnic groups ($p < 0.01$). Adjustment for SES did somewhat diminish the associations, but not the level of significance (Table 2.3). Further adjustment for other confounding factors yielded similar results (Table 2.3). The healthy pattern was most pronounced within the groups of Turkish and Moroccan children (0.660 ± 0.092 for Moroccan and 0.602 ± 0.125 for Turkish, $p < 0.01$). Adjustment for SES and other factors did not change the results.

Table 2.2. Component loadings (≥0.3) of the 41 food groups per dietary pattern.

Dietary patterns				
	Snacking	Full-fat	Meat	Healthy
Explained variance (%)	7.1	4.6	4.6	4.4
Savory snacks	0.47	-	-	-
Refined breakfast products	0.45	-	-	-
Ice cream	0.42	-	-	-
Sauces	0.41	-	0.35	-
Chocolate and candy	0.38	-	-	-
Fruit drink	0.31	-	-	-
Full-fat dairy	0.30	-	-	-
Low-fat spreads	-0.38	-0.55	-	-
Sandwich toppings (sweet)	-0.38	-	-	-0.33
Whole grain breakfast products	-0.74	-	-	-
Tomato sauce for pasta	-	0.61	-	-
Full-fat spreads	-	0.48	-0.30	-

Refined grain products warm meal	-	0.46	0.34	-
Full-fat cheese	-	0.37	-	-
Low-fat cheese	-	-0.35	-	-
Low-fat meat	-	-	0.44	-
High-fat meat	-	-	0.39	-
Healthy meals	-	-	0.31	-
Boiled potatoes	-	-	0.30	-
Unhealthy meals	-	-	-0.32	-
Peanut butter	-	-	-0.34	-
Water and tea	-	-	-	0.48
Vegetables	-	-	-	0.47
Fish	-	-	-	0.46
Fruits	-	-	-	0.38
Whole grain products warm meal	-	-	-	0.36
Nuts	-	-	-	0.31
Pulses	-	-	-	0.30
Artificially sweetened sodas	-	-	-	-
Biscuits and pastries	-	-	-	-
Egg	-	-	-	-
Fried potato products	-	-	-	-
Fruit drink concentrate	-	-	-	-
Granola bars	-	-	-	-
Healthy snacks	-	-	-	-
Low-fat dairy	-	-	-	-
Meat alternatives and soy products	-	-	-	-
Medium-fat dairy	-	-	-	-
Processed meats	-	-	-	-
Sugar	-	-	-	-
Sugar sweetened sodas	-	-	-	-

a. Rotation converged in 12 iterations.

Component loadings (≥0.3) were considered important for interpretability of the dietary patterns. A larger factor loading indicates a higher positive or negative correlation between the food group and dietary pattern.

Table 2.3. Mean dietary pattern scores by ethnicity in the ABCD cohort (n=2 769).

Dietary pattern	Dutch		Surinamese		Turkish		Moroccan		Other ethnicities		Pvalue ANOVA
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Snacking											
Model 1: Crude	-0.171	0.019 [a]	0.797	0.086 [b d]	1.363	0.118 [a]	0.819	0.087 [b d]	0.626	0.066 [b d]	<0.01
Model 2: SES	-0.124	0.019 [a]	0.576	0.084 [b]	0.998	0.117 [b e f]	0.516	0.087 [b d]	0.491	0.064 [b d]	<0.01
Model 3: Fully adjusted	-0.122	0.019 [a]	0.567	0.084 [b]	0.987	0.119 [b e f]	0.505	0.089 [b d]	0.485	0.064 [b d]	<0.01
Full-fat											
Model 1: Crude	-0.003	0.021	-0.127	0.093	0.283	0.128 [e]	-0.247	0.094 [d f]	0.167	0.071 [e]	<0.01
Model 2: SES	-0.019	0.021	-0.054	0.094	0.409	0.131 [e]	-0.146	0.097 [d]	0.212	0.072	<0.01
Model 3: Fully adjusted	-0.021	0.021 [d]	-0.054	0.094	0.433	0.132 [b e]	-0.136	0.099 [d]	0.217	0.072	<0.01
Meat											
Model 1: Crude	-0.020	0.021 [c]	0.589	0.092 [a]	-0.088	0.127 [c]	-0.001	0.094 [c]	-0.088	0.071 [c]	<0.01
Model 2: SES	0.002	0.021 [c]	0.484	0.093 [a]	-0.253	0.130 [c]	-0.143	0.096 [c]	-0.152	0.071 [c]	<0.01
Model 3: Fully adjusted	0.007	0.021 [c]	0.469	0.093 [a]	-0.297	0.131 [c]	-0.182	0.098 [c]	-0.157	0.071 [c]	<0.01
Healthy											
Model 1: Crude	-0.085	0.020 [d e f]	0.023	0.091 [d e f]	0.602	0.125 [b c]	0.660	0.092 [b c]	0.415	0.070 [b c]	<0.01
Model 2: SES	-0.085	0.021 [d e f]	0.023	0.092 [d e f]	0.597	0.129 [b c]	0.659	0.095 [b c]	0.415	0.071 [b c]	<0.01
Model 3: Fully adjusted	-0.089	0.021 [d e f]	0.033	0.092 [d e f]	0.645	0.130 [b c]	0.703	0.097 [b c]	0.414	0.070 [b c]	<0.01

Ethnicity was based on the country of birth of the pregnant woman and her mother including both first-generation women and second generation women.

Mean, SE pattern score per dietary pattern by ethnicity.

Mean pattern scores for the total group was set to 0.000 based on PCA method.

Model 1: unadjusted.

Model 2: adjusted for SES.

Model 3: adjusted for SES, age, gender and maternal age.

Sign ($P < 0.01$) is based on ANOVA and Post-hoc Bonferroni; [a]-sign with all groups; [b]-sign with Dutch; [c]-sign with Surinamese; [d]-sign with Turkish; [e]-sign with Moroccan; [f]-sign with other ethnicities.

Socioeconomic status and dietary patterns

SES was significantly related to snacking, full-fat and meat dietary pattern scores ($p < 0.01$, Table 2.4). Post-hoc analyses showed that low SES children had significantly higher snacking pattern scores (0.864 ± 0.052) compared to middle (0.171 ± 0.030) and high SES groups (−0.297 ± 0.024, $p < 0.01$). After adjustment for ethnicity the associations were less pronounced (0.590 ± 0.054 for low SES, 0.137 ± 0.029 for middle SES and −0.216 ± 0.024 for high SES), but still significant. Further adjustment for age, gender and maternal age did not change the results. The full-fat pattern was most pronounced within the group of high SES children (0.055 ± 0.026, $p < 0.01$). The meat pattern was most pronounced in low SES children (0.229 ± 0.056, $p < 0.01$). After adjustment for ethnicity, associations were more pronounced (Table 2.4). Further adjustment for age, gender and maternal age did not change the results (Table 2.4). SES was significantly related to the healthy pattern in the crude model ($p < 0.01$, Table 2.4) showing low SES children had higher healthy pattern scores (0.217 ± 0.056) compared to middle (0.004 ± 0.032) and high SES children (−0.049 ± 0.026). After adjustments in either model 2 or 3, SES was no longer significantly associated with the healthy pattern.

Table 2.4. Mean dietary pattern scores by socioeconomic status in the ABCD cohort (n=2 769).

Dietary pattern	Low SES		Middle SES		High SES		P value ANOVA
	Mean	SE	Mean	SE	Mean	SE	
Snacking							
Model 1: Crude	0.864	0.052 [a]	0.171	0.030 [a]	-0.297	0.024 [a]	<0.01
Model 2: Ethnicity	0.590	0.054 [a]	0.137	0.029 [a]	-0.216	0.024 [a]	<0.01
Model 3: Fully adjusted	0.591	0.054 [a]	0.134	0.029 [a]	-0.214	0.024 [a]	<0.01
Full-fat							
Model 1: Crude	-0.179	0.056 [b]	-0.026	0.032	0.055	0.026 [c]	<0.01
Model 2: Ethnicity	-0.217	0.060 [b]	-0.028	0.032	0.065	0.027 [c]	<0.01
Model 3: Fully adjusted	-0.213	0.060 [b]	-0.025	0.032	0.061	0.027 [c]	<0.01
Meat							
Model 1: Crude	0.229 b	0.056	0.098	0.032 [b]	-0.114	0.026 [a]	<0.01
Model 2: Ethnicity	0.242	0.060 [b]	0.096	0.032 [b]	-0.115	0.026 [a]	<0.01
Model 3: Fully adjusted	0.231	0.060 [b]	0.093	0.032 [b]	-0.111	0.026 [a]	<0.01
Healthy							
Model 1: Crude	0.217	0.056 [a]	0.004	0.032 [c]	-0.049	0.026 [c]	<0.01
Model 2: Ethnicity	0.025	0.059	-0.019	0.031	0.008	0.026	0.716
Model 3: Fully adjusted	0.043	0.059	-0.019	0.031	0.003	0.026	0.618

SES was based on maternal educational: low SES (<6y), middle SES (6-10y) and high SES (>10y) post-primary education.

Mean, SE pattern scores per dietary pattern by socioeconomic group.

Mean pattern scores for the total group was set to 0.000, based on PCA method.

Model 1: unadjusted.

Model 2: adjusted for ethnicity.

Model 3: adjusted for ethnicity, age, gender and maternal age.

Sign ($P < 0.01$) is based on ANOVA and Post-hoc Bonferroni; [a]-sign with all groups; [b]-sign with high SES group; [c]-sign with low SES group.

Ethnicity, socioeconomic status and dietary patterns

The main positive significant associations between ethnicity, SES and dietary patterns in the fully adjusted model are shown in Figure. 2.2. We tested for interaction between SES and ethnicity in relation to pattern scores and found a borderline significant interaction for the full-fat (p = 0.018) and meat pattern (p = 0.017), whereas no interaction was present for the snacking (p = 0.324) and healthy (p = 0.260) pattern. Profile plots showed that both ethnicity and SES were independently related to dietary patterns [See Supplemental Figure 2.3].

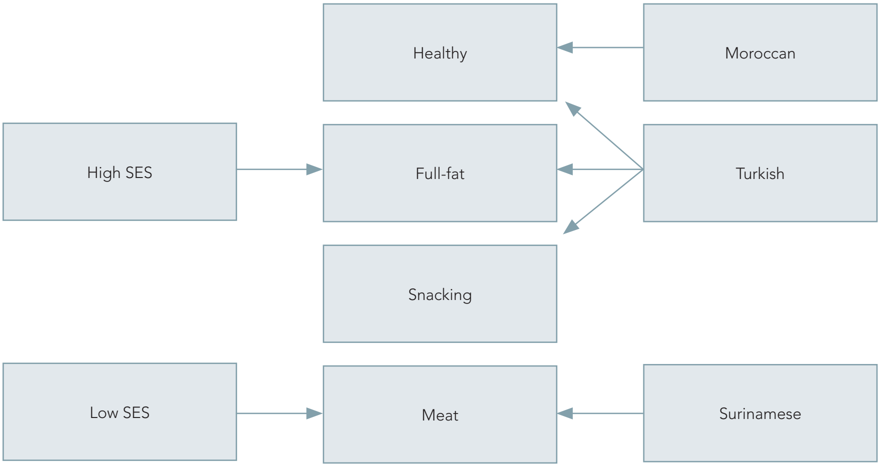

Figure 2.2. The main positive significant associations between ethnicity, SES and dietary patterns (n=2769).

Discussion

We have identified four dietary patterns in the large multi-ethnic ABCD cohort, consisting of 2769 children. Already at age 5, both ethnicity and SES were independently related to dietary patterns. Non-Dutch had high snacking and healthy pattern scores, whereas Turkish children scored higher on full-fat and Surinamese children scored higher on meat pattern scores. Low SES children had high snacking, meat and low full-fat pattern scores. Both ethnicity and SES seem to contribute independently to the differences in dietary patterns.

Interpretation and comparison with previous studies

Results of a systematic review including 14 publications utilizing PCA in 1–8 year old native children in mainly European countries [15] showed that most studies identified between two and six dietary patterns, with the majority of studies identifying a healthy, unhealthy/processed/snacking, and local/traditional pattern [5, 15, 22, 38]. Among the cohorts that evaluated the diets of children aged 3–5 years, a healthy and unhealthy pattern were most often identified [15, 17, 21, 38–42] with similar dietary patterns as the healthy and snacking pattern, which were observed in the present analysis. Our full-fat pattern shows similarities with the varied traditional Norwegian pattern, found by Oellingrath in 9–10 year old Norwegian children, which was characterized by high component loadings on full-fat cheese and full-fat spreads [5], food groups that also characterized the full-fat pattern in this study. We have identified an association between ethnicity and dietary patterns. Up to now, data on the association between ethnicity and dietary patterns has been scarce. In ALSPAC a snacking pattern was related to white ethnicity at age 3 and 7 [17, 19] and a healthy pattern with non-white ethnicity at age 4 to 7 years [19]. We found both higher healthy and snacking pattern scores in non-Dutch groups. In the Netherlands, the consumption of fruit and vegetables is higher in 7–9 year old children from Turkish and Moroccan origin [43] and 9–10 year old children from non-western origin [44] than that of Dutch children. However also consumption of snacking items and soft drinks has been found to be higher in 5-6y old non-ethnic groups, mainly of Turkish origin [42] which is in line with findings in our study. Additionally, the present study showed a full-fat and a meat pattern. Surinamese children have higher meat pattern scores than children from other ethnic groups and Turkish children have higher full-fat pattern scores. It has been reported in Dutch National Food Survey's that intake of fat and full-fat dairy products is high among groups from Turkish origin [25, 26]. Several studies have observed SES differences in dietary patterns in children [15–23] with maternal education being the most important variables [18, 21]. In four large prospective birth cohorts (ALSPAC, the EDEN mother-child cohort, the Norwegian Mother and Child Cohort Study and the Southampton Women's Cohort Survey) healthier dietary patterns in young children (1-7y) were associated with higher maternal education [17, 19, 21, 23, 39]. We did not find significantly different healthy pattern scores between SES groups however low SES children had higher healthy pattern scores than middle and high SES groups. In the ALSPAC cohort, the junk pattern at age 4 and 7 was more likely when maternal education level was low [20]. In line with these findings, we found that low SES children have higher snacking pattern scores. Our high SES children had higher full-fat pattern scores (full-fat spreads, full-fat cheese and refined pasta dishes) and low meat pattern scores (low and high fat meat, sauces and refined grain products for warm meals). We did not find other studies describing this full-fat dietary pattern in high SES children. In the present study, the non-Dutch groups (Surinamese, Turkish, Moroccan and other ethnicity) came disproportionally from lower SES groups (Table 2.1). Although ethnicity and SES are strongly correlated, we showed that both ethnicity and SES explained differences in dietary pattern scores between groups at age 5y. This suggests that both ethnicity and SES seem to be a predictor for adherence to a specific dietary pattern.

Methodological consideration

A problem common in studies using the PCA method is that the number of dietary patterns is based on scree plots, eigenvalues and the interpretability of the dietary patterns which is a limitation in objectivity [45]. The labelling of the identified patterns is subjective, which can be judged by the reader from the presented component loadings (Table 2.2). The 4 identified dietary patterns in this cohort explained 20.8% of the variation of dietary intake which is common in studies using the PCA method. FFQs are considered an appropriate method for population-based evaluations of dietary patterns in childhood and are favoured in large-scale studies because they are less burdensome to participants and reduce post collection processing of dietary data [27]. A possible limitation is that the FFQ was based on food commonly consumed by the Dutch population as determined by the Dutch Food Consumption Survey 1997–1998 [46]. However sub analysis showed that energy intake related to energy requirements (based on Schofield resting metabolism) was not different between Dutch and non-Dutch groups. It might be possible that some ethnic specific food items were not registered by the mother. The open question at the end of the FFQ gave the mother the opportunity to register consumed food items that were not literally asked in the 71-items. Based on methodological considerations (not all mothers filled-in this open question and there was the risk of double registration), we decided to not analyse these registered items. The FFQ was validated with the gold standard of doubly labelled water in a group of 4- to 6-year-old children, who did not exactly reflect the non-Dutch groups [29]. The present study had a response rate of 33% of the original cohort. Smaller numbers in ethnic groups is inherent to the ABCD study design but it is possible that some biases may have been introduced into the analyses, particularly as the non-responders tended to come disproportionately from lower SES and ethnic minority groups that consumed more according to the snacking pattern. Response rates per ethnic and SES group were 53% for Dutch, 23% for Surinamese, 14% for Turkish, 15% for Moroccan, 9% for other ethnicities, 16% for low SES, 31% for middle SES and 47% for high SES. A nonresponse analysis determining the degree of selective response and selection bias between pregnancy and birth outcomes, indicated that selective non-response was present in the ABCD-study, but selection bias was acceptably low and did not influence the studied birth outcomes [47]. Strengths of this study includes the sample size of 2769 children in which dietary pattern analyses was performed. The present study is one of few that provides insight into dietary patterns in children in a multi-ethnic population.

Implications for research and interventions

In this group of young children, we identified specific ethnic and SES groups that consumed more according to unfavourable dietary patterns. Dietary tracking, the maintenance of a dietary pattern over a certain time period, has been observed during childhood and from childhood to adolescence and unhealthy eating habits have been found to track into adolescence and adulthood. Dietary habits are a major determinant of overweight [4, 5]. Non-native, especially children of Turkish origin, and low SES groups show higher adherence to the unfavourable snacking pattern and show disproportionally higher prevalence of overweight and obesity (7% for Dutch, 14% for Surinamese, 25% for Turkish, 23% for Moroccan, 17% for low SES, 12% for middle SES and 8% for high SES) at age 5 [48]. Future studies could analyse the explanatory factors in early childhood contributing to these (differences in) dietary choices and the possible relationships these dietary patterns may have with weight development and health inequalities in later childhood.

Conclusion

This study indicates that both ethnicity and SES are relevant for dietary patterns at age 5 and may enable more specific nutrition education to specific ethnic and low SES target groups, in order to avoid overweight and other health inequalities.

Abbreviations

ABCD: Amsterdam Born Children and their Development;
SES: socioeconomic status;
ANOVA: Analysis of Variance;
ALSPAC: The Avon Longitudinal Study of Parents and Children; FFQ: Food Frequency Questionnaire;
PCA: Principal Component Analysis

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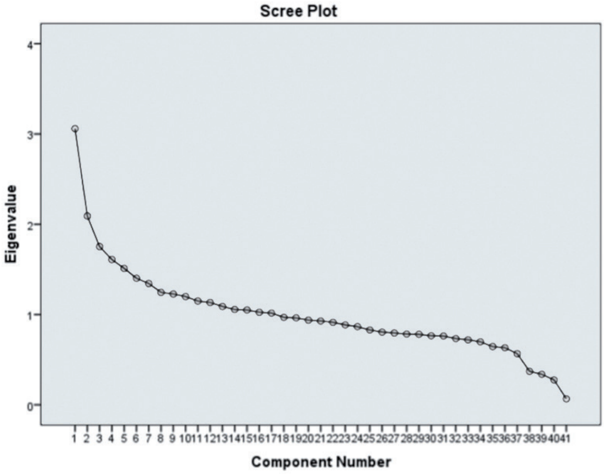
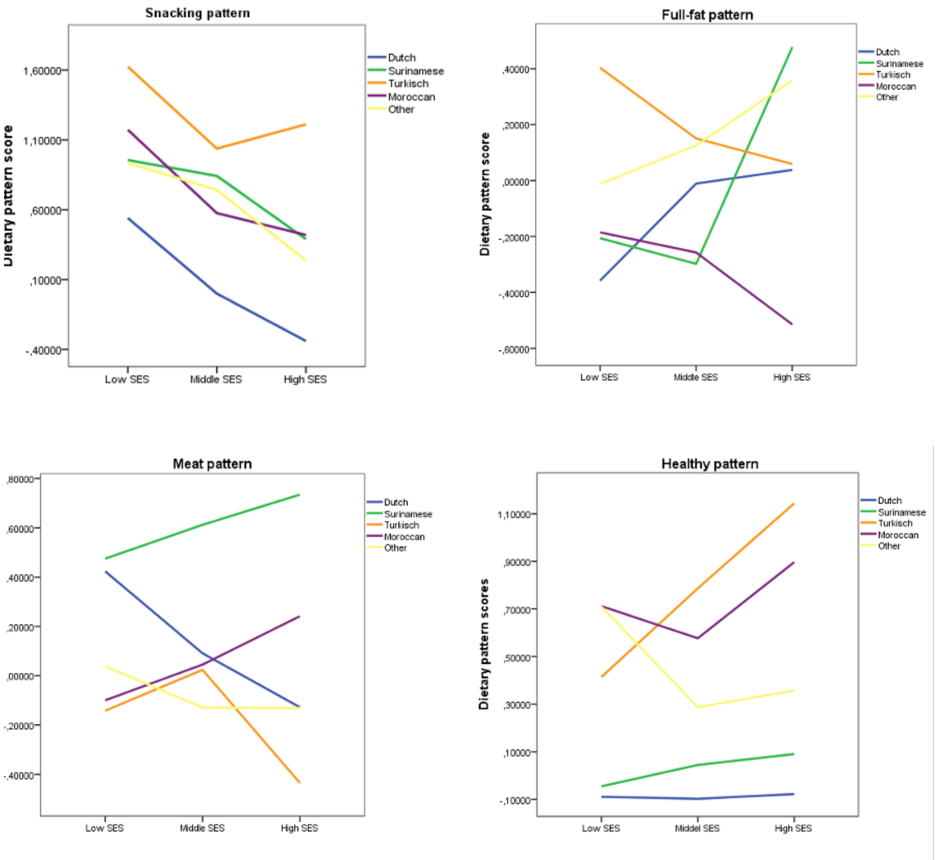
Supplemental Table 2.1. Food groups and their products, used in the principal component analysis in the ABCD cohort (n=2 769).

Food group	Products assigned to the food group
Fruits	All sorts of fruits
Vegetables	All sorts or raw and boiled vegetables (excluding vegetables in the mashed potato stew)
Refined breakfast products	White/refined bread, rusks, crackers, crispbreads, Cornflakes, Cruesli, Rice Krispies, Frosties, Smacks, Honey Loops
Whole grain breakfast products	Brown- and whole grain bread, rusks, crackers, crispbreads and rye bread, muesli
Low-fat spreads	Low-fat margarine, Blue Band Good Start
Full-fat spreads	Butter, margarine
Low-fat cheese	Low-fat or light cheese (spreads) 20+ 30+
Full-fat cheese	Full-cream cheese (spreads) 48+, Brie 60+, goat cheese, including cheese added to hot meals
Processed meats	Ham, corned beef, liver products, salami, meatloaf, smoked dried beef
Peanut butter	Peanut butter
Sandwich toppings (sweet)	Chocolate spreads and sprinkles, jam, apple syrup, honey, fruit sprinkles, coconut slices, Schuddebuikjes
Low-fat dairy	Skimmed, low-fat or artificially sweetened vanilla, fruit or natural quark/yoghurt(drink)/Biogarde/(chocolate) milk, buttermilk
Medium-fat dairy	Semi-skimmed vanilla, fruit or natural quark/yoghurt(drink)/Biogarde/(chocolate) milk, Barley gruel
Full-fat dairy	Custard, milk pudding, Danoontje, full-cream vanilla, fruit or natural quark/yoghurt(drink)/Biogarde/(chocolate) milk, ready-made porridge from oats, semolina or rice
Unhealthy meals	Pizza, quiche, filled tortillas or taco's, poffertjes, pancackes
Healthy meals	Mashed potato stew with vegetables, nasi, bami, noodles
Tomato sauce (for pasta)	Tomato sauce in pasta dishes
Refined grain products	White rice, macaroni, spaghetti or other pasta
Whole grain products warm meal	Whole grain rice, macaroni, spaghetti or other pasta
Fried potato products	Rösti, fried potato or French fries
Boiled potatoes	Boiled or mashed potatoes
Sauces	Gravy, mayonaise or salad cream
Pulses	Brown, white beans and marrowfat peas etc.
Fish	All types of fish
Eggs	Boiled and baked eggs
Low-fat meat	Chicken breast or leg, chop, pork slices/steak/filet, stewing beef or steak, steak tartar, roast beef,
High-fat meat	Chicken burger/nuggets, minced meat, bacon, sausage, hamburger, schnitzel, frankfurters or cocktail sausages as a snack or on bread
Meat alternatives and soy products	Flavoured or natural soy milk(dessert). Vegetarian schnitzel/burger, tahoe/tofu, tempé, Quorn or Valess.
Granola bars	Granola bars, Sultana, Liga nutritional biscuits
Biscuits and pastries	Sweet pie, pastries, fruit flan, cakes and biscuits
Ice cream	Ice cream
Chocolate and candy	All types of chocolate bars, chewing gum and sweets
Healthy snacks	Ginger cake, sponge cake, raisins, ice lolly, breadsticks or rice cakes

Savory snacks	Kroket, frikandel, satay, crisps, nibbits, prawn crackers, salty biscuits, sausage roll
	Nuts (coated) peanuts
Sugar sweetened sodas	Sugar containing soft drinks and squashes
Artificially sweetened sodas	Light and artificially sweetened soft drinks and squashes
Fruit drink	Apple juice, orange juice, Dubbeldrank and multi-fruit drink
Fruit drink concentrate	Fruit concentrate diksap, Roosvicee and Karvan Cevitam
Water and tea	(Mineral)water and tea without sugar
Sugar	Added sugar or calorie containing sweeteners in cereals, desserts or tea



Supplemental Figure 2.2. Scree plot of the 41 components in the PCA in the ABCD cohort (n=2 769).



Supplemental Figure 2.3. Profile plots of the interaction between ethnicity and SES per dietary pattern (n=2 769).

CHAPTER 3

Beyond maternal education: socio-economic inequalities in children's diet in the ABCD cohort

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Abstract

Objective

We examined whether the role of maternal education in children's unhealthy snacking diet is moderated by other socio-economic indicators.

Methods

Participants were selected from the Amsterdam Born Children and their Development cohort, a large ongoing community-based birth cohort. Validated Food Frequency Questionnaires (FFQ) (n=2782) were filled in by mothers of children aged 5.7±0.5yrs. Based on these FFQs, a snacking dietary pattern was derived using Principal Component Analysis. Socio-economic indicators were: maternal and paternal education (low, middle, high; based on the highest education completed) household finance (low, high; based on ability to save money) and neighbourhood SES (composite score ncluding educational level, household income and employment status of residents per postal code). Cross-sectional multivariable linear regression analysis was used to assess the association and possible moderation of maternal education and other socio-economic indicators on the snacking pattern score. Analyses were adjusted for children's age, sex and ethnicity.

Results

Low maternal education (B 0.95, 95% CI 0.83;1.06), low paternal education (B 0.36, 95% CI 0.20;0.52), lower household finance (B 0.18, 95% CI 0.11;0.26) and neighbourhood SES (B -0.09, 95% CI -0.11;-0.06) were independently associated with higher snacking pattern scores ($p<0.001$). The association between maternal education and the snacking pattern score was somewhat moderated by household finance ($p=0.089$) but remained strong. Children from middle-high educated mothers (B 0.44, 95% CI 0.35;0.52) had higher snacking pattern scores when household finance was low (B 0.49, 95% CI 0.33;0.65).

Conclusions

All socio-economic indicators were associated with increased risk of unhealthy dietary patterns in young children, with low maternal education conferring the highest risk. Yet, within the group of middle-high educated mothers, lower household finance was an extra risk factor for unhealthy dietary patterns. Intervention strategies should therefore focus on lower educated mothers and middle-high educated mothers with insufficient levels of household finance.

Introduction

Maternal education is an important determinant of children's diet, with lower education being associated with less healthy diets and dietary patterns in children [1,2]. A potential mechanism is that mother's education reflects knowledge, attitudes and skills regarding diet and food preparation [3]. However, maternal influence on diet is not independent of other indicators of socio-economic status (SES). For example there is evidence that paternal education [4-8], household finance [5,7,9] and neighbourhood SES [8,10,11] also play a role in the dietary patterns of children.

While the role of maternal education in children's diets has been extensively studied, there has been less consideration of how this association might be modified by other SES indicators. For instance, paternal education can also be linked to dietary patterns through knowledge and attitudes but its role in children's diets may reflect gender roles. Household finance, on the other hand may be indicative of the potential to purchase a healthy diet [3], although it's possible that maternal knowledge and skills can overcome financial barriers to a healthy diet. While parents are likely have a decisive role in the food consumption pattern of young children, meso-level factors such as neighbourhood SES might play an indirect role on children's diets [8] via its influence on mothers (and fathers) via the food environment. Childhood overweight prevalence is unevenly distributed across neighbourhoods [12] and there is evidence that individuals living in low-income neighbourhoods are subject to a greater degree of food advertising [13] and have greater accessibility to unhealthy food establishments and lower accessibility to healthy food stores [14]. At the same time, there is evidence for an association between SES and food costs for diet quality [15,16]. Insight into the influence of different SES factors is relevant in helping to identify groups at higher risk of unhealthy dietary patterns. In a previous study, we observed that lower maternal education was associated with higher scores on a unhealthy snacking pattern (characterized by high intakes of sweet and savoury snacks, refined breakfast products and low intakes of whole-grain breakfast products) [17]. In this study, we wanted to investigate the additional influence of SES factors. Therefore the aim of our present study was to examine whether the role of maternal education in children's diet is modified by other SES indicators.

Materials and Methods

Study design and population

Data were used from the Amsterdam Born Children and their Development (ABCD) study, a large ongoing community-based birth cohort (http://www.abcd-study.nl/). The cohort study design has been described previously [18]. Between January 2003 and March 2004, all pregnant women living in Amsterdam were invited to participate in the ABCD study. Of the 12373 women approached, 8266 women filled out a pregnancy questionnaire that was available in Dutch, English, Turkish and Arabic. A 5-year questionnaire was sent to the woman's home address and 4488 questionnaires were filled out by the mothers. These woman's received a self-administered Food Frequency Questionnaire (FFQ) and 2851 mothers returned the FFQ. At age 10, fathers received a 10-year questionnaire and 2268 questionnaires were returned. A number of 2782 children were included in the present analysis (Fig 3.1). This study was conducted according to the guidelines laid down in the Declaration of Helsinki. Approval of the study was obtained from the Central Committee on Research Involving Human Subjects in the Netherlands, the medical ethics review committees of the Academic Medical

Center, Amsterdam, the VU University Medical Center Amsterdam and the Registration Committee of the Municipality of Amsterdam. All women provided written informed consent. This informed consent procedure was approved by the committees of the Academic Medical Center, Amsterdam, the VU University Medical Center Amsterdam and the Registration Committee of the Municipality of Amsterdam.

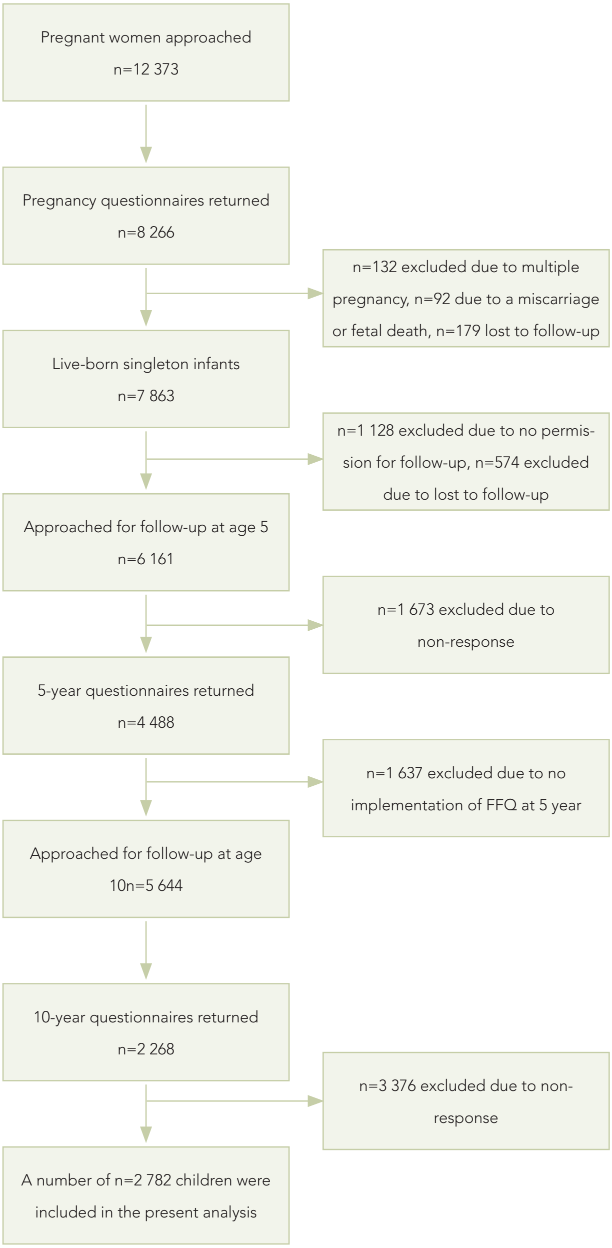

Figure 3.1. Flow-chart of the sampling procedure of the ABCD cohort (n=2 782).

Assessment of socio-economic factors

Data on maternal education, household finance and neighbourhood SES were collected as part of the 5-year questionnaire. Paternal education was collected as part of the 10-year questionnaire. Level of maternal and paternal education were defined as the highest education completed and were defined as: low: (a few years of) primary education/lower secondary education/lower vocational education, middle: general higher secondary education/intermediate vocational education or high: higher professional programmes or university programmes leading to a bachelor or master degree [19]. Household finance was based on the question 'what is your current financial situation?' and defined as low (insufficient or exactly enough) or high (ability to save money). Neighbourhood SES was determined using 2010 status scores obtained from the Social and Cultural Plan Bureau (SCP), a division of the Netherlands Institute for Social Research [20]. The children's neighbourhoods were defined by the four digit postal code at the time of their residence at age 5. Postal code areas in Amsterdam are on average 2.5 km2 and they had a mean population of approximately 9593 residents in 2010 (interquartile range (IQR): 4530–13345) [21]. Status scores were calculated by the SCP for each postal code area using data from registries on the mean educational level, household income and employment status of area residents, analysed by Principal Component Analysis. Mean (SD) status score in the study population was 0.414 (1.18) and mean status score in Amsterdam was -0.282 (1.458) in 2010. Higher status scores represent higher SES of the neighbourhood.

Assessment of potential covariates

Potential covariates that might influence the association between dietary patterns and SES factors were children's age (y), sex (boys/girls) and ethnicity. Age and sex were collected via the FFQ and ethnicity via the pregnancy questionnaire. Ethnicity was based on the country of birth of the pregnant woman and her mother including both first-generation women (born outside the Netherlands) and second generation women (born in the Netherlands but whose mother was born in another country). Five ethnic categories were formed: Dutch, African Surinamese, Turkish, Moroccan and other ethnicities (mainly non-western origin).

Assessment of diet

At age 5, mothers filled in a validated 71-item FFQ developed by TNO Food (Zeist, The Netherlands) [22]. In brief, per food item, consumption frequency, portion size and the type of product consumed over the last 4 weeks was reported by the mother of the child. Frequency options were "never", "less than once a week", "once a week", "2–3 times a week", "4–5 times a week", and "6–7 times a week". Food items were assessed in units (e.g. a piece of fruit and a slice of bread) and in household units (e.g. a glass and a tablespoon). Intake of items such as breakfast cereals, vegetables or pasta were asked in standard tablespoons which could give a reliable idea of the actual eaten portion size for children. Dietary patterns were derived in a previous study using Principal Component Analyses (PCA) [17]. In that study four dietary patterns were identified: snacking; full-fat; meat; and healthy, explaining 21% of the variation in dietary intake. In the current study we focused on children's intake of the snacking pattern.

Statistical analysis

Population characteristics were described in number, percentages or means with standard deviations (SD). ANOVA and Post-hoc Bonferroni were used to show differences by maternal education group. Non-parametric correlation by Spearman was used to check for multicollinearity between maternal education and other variables (paternal education 0.436, household finance 0.292, neighbourhood SES 0.295, snacking pattern score -0.381, age -0.109, sex 0.011 and ethnicity -0.341) and for correlations between paternal education and other variables (household finance 0.219, neighbourhood SES 0.215, snacking pattern score -0.249, age -0.021, sex 0.035 and ethnicity -0.186). Multiple linear regression analysis with listwise deletion was used to assess the association between maternal education (n=2766) and paternal education (n=1803), household finance (n=2738), and neighbourhood SES (n=2752) on the snacking pattern score (n=2782). The individual snacking pattern score was used as continuous dependent variable and SES factors (maternal and paternal education level, household finance and neighbourhood SES) used as independent variables. Model 1 describes the association between maternal education and the snacking pattern score. Subsequently, in model 2, 3 and 4, one individual SES factor (resp. paternal education, household finance or neighbourhood SES) was added. In model 5, all SES factors were added simultaneously, to examine the association of all SES factors combined on the snacking pattern score. All models were adjusted for child's age, sex and ethnicity. Effect modification between maternal education and paternal education, household finance and neighbourhood SES was tested by multiple linear regression analysis and considered potentially significant at a p-value<0.10. Additionally they were tested for heterogeneity by sex by including an interaction term of sex with each of the SES factors. No effect modification was found indicating that the association between maternal education and SES factors on the snacking pattern score, were similar in boys and girls. Statistical analyses were performed in SPSS version 22 for windows and the level of statistical significance was set at 0.01.

Results

Population characteristics

Population characteristics based on maternal education level are presented in Table 3.1. Children with lower educated mothers had significantly more often lower educated fathers, lower household finance, lower neighbourhood SES and higher pattern scores than children from middle-high and higher educated mothers, reflecting higher intakes of snack items.

Table 3.1. Socio-economic characteristics of the study population by maternal education (n=2 766).

Population	Population by maternal education n= 2 766					
Characteristics	Low n=287 (10.4%)		Middle-high n=552 (20.0%)		High n=1 927 (69.6%)	
Age, in years						
Mean, SD	5.83	(0.52)	5.75	(0.50)	5.67	(0.47)*
Sex						
Boys, n (%)	154	(50.7)	280	(50.7)	980	(50.9)
Ethnicity						
Dutch, n (%)	140	(48.8)*	390	(70.7)*	1750	(90.8)*
Surinamese, n (%)	23	(8.0)*	58	(10.5)*	35	(1.8)*
Turkish, n (%)	31	(10.8)*	20	(3.6)*	9	(0.5)*
Moroccan, n (%)	48	(16.7)*	42	(7.6)*	20	(1.0)*
Other ethnicities, n (%)	45	(15.7)*	42	(7.6)*	113	(5.9)*
Paternal education						
Low, n (%)	51	(44.0)*	42	(13.8)*	48	(3.5)*
Middle, n (%)	39	(33.6)*	118	(38.7)*	181	(13.1)*
High, n (%)	26	(22.4)*	145	(47.5)*	1149	(83.4)*
Household finance						
Low, n (%)	191	(68.0)*	243	(44.7)*	468	(24.5)*
High, n (%)	90	(32.0)*	301	(55.3)*	1443	(75.5)*
Neighbourhood SES						
Mean, SD	-0.727	1.24*	-0.069	1.28*	0.500	1.15*
Snacking pattern score						
Mean, SD	0.992	1.11*	0.329	1.01*	-0.246	0.84*

Maternal education was based on the highest education completed. Increasing neighbourhood SES scores represent higher neighbourhood SES and positive snacking pattern scores indicate higher consumption of food groups in that pattern.

* Sign (P<0.01) is significant with all groups and based on ANOVA and Post-hoc Bonferroni.

SES indicators, including maternal education, in relation to the snacking pattern

The associations between maternal education, paternal education, household finance, neighbourhood SES and the snacking pattern score are presented in Table 3.2. Maternal education was strongly related to the child's snacking pattern score. Model 1 shows a 0.946 SD higher snacking pattern score (95% CI 0.829; 1.064) for children from low educated mothers and a 0.438 SD (95% CI 0.352; 0.524) higher snacking pattern score for children from middle-high educated mothers compared to children from high educated mothers. After adding paternal education to the model (Model 2), the association between maternal education and snacking score remained strong. Adding household finance and neighbourhood SES (resp. Model 3 and 4) also had a minimal influence on the association between maternal education and snacking pattern scores. Although paternal education, household finance and neighbourhood SES were all significantly associated with the snacking pattern score individually (Table 3.2), these factors did not overrule the strong association between maternal education and snacking pattern score. Adding all SES factors to the model simultaneously (Model 5) showed similar results.

Effect modification between maternal education and household finance

We observed that the role of middle-high maternal education on the snacking pattern score was somewhat moderated by low household finance (p=0.089), indicating a difference in the association between maternal education and finance on the snacking pattern score. Therefore analyses were stratified by household finance and all models were run within the low and high household finance group separately (Table 3.3). Higher maternal education was used as the reference. In Model 1, the association between maternal education and the snacking pattern remained strong in both groups. Within the low household finance group, children from lower educated mothers had a 0.821 SD (95% CI 0.641; 1.000) higher snacking pattern score and children from middle-high educated mothers had a 0.4.92 SD (95% CI 0.334; 0.651) higher snacking pattern score compared to children from high educated mothers. We also examined the potential effect modification between household finance and the other SES factors (Supplemental Table 3.1). Results of paternal education were similar to those for maternal education, but the association with neighbourhood SES was small and not statistically significant.

Table 3.2. Associations between maternal education, different SES indicators and the snacking pattern score (n=2 782).

	Maternal education		Paternal education		Household finance	Neighbourhood SES
	Low B (95%-CI)	Middle-high B (95%-CI)	Low B (95%-CI)	Middle-high B (95%-CI)	Low B (95%-CI)	Continuously B (95%-CI)
Model 1: maternal education	0.946 (0.829; 1.064)	0.438 (0.352; 0.524)				
Model 2: paternal education	0.725 (0.547; 0.903)	0.292 (0.183; 0.401)	0.359 (0.198; 0.519)	0.216 (0.112; 0.320)		
Model 3: household finance	0.881 (0.760; 1.002)	0.416 (0.329; 0.503)			0.141 (0.050; 0.231)	
Model 4: neighbourhood SES	0.874 (0.754; 0.994)	0.406 (0.267; 0.479)				-0.085 (-0.113; -0.057)
Model 5: all SES factors	0.673 (0.491; 0.855)	0.283 (0.173; 0.393)	0.304 (0.142; 0.466)	0.199 (0.093; 0.304)	0.108 (0.022; 0.203)	-0.045 (-0.079; -0.011)

Maternal education was based on the highest education completed. Values are based on multivariable linear regression and reflect differences (95% CI) in socio economic factors (maternal education, paternal education, household finance and neighbourhood SES) on the snacking pattern score. Model 1: describes the association between maternal education and the snacking pattern score (n=2766). Model 2: describes the association between maternal education, paternal education and the snacking pattern score (n=1799). Model 3: describes the association between maternal education, household finance and the snacking pattern score (n=2736). Model 4: describes the association between maternal education, neighbourhood SES and the snacking pattern score (n=2738). Model 5: describes the association between all SES factors and the snacking pattern score (n=1765). All models were adjusted for age, sex and ethnicity.

Table 3.3. Effect modification between maternal education and other SES factors, stratified by household finance (n=2 736).

		Low household finance		High household finance	
		Maternal education		Maternal education	
		Low	Middle-high	Low	Middle-high
Model 1: maternal education	B (95%-CI)	0.821 (0.641; 1.000)	0.492 (0.334; 0.651)	0.982 (0.800; 1.163)	0.361 (0.258; 0.465)
	B	0.298	0.194	0.241	0.152
Model 5: all SES factors	B (95%-CI)	0.503 (0.223; 0.782)	0.303 (0.088; 0.517)	0.900 (0.624; 1.176)	0.254 (0.125; 0.384)
	B	0.182	0.126	0.178	0.107

Maternal education was based on the highest education completed. Values are based on multivariable linear regression and reflect differences (95%-CI) in socio-economic factors (maternal education, paternal education and neighbourhood SES) on the snacking pattern score. Model 1: describes the association between maternal education and the snacking pattern score in the low and high household finance group (n=2736). Model 5: describes the association between maternal education, paternal education and neighbourhood SES and the snacking pattern scores in the low and high household finance group (n=1765). Both models were adjusted for age, sex and ethnicity.

Discussion

We aimed to examine whether the role of maternal education in children's dietary patterns is modified by other SES indicators. Our results showed that of all SES indicators, maternal education was most strongly associated with children's snacking patterns. Moreover, it was independent of other SES indicators and was not moderated by other SES factors studied except for household finance. We found higher snacking pattern scores in children from middle-high educated mothers when household finance was low.

In this study, we used SES indicators commonly used in public health research that are related to dietary patterns, i.e. maternal education, paternal education, household finance and, less frequently studied, neighbourhood SES. Our study corroborates the findings of studies that have considered a range of SES factors in relation to unfavourable dietary patterns in young children. Maternal education, paternal education and household finance (individually or in combination with each other) have been associated with unfavourable dietary patterns [5-7,23-26]. Also in line with our results, studies demonstrated that the influence of household finance on dietary patterns was less pronounced than that of maternal and paternal education [7,27-29].

Furthermore, studies in two other cohorts have observed that maternal education was a stronger determinant of children's dietary patterns than other SES factors [5,26,30,31]. Only a few studies have considered the role of neighbourhood SES. A Canadian study found higher diet quality in adolescents living in high versus low SES neighbourhoods [10]. An Australian study [8], found a minimal role for neighbourhood SES on dietary patterns. Within the ABCD cohort, earlier results showed that adiposity at age 5-6y was associated with neighbourhood characteristics [32] but that study did not investigate the role of dietary intake. None of the studies mentioned above explicitly investigated whether the role of maternal education on the dietary pattern of young children was moderated by other SES factors. Béghin et al observed that cultural and geographical factors could attenuate the relationship between paternal education and adolescents' diet quality [26], indicating a potential moderating role of other SES factors. In our study, maternal education was the strongest indicator for an unfavourable snacking pattern, but we also observed a moderating effect of household finance. Higher snacking pattern scores were found in children from middle-high educated mothers when household finance was low.

Interpretations of findings

The associations between different SES indicators and unhealthy dietary patterns indicate distinct pathways of influence. First, higher educated parents may have higher nutritional knowledge and may perceive long term consequences of diet on the health of their children [33], which is associated with healthier food purchasing leading to healthier dietary patterns of their children [34]. Potential explanations are maternal nutrition knowledge; positive concern and attitudes of the mother towards healthy eating [33,35], self-efficacy, feeding practices and modelling, as well as the quality of foods made available and accessible at home [36]. Knowledge and skills attained through education may affect a person's cognitive functioning, making them more receptive to health education messages, or more able to communicate with and access appropriate health services [3]. Parents, and in particular the mother is considered to take the role of gate-keeper that decides which food items are present in the house and on the table [37,38]. In the HELENA study, results from the Healthy Eating Questionnaire showed that mother-child communication was more effective than father-child communication. Mother was the family member most likely to promote healthy dietary habits [26,39].

Second, household finance reflects the availability of economic and material resources and reflect the potential to purchase a healthy diet [3,4]. Possible determinants are the lower cost per mega joule of energy dense and nutrient poor diets and the easy physical access to low-cost energy-dense foods [40]. Other suggested mechanisms are access to health services and indirect to education, promoting self- esteem and social standing [3]. In the group of middle-high educated women, economic recourses are perhaps a stronger limiting factor than knowledge and attitudes.

Finally, studies in the US and Australia, have shown that the foods available in low SES neighbourhoods are of lower quality, cost more, and have less variety, than foods available in higher SES neighbourhoods [10,11]. At the age of 5, familial factors probably play a more important role in influencing dietary patterns than neighbourhood SES [41], but it's possible that a poor food environment might influence children through its effect on their parents. Indeed we found an independent association between neighbourhood SES and unhealthy snacking pattern. However, we also found that the association between maternal education and the unhealthy snacking pattern was not moderated by neighbourhood SES levels, implying that maternal education (and the underlying mechanisms) may provide some resistance to challenges presented by a low SES neighbourhood.

Strength and limitations

A major strength of this study is the ability to examine whether the role of maternal education in young children's diet is moderated by other SES indicators. Additionally, this study is one of the few studies taking into account the potential role of neighbourhood SES on unfavourable dietary patterns in young children, in combination with more commonly used SES indicators as parental education and household finance. Studying the role of these SES indicators individually, simultaneously and the possible moderating effect of these indicators allowed specific relationships to be highlighted according to the differences in SES. Neighbourhood SES was calculated based on postal codes where children were living at age 5, when most SES factors and dietary intake were measured.

Several limitations should be taken into account. A possible limitation is that we did not have exact data on how long children had been living in their current neighbourhood. It could have been possible that a family moved to a neighbourhood only recently and was living in a neighbourhood with a different neighbourhood SES before. Our study population (mean neighbourhood status score 0.414 (1.18)), may not be representative of children in Amsterdam (-0.282 (1.458)), or other main cities in the Netherlands (-0.969 (1.573) in Rotterdam and 0.0069 (1.705) in the Hague), indicating higher SES of neighbourhoods in our study population. Neighbourhood SES was calculated by the SCP based on 4-digit postal codes. Using 6-digit postal codes would provide more specific information about actual neighbourhood SES, especially for children living at transitional areas of neighbourhoods [42]. However to our knowledge, no appropriate calculation of status score based on 6-digit postal codes was available for our population.

A multilevel approach for data analysis could be considered, given the hierarchical nature of studying how neighbourhood's SES may affect snacking pattern scores in children. By using multiple linear regression analysis instead, it might be possible that the assumption of independence were violated and the generalization of the research findings are limited. 388 different 4-digit postal codes were included in our analysis and the mean number of participants per postal code was 7.1 (13.6). To ensure sufficient power for statistical analysis, postal code areas with less than 10 children would have been excluded to ensure sufficient power for statistical analysis [32].

Paternal education was collected during the 10-year questionnaire and the number of missing values was substantial (n=979). Compared to children with complete data, children with missing data on paternal education had more often lower educated mothers (resp. 6.4% and 17.5%), lower household finance (resp. 27.4% and 42.3%), lower neighbourhood SES (resp. 0.414 (1.179) and -0.038 (1.344)) and higher snacking pattern scores (-0.146 (0.902) and 0.268 (1.109)). However, sensitivity analyses within children with complete data on dietary patterns and all SES factors and potential confounders (n=1765) showed similar results.

Attrition of study population was largely due to untraceable changes in address or migration. A non-response analysis determining the degree of selective response and selection bias between pregnancy and birth outcomes, indicated that selective non-response was present in the ABCD-study, but selection bias was acceptably low and did not influence the studied birth outcomes [43]. No further nonresponse analysis was done. It is possible that some biases may have been introduced into the analyses, particularly as the non-responders tended to come disproportionately from lower SES and ethnic minority groups.

Implications

We found that all SES indicators were independently related to snacking pattern scores of children age 5 and we observed a cumulative association of these different SES indicators that add to the risk of an unhealthy dietary pattern. However, the influence of maternal education remained strong, despite addition of other SES indicators. Lower snacking pattern scores were found in children of middle-high educated woman with sufficient household income. This suggests that primary focus for intervention strategies should be given to lower educated mothers, with particularly targeting of mothers were more unfavourable SES indicators are prevalent and middle-high educated mothers with insufficient levels of household finance.

Conclusions

Our results show that all SES indicators contribute to the risk of unhealthy dietary patterns in a population of young children. Low paternal education, lower household finance and lower neighbourhood SES were all independently related to higher snacking pattern scores, but they did not affect the strong relationship between low maternal education and the intake of a dietary pattern characterized by snack foods. Within the group of middle educated mothers, higher snacking patterns were found when the level of household finance was low.

List of abbreviations

SES: socio-economic status
FFQ: Food Frequency Questionnaire
ABCD: Amsterdam Born Children and their Development
SCP: Social and Cultural Plan Bureau
PCA: Principal Component Analysis
SD: standard deviations
ALSPAC: The Avon Longitudinal Study of Parents and Children

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Supplemental Table 3.1. Interaction between maternal education and other SES factors and the snacking pattern score (n=2 782).

		Maternal education		Paternal education		Neighbourhood SES
		Low	Middle	Low	Middle	Continuously
Low household finance						
Model 1:	B (95%-CI)	0.821 (0.641; 1.000)	0.492 (0.334; 0.651)			
	B	0.298	0.194			
Model 5: all SES factors	B (95%-CI)	0.503 (0.223; 0.782)	0.303 (0.088; 0.517)	0.314 (0.050; 0.578)	0.345 (0.140; 0.551)	-0.069 (-0.114; 0.003)
	B	0.182	0.126	0.113	0.147	-0.083
High household finance						
Model 1:	B (95%-CI)	0.982 (0.800; 1.163)	0.361 (0.258; 0.465)			
	B	0.241	0.152			
Model 5: all SES factors	B (95%-CI)	0.900 (0.624; 1.176)	0.254 (0.125; 0.384)	0.326 (0.109; 0.542)	0.117 (-0.006; 0.240)	-0.036 (-0.075; 0.003)
	B	0.178	0.107	0.084	0.052	-0.049

Maternal education was based on the highest education completed. Values are based on multivariable linear regression and reflect differences (95% CI) in socio economic factors (maternal education, paternal education, household finance and neighbourhood SES) on the snacking pattern score. Model 1: describes the association between maternal education and the snacking pattern score (n=2766). Model 2: describes the association between maternal education, paternal education and the snacking pattern score (n=1799). Model 3: describes the association between maternal education, household finance and the snacking pattern score (n=2736). Model 4: describes the association between maternal education, neighbourhood SES and the snacking pattern score (n=2738). Model 5: describes the association between all SES factors and the snacking pattern score (n=1765). All models were adjusted for age, sex and ethnicity.

CHAPTER 4

Weight development between age 5 and 10 years and its associations with dietary patterns at age 5 in the ABCD cohort

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Abstract

Background

Social inequalities in bodyweight start early in life and track into adulthood. Dietary patterns are an important determinant of weight development in children, towards both overweight and underweight. Therefore, we aimed to examine weight development between age 5 and 10 years by ethnicity, SES and thereafter by BMI category at age 5, to explore its association with dietary patterns at age 5.

Methods

Participants were 1 765 children from the Amsterdam Born Children and their Development (ABCD) cohort that had valid data on BMI at age 5 and 10 and diet at age 5. Linear mixed model analysis was used to examine weight development between age 5 and 10 years and to assess if four previously identified dietary patterns at age 5 (snacking, full-fat, meat and healthy) were associated with weight development. Analyses were adjusted for relevant confounders, stratified by ethnicity and SES and thereafter stratified per BMI category at age 5.

Results

Overall, weight decreased in Dutch and high SES children and increased in non-Dutch and low/middle SES children. Across the range of bodyweight categories at age 5, we observed a conversion to normal weight, which was stronger in Dutch and high SES children but less pronounced in non-Dutch and low/middle SES children. Overall, the observed associations between weight development and dietary patterns were mixed with some unexpected findings: a healthy dietary pattern was positively associated with weight development in most groups, regardless of ethnicity and SES (e.g. Dutch B 0.084, 95% CI 0.038;0.130 and high SES B 0.096, 95% CI 0.047;0.143) whereas the full-fat pattern was negatively associated with weight development (e.g. Dutch B -0.069, 95% CI -0.114;-0.024 and high SES B -0.072, 95% CI -0.119;-0.026).

Conclusions

We observed differential weight development per ethnic and SES group. Our results indicate that each ethnic and SES group follows its own path of weight development. Associations between dietary patterns and weight development showed some unexpected findings; follow-up research is needed to understand the association between dietary patterns and weight development.

Background

In recent years, research and Public Health has focussed on the high prevalence of obesity and overweight among children, mainly present in ethnic minority and lower Socio-economic (SES) groups [1, 2, 3, 4]. Concurrently, there is evidence of a growing prevalence of underweight in children of native origin in high-income countries [5, 6]. Although it is not clear how important this trend is for clinical practice, both underweight and overweight/obesity are a risk factor for health problems in later life [7, 8]. Therefore it's important to focus on the total range of bodyweight.

Social inequality in bodyweight starts early in life and tracks into adulthood. Children who are already overweight or obese in mid-childhood are likely to remain so by the start of adolescence [9, 10], and later into adulthood [11] and associations between rapid infancy growth and obesity in childhood were strongest in populations consisting of greater proportions of ethnic minority and low SES children [12]. In the Netherlands ethnic differences in overweight are present from 2-4 years onwards [1, 2, 13, 14]. Data from the Amsterdam Born Children and their Development (ABCD) cohort observed ethnic differences in overweight at age 2 [1] and overweight at this age was, specifically in non-Dutch children, a strong predictor of staying overweight (tracking) at age 5-6 years [1, 15]. In a British birth cohort study, differences in BMI trajectories were found between 4 year old children from different maternal education background. And these differences widened with increasing age [16].

Studying the total range of weight development in high-income countries is a relatively new focus in Public Health research and studies are lacking. Based on the observation that underweight is increasing in prevalence in Europe [5, 6], it is important to also consider how this tracks in childhood and whether it is associated with ethnicity and/or SES. Earlier results in the ABCD cohort showed that both ethnicity and SES were related to different dietary patterns at age 5 [17].

There is growing interest in the role of dietary patterns in early childhood as a determinant of obesity risk [18]. Diets of poor quality might be important, as they are often characterized by high consumption of energy-dense foods [19, 20, 21]. Children with higher intakes of food from unhealthy patterns showed an increase in total and central body adiposity [22]. Remarkably, in 9-10 year old Norwegian children a higher prevalence of overweight and obesity was found in children consuming dietary patterns identified as healthy, and less overweight was found in children adhering to a dietary pattern high in processed foods [23, 24]. Therefore, it is of interest to confirm the association between dietary patterns and weight development in the ABCD cohort. The aims of this study were to examine (1) weight development between age 5 and 10 years by ethnicity, SES and thereafter by BMI category at age 5 and (2) its association with dietary patterns at age 5.

Methods

Study design and population

Data were used from the ABCD cohort, a large ongoing community-based birth cohort (http://www.abcd-study.nl/). The cohort study design has been described previously [25]. In brief, between January 2003 and March 2004, all pregnant women living in Amsterdam, the Netherlands, were invited to participate in the ABCD cohort by their obstetric care provider at their first parental care visit. Of the 12 373 women approached, 8 266 women filled out a pregnancy questionnaire that covered socio-demographic characteristics, obstetric history and lifestyle characteristics. The questionnaire was available in

Dutch, English, Turkish and the Arabic language. When the children turned 5 years of age, the addresses of 6 161 mothers were retrieved from the Youth Health Care registry. A 5-year questionnaire was sent to the woman's home address and 4 488 questionnaires were filled out by the mothers. These women received an invitation for a health check and a self-administered Food Frequency Questionnaire (FFQ) for their children. The health check was completed by 3 321 children and a number of 2 851 mothers returned the FFQ. At age 10, parents received an invitation for a regular preventive health check of their child, provided by the department of Youth Health Care of the Public Health Service Amsterdam carried out at their primary school. Finaly, a number of 1 765 children had valid data on diet at age 5 and BMI at age 5 and 10 years, and were included in the present analysis (Figure 4.1).

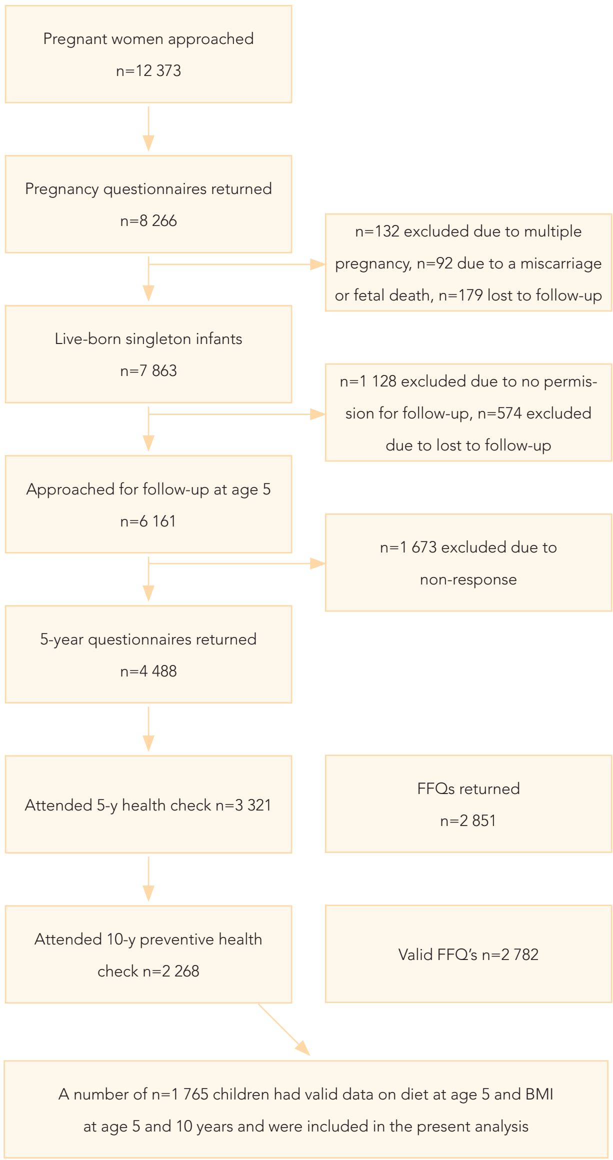

Figure 4.1. Flow-chart of the sampling procedure of the ABCD study population (n=1 765).

Assessment of BMI

At age 5, height and weight were measured during the ABCD health check were children were measured by a team of trained researchers according to standard protocols using a Leicester portable height measure (Seca) and a Marsden weightening scale (model MS-4102), respectively. At age 10, height and weight were measured by a health professional during the regular preventive health check at the children's primary school. During both measurements, children were dressed in light clothing. Data on height and weight were converted to Body Mass Index (BMI) scores [weight (kg) / height (m)2]. BMI scores were classified in age- and sex-specific BMI cut-offs from the International Obesity Task Force [7, 26] and three categories were formed: underweight, normal weight and overweight/obesity. BMI scores were also converted to age- and sex-specific BMI z-scores (SD scores), by comparison with the 'World Health Organization standards' [27].

Assessment of dietary patterns

The assessment of dietary patterns within the ABCD cohort at age 5 has been previously described [24]. Mothers filled in a validated 71-item FFQ developed by TNO Food (Zeist, The Netherlands) [28]. In brief, per food item, consumption frequency, portion size and the type of product consumed over the last 4 weeks was reported. Frequency options were "never", "less than once a week", "once a week", "2-3 times a week", "4-5 times a week", and "6-7 times a week". Mothers were given the possibility to fill in food items that were not included in the FFQ. Based on the data clearance protocol developed by TNO Food, the returned FFQs were scanned and the data on amounts (g/day) of products consumed and intake of energy was calculated using the Dutch Food Composition Database (NEVO) 2010 [29]. Energy adjusted intake (g/d) of 41 composed food groups were derived to assess dietary patterns, using Principal Component Analyses (PCA) with varimax rotation. Four dietary patterns were derived: a snacking (sweet and savoury snacks, refined breakfast products and low intakes of whole-grain breakfast products), full-fat (full-fat spreads and pasta dishes and low intakes of low-fat spreads), meat (low and high fat meat, sauces and refined grain products for warm meals) and healthy pattern (water and tea, vegetables, fish and fruits). Individuals were given a pattern score for each dietary pattern as a sum of the 41 standardized food group intakes, each weighted according to their factor loading. Positive pattern scores indicate higher consumption of food groups in that pattern.

Assessment of ethnicity and socio-economic status

Data on ethnicity was collected via the pregnancy questionnaire and based on the country of birth of the pregnant woman and her mother including both first-generation women (born outside the Netherlands) and second generation women (born in the Netherlands but whose mother was born in another country). Five ethnic categories were formed: Dutch, African Surinamese, Turkish, Moroccan and "other" ethnicities (mainly of non-western origin). Level of maternal education was collected via the 5-year questionnaire and was used as a proxy for SES. It was defined as the highest education completed: low: (a few years of) primary education / lower secondary education / lower vocational education, middle: general higher secondary education / intermediate vocational education or high: higher professional programmes or university programmes leading to a bachelor or master degree [30].

Assessment of potential confounders

Covariates were selected on the basis of theory and previous literature and were included in case of a significant change (≥10%) effect estimated on the dietary patterns. Potential covariates that might influence weight development and its relation with dietary patterns were sex, children's exact age at the 5-years health check, screen time at age 5 and maternal BMI at age 5. Maternal BMI (kg/m2) was based on mothers self-reported height and weight when the child was 5-year old and screen time (hour/day) was based on the duration in hours that the child spent watching TV or used a computer or console per day at age 5 [31].

Statistical analysis

Population and anthropometric characteristics were described in numbers, percentages or means with standard deviations (SD) for the total population and by ethnic and SES groups separately. Of the children that were included in this analyses (n=1 765), 1 765 children had complete data on sex, age and ethnicity, 1 759 on SES, 1 756 on screen time and 1 666 on maternal BMI.

For the first research objective, linear mixed model analyses were used to examine the change in BMI z-scores over time (from age 5 to 10 years) (i.e. weight development) in the total population by including time as a fixed effect. This method incorporates all available repeated measurements of the BMI z-scores simultaneously and takes into account that these measurements are correlated within participants. The likelihood ratio tests were used to determine a suitable random effect structure. The model with a random intercept and slope with time was considered most appropriate for all analyses. We tested for interactions between weight development between age 5 and 10 years and ethnic and SES groups by including an interaction term of ethnic and SES groups with time (significant at a p-value<0.10). No significant interactions were found between the low and middle SES groups, therefore we reported the results for these groups combined. We further examined weight development between age 5 and 10 years by ethnicity and SES. (Model 1). Adjustments were made for children's sex, exact age, screen time, and maternal BMI, ethnicity or SES (Model 2). Model 2 was further stratified by BMI categories at age 5: underweight (Model 2a), normal weight (Model 2b) and overweight/obesity (Model 2c). In sensitivity analysis, we tested for interaction between weight development between age 5 and 10 years and sex within the total population, by including an interaction term of sex with time.

For the second research objective, linear mixed effect models were used to examine the association between dietary patterns at age 5 and BMI z-scores at age 5 and 10 years (i.e. weight development) by ethnicity and SES (Model 1). Adjustments were made for children's sex, age, screen time, and maternal BMI, ethnicity or SES (Model 2). We performed two sensitivity analyses. First, Model 2 was additionally adjusted for total energy intake, in order to obtain insight into the role of energy intake in this relationship. Second, per ethnic and SES group, Model 2 was further stratified by BMI categories at age 5: underweight (Model 2a), normal weight (Model 2b) and overweight/obesity (Model 2c). All statistical analyses were performed in SPSS version 24 for windows and the level of statistical significance was set at 0.05.

Results

Population characteristics

Population characteristics of the total study population (n=1 765) including stratification by ethnicity and SES groups are presented in table 4.1. Mean (SD) age was 5.7 (0.5) y at the 5-years health check and 10.6 (0.4) y at the 10-years health check. Most children were from Dutch origin (79.3%), followed by Moroccan (5.4%), African Surinamese (4.4%), Turkish (2.6%) and "other" ethnicities (8.3%). The majority of children (68.3%) belonged to the high SES group and 31.7% belonged to the low/middle SES group. Highest BMI z-scores at age 5 were found in Turkish (0.60 SD 0.99) and Moroccan children (0.55 SD 1.67) and lowest BMI z-scores were found in Dutch (-0.04 SD 0.86) and high SES children (-0.06 SD 0.81).

Results in figure 4.2 presents the change, over BMI categories between age 5 and 10 years. In most groups, the majority of children that were underweight at age 5 switched to normal weight at age 10 (e.g. 64% in African Surinamese and 56% in Moroccan children). However, in Dutch and high SES children, respectively 51% and 50% of the children switched to normal weight and a higher percentage of children remained underweight at age 10. In children that were normal weight at age 5, mainly African Surinamese (24%) and Turkish children (33%) switched to the overweight/obesity category at age 10 (e.g. 9% in Moroccan children and 16% in low/middle SES children). In none of the groups, children switched from underweight to overweight/obesity or from overweight/obesity to underweight.

Mean (SD) BMI z-scores per BMI category at age 5 and 10 years are presented in Supplemental Table 4.1. In 10-year old overweight/obese children, mean (SD) BMI z-scores were lower in Dutch (1.44 SD 0.71) and high SES children (1.25 SD 0.61) than in other groups (e.g. Moroccan: 1.85 SD 0.63 and low/middle SES: 1.89 SD 0.66). Anthropometric characteristics further specified by sex are shown in Supplemental Table 4.2.

Weight development between age 5 and 10 years

Within the total population (n=1 765), there was a non-significant decrease in weight between age 5 and 10 years (B -0.018, 95% CI -0.052; 0.016). When this model was adjusted for confounders, the association was comparable (B -0.021, 95% CI -0.056; 0.014).

Table 4.1. Population characteristics at age 5 and 10 years by ethnicity and SES in the ABCD study population (n=1 765).

			Ethnicity (n=1 765)					SES (n=1 759)	
		Total n=1 765	Dutch (n=1 399)	African Surinamese (n=78)	Turkish (n=46)	Moroccan (n=96)	Other (n=146)	Low/middle (n=557)	High (n=1 202)
Age (years), mean (SD)	Age 5	5.7 (0.5)	5.6 (0.4)	5.8 (0.5)	5.9 (0.5)	6.0 (0.6)	5.7 (0.5)	5.8 (0.5)	5.6 (0.4)
	Age 10	10.6 (0.4)	10.7 (0.4)	10.6 (0.4)	10.6 (0.4)	10.6 (0.5)	10.6 (0.4)	10.7 (0.4)	10.6 (0.4)
Sex,									
Boys, n (%)		877 (49.7)	691 (49.4)	38 (48.7)	27 (58.7)	54 (56.3)	67 (45.9)	287 (51.9)	449 (49.3)
BMI, mean (SD)	Age 5	15.4 (1.5)	15.3 (1.3)	15.9 (2.3)	16.4 (1.7)	16.4 (2.0)	15.4 (1.4)	15.8 (1.8)	15.2 (1.2)
	Age 10	17.3 (2.5)	17.0 (2.2)	18.7 (3.8)	19.5 (3.2)	18.6 (3.2)	17.7 (2.6)	18.3 (3.2)	16.7 (1.9)
BMI z-score, mean (SD)	Age 5	0.03 (0.93)	-0.04 (0.86)	0.23 (1.37)	0.60 (0.99)	0.55 (1.67)	0.03 (0.93)	0.21 (1.11)	-0.06 (0.81)
	Age 10	0.01 (1.08)	-0.11 (1.01)	0.49 (1.40)	0.89 (1.20)	0.52 (1.16)	0.21 (1.08)	0.38 (1.22)	-0.17 (0.96)
BMI category									
Underweight, n (%)	Age 5	237 (13.5)	192 (13.8)		17 (21.8)	2 (4.4)	9 (9.4)	17 (11.6)	80 (14.4)156 (13.0)
	Age 10	216 (12.3)	183 (13.1)		7 (9.0)	4 (8.7)	8 (8.3)	14 (9.6)	60 (10.8)156 (13.0)
Normal weight, n (%)	Age 5	1 379 (78.1)	1 120 (80.0)	46 (59.0)	33 (71.7)	66 (68.8)	114 (78.1)	390 (70.0)	986 (82.0)
	Age 10	1 342 (76.0)	1 101 (78.7)	48 (61.5)	22 (47.8)	65 (67.7)	106 (72.6)	368 (66.0)	969 (80.6)
Overweight/obesity, n (%)	Age 5	149 (8.4)	87 (6.2)	15 (19.2)	11 (23.9)	21 (21.8)	15 (10.3)	87 (15.6)	60 (5.0)
	Age 10	207 (11.7)	115 (8.2)	23 (29.5)	20 (43.5)	23 (24.0)	26 (17.8)	129 (23.2)	77 (6.4)
Screen time (hour/day), mean (SD)	Age 5	1.43 (0.97)	1.26 (0.80)	2.26 (1.34)	2.14 (0.92)	2.14 (0.92)	1.90 (1.47)	1.99 (1.15)	1.17 (0.75)
Maternal BMI, mean (SD)	Age 5	23.7 (4.2)	23.2 (3.7)	25.4 (5.2)	26.9 (4.7)	26.9 (4.7)	25.2 (6.1)	25.5 (5.3)	22.9 (3.3)
Dietary pattern scores									
Snacking pattern score, mean (SD)	Age 5	0.062 (1.023)	-0.134 (0.873)	0.826 (1.099)	1.205 (0.882)	0.761 (1.054)	0.716 (1.378)	0.644 (1.083)	-0.210 (0.868)
Full-fat pattern score, mean (SD)	Age 5	0.023 (0.988)	0.019 (0.977)	-0.088 (1.040)	0.443 (1.055)	-0.258 (0.943)	0.173 (1.011)	-0.055 (1.040)	0.059 (0.962)
Meat pattern score, mean (SD)	Age 5	0.004 (1.006)	-0.000 (0.955)	0.651 (1.153)	-0.064 (0.975)	-0.029 (0.993)	-0.262 (1.253)	0.288 (1.027)	-0.128 (0.969)
Healthy pattern score, mean (SD)	Age 5	0.054 (0.990)	-0.033 (0.955)	-0.087 (1.108)	0.568 (0.776)	0.697 (1.113)	0.387 (0.954)	0.091 (1.092)	0.035 (0.939)

Ethnicity was based on the country of birth of the pregnant woman and her mother including both first-generation women and second generation women. SES was based on maternal education: low SES (<6y), middle SES (6-10y) and high SES (>10y) post-primary education. BMI categories were based on classification of Cole [7, 26]. Screen time (hour/day) was based on the duration in hours that the child spent watching TV or used a computer or console per day. Positive dietary pattern scores indicate higher consumption of food groups in that pattern.

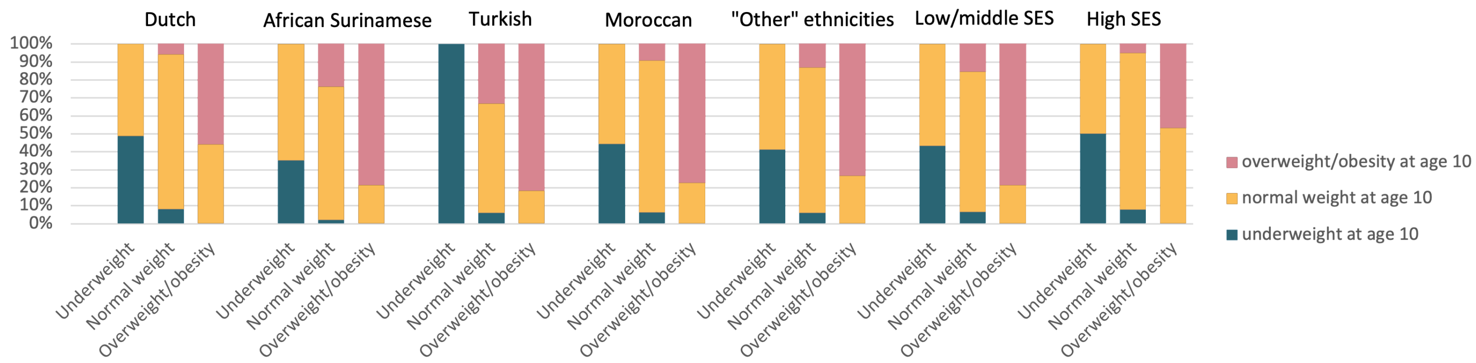

Figure 4.2. Change over BMI categories between age 5 and 10 years by ethnicity and SES in the ABCD study population n =1 765.

Weight development by ethnicity

Significant interactions were found between weight development and most ethnic groups; between Dutch and African Surinamese, Dutch and Turkish, Dutch and children of “other” ethnicities ($p<0.001$), between Moroccan and African Surinamese ($p=0.022$), Moroccan and Turkish ($p=0.011$) and between high and low/middle SES children ($p<0.001$). Therefore analyses of weight development between age 5 and 10 years are shown per ethnic group separately (Table 4.2 and Figure 4.3). In Dutch children, weight decreased (B -0.070, 95% CI -0.107; -0.033; Model 2). In Moroccan children there was no change in weight (B -0.001, 95% CI -0.182; 0.179). In African Surinamese, Turkish and children of “other” ethnicities weight increased. Weight development differed depending on children’s BMI category at age 5. In children that were underweight at age 5 we observed an increase in weight across all ethnic groups (e.g. in Dutch children: B 0.186, 95% CI 0.092; 0.280; Model 2a). In children with a normal weight at age 5 we observed a decrease in weight in Dutch and Moroccan children, although in the latter group this was not statistically significant. In Turkish, African Surinamese and children of “other” ethnicities however we observed an increase in weight (e.g. B 0.455, 95% CI 0.175; 0.734 in Turkish children). In overweight/obese children we observed a decrease in weight except in the Turkish or “other” ethnicities groups.

Weight development by SES

Analyses of weight development between age 5 and 10 years per SES group are presented in table 4.2 and figure 4.3. In low/middle SES children, weight increased (B 0.174, 95% CI 0.103; 0.245; Model 2) while in high SES children weight decreased (B -0.107, 95% CI -0.145; -0.068). In children that were underweight at age 5 we observed an increase in weight in both SES groups. In children with a normal weight at age 5 we observed an increase in weight in low/middle SES children and a decrease in high SES children. In overweight/obese children we observed a decrease in weight in both SES groups. Sensitivity analyses showed that weight development was significant different between boys (B 0.056, 95% CI 0.005; 0.106) and girls (B -0.097, -0.145; 95% CI -0.049) in the total population ($p<0.001$).

Table 4.2. Weight development between age 5 and 10 years by ethnicity and SES in the ABCD study population (n=1 765).

	B (95%-CI) Ethnicity (n=1 765)					SES (n= 1 759)	
	Dutch (n=1 399)	African Surinamese (n=78)	Turkish (n=46)	Moroccan (n=96)	Other (n=146)	Low/middle (n=557)	High (n=1 202)
Model 1: crude	-0.066 (-0.102; -0.029)	0.265 (0.059; 0.471)	0.314 (0.064; 0.564)	-0.015 (-0.175; 0.144)	0.179 (0.054; 0.304)	0.171 (0.103; 0.238)	-0.106 (-0.144; -0.069)
Model 2: adjusted	-0.070 (-0.107; -0.033)	0.274 (0.045; 0.502)	0.346 (0.089; 0.602)	-0.001 (-0.182; 0.179)	0.189 (0.059; 0.319)	0.174 (0.103; 0.245)	-0.107 (-0.145; -0.068)
Model 2a: underweight	0.186 (0.092; 0.280)	0.603 (0.153; 1.052)	-	0.896 (0.456; 1.336)	0.363 (0.043; 0.683)	0.504 (0.326; 0.682)	0.125 (0.033; 0.216)
Model 2b: normal weight	-0.091 (-0.132; -0.052)	0.313 (0.053; 0.573)	0.455 (0.175; 0.734)	-0.075 (-0.286; 0.136)	0.173 (0.027; 0.319)	0.172 (0.094; 0.251)	-0.125 (-0.167; -0.082)
Model 2c: overweight/obesity	-0.356 (-0.478; -0.232)	-0.418 (-0.692; -0.144)	0.072 (-0.121; 0.266)	-0.203 (-0.403; -0.003)	0.109 (-0.201; 0.420)	-0.164 (-0.279; -0.012)	-0.413 (-0.533; -0.292)

Ethnicity was based on the country of birth of the pregnant woman and her mother including both first-generation women and second generation women. SES was based on maternal education: low SES (<6y), middle SES (6-10y) and high SES (>10y) post-primary education. Values were based on linear mixed model analysis with random intercept and slope with time and reflect differences (95% CI) in weight development between ages 5 and 10 years stratified by ethnicity and SES. Model 2 was adjusted for sex, children's exact age at the 5-years health check, screen time at age 5, maternal BMI at age 5 and ethnicity or SES.

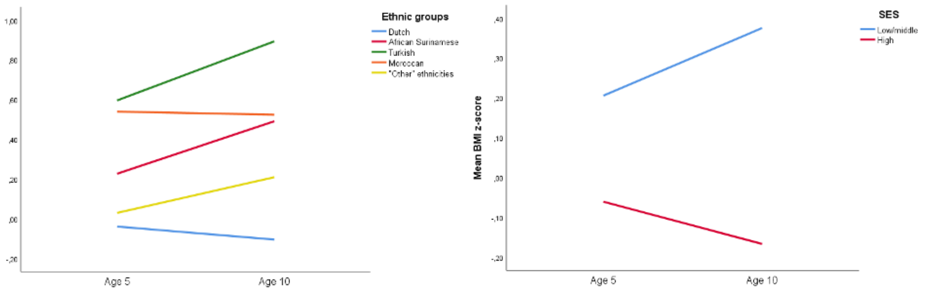

Figure 4.3. Observed mean BMI z-scores at age 5 and 10 years by ethnicity and SES in the ABCD study population (n=1 765).

Dietary patterns and weight development by ethnicity

Associations between dietary patterns at age 5 and weight development between age 5 and 10 years per ethnic group are presented in table 4.3. In Dutch children, full-fat pattern scores at age 5 were negatively associated with weight development between age 5 and 10 years (B -0.069, 95% CI -0.114; -0.024; Model 2), while healthy pattern scores were positively associated with weight development (B 0.092, 95% CI 0.047; 0.137). Also in Moroccan children, healthy pattern scores were positively associated with weight development (B 0.259, 95% CI 0.002; 0.516).
Other results were not statistically significant but showed comparable associations: also in Turkish and children of "other" ethnicities, we observed that full-fat pattern scores were negatively associated, and healthy pattern scores positively associated with weight development. In most ethnic groups, snacking pattern scores were negatively associated and meat pattern scores were positively associated with weight development between age 5 and 10 years.

Dietary patterns and weight development by SES

The associations between dietary patterns at age 5 and weight development between age 5 and 10 years by SES group are presented in table 4.3. In low/middle SES children, healthy pattern scores at age 5 were positively associated with weight development (B 0.094, 95% CI 0.008; 0.179; Model 2). In high SES children, snacking (B -0.081, 95% CI -0.136; -0.025) and full-fat pattern scores (B -0.072, 95% CI -0.119; -0.026) were negatively associated with weight development while healthy pattern scores were positively associated with weight development (B 0.096, 95% CI 0.047; 0.143).

Table 4.3. The association between dietary patterns at age 5 and weight development between age 5 and 10 years by ethnicity and SES (n=1 765).

	B (95%-CI) Ethnicity (n=1 765)					SES (n=1 759)	
	Dutch (n=1 399)	African Surinamese (n=78)	Turkish (n=46)	Moroccan (n=96)	Other (n=146)	Low/middle SES (n=557)	High SES (n=1 202)
SNACKING							
Model 1: crude	0.016 (-0.034; 0.070)	-0.100 (-0.363; 0.162)	0.124 (-0.235; 0.482)	0.027 (-0.185; 0.240)	0.070 (-0.042; 0.182)	0.117 (0.035; 0.198)	-0.049 (-0.100; 0.003)
Model 2: adjusted	-0.047 (-0.102; 0.008)	-0.096 (-0.345; 0.152)	0.203 (-0.209; 0.615)	-0.093 (-0.356; 0.171)	-0.025 (-0.154; 0.104)	0.019 (-0.071; 0.108)	-0.081 (-0.136;-0.025)
FULL-FAT							
Model 1: crude	-0.118 (-0.163;-0.073)	-0.038 (-0.323; 0.247)	-0.111 (-0.416; 0.194)	0.032 (-0.232; 0.296)	-0.142 (-0.293; 0.009)	-0.104 (-0.190;-0.019)	-0.106 (-0.152;-0.060)
Model 2: adjusted	-0.069 (-0.114;-0.024)	0.150 (-0.090; 0.390)	-0.165 (-0.486; 0.155)	0.125 (-0.168; 0.417)	-0.130 (-0.285; 0.025)	-0.062 (-0.147; 0.023)	-0.072 (-0.119;-0.026)
MEAT							
Model 1: crude	0.055 (0.009; 0.101)	-0.100 (-0.351; 0.152)	0.186 (-0.161; 0.533)	0.218 (-0.010; 0.446)	-0.068 (-0.058; 0.189)	0.058 (-0.029; 0.144)	0.023 (-0.024; 0.069)
Model 2: adjusted	0.020 (-0.027; 0.066)	-0.033 (-0.245; 0.180)	0.272 (-0.091; 0.634)	0.080 (-0.163; 0.324)	0.030 (-0.101; 0.161)	0.042 (-0.045; 0.128)	0.013 (-0.033; 0.059)
HEALTHY							
Model 1: crude	0.084 (0.038; 0.130)	0.224 (-0.042; 0.490)	0.222 (-0.166; 0.609)	0.203 (-0.034; 0.439)	0.051 (-0.110; 0.211)	0.169 (0.088; 0.250)	0.092 (0.045; 0.140)
Model 2: adjusted	0.092 (0.047; 0.137)	-0.014 (-0.264; 0.237)	0.221 (-0.190; 0.632)	0.259 (0.002; 0.516)	0.047 (-0.122; 0.216)	0.094 (0.008; 0.179)	0.096 (0.047; 0.143)

Ethnicity was based on the country of birth of the pregnant woman and her mother including both first-generation women and second generation women. SES was based on maternal education: low SES (<6y), middle SES (6-10y) and high SES (>10y) post-primary education. Positive dietary pattern scores indicate higher consumption of food groups in that pattern. Values were based on linear mixed model analysis with random intercept and slope with time and reflect differences (95% CI) in weight development between age 5 and 10 years per dietary pattern, stratified by ethnicity. Model 2: was adjusted for sex, children's exact age at the 5-years health check, screen time at age 5, maternal BMI at age 5, interaction between gender and time and ethnicity or SES.

Sensitivity analyses dietary patterns and weight development by BMI category

Dietary patterns were associated with weight development, independently of energy intake: additional adjustment for total energy intake (B reflects the intake per kcal) did not change the results (e.g. in Dutch children, full-fat pattern scores were B -0.069, 95% CI -0.116; -0.026 without adjustment for total energy intake and B -0.071, 95% CI -0.116; -0.026 with adjustment for total energy intake). In the same model, energy intake was not associated with weight development in ethnic or SES groups (e.g. B -0.0003, 95% CI -0.0010; 0.0004 in Turkish children and B -0.0001, 95% CI -0.0005; 0.0002 in children of "other" ethnicities). Finally, when Model 2 was further stratified by BMI categories at age 5: underweight (Model 2a), normal weight (Model 2b) and overweight/obesity (Model 2c), no clear pattern was found among children in different BMI categories. In normal weight Dutch children, healthy pattern scores were associated with positive weight development (B 0.070, 95% CI 0.035; 0.106). And in normal weight high SES children, snacking pattern scores were negatively associated with weight development (B -0.051, 95% CI -0.096; -0.006) and healthy pattern scores were associated with positive weight development (B 0.070, 95% CI 0.031; 0.109) between age 5 and 10 years. Other results were mainly non-significant associations without a clear structure.

Discussion

This study revealed differences in weight development between age 5 and 10 years between ethnic and SES groups in the large multi-ethnic ABCD cohort, consisting of 1 765 children, indicating that these groups follow different patterns of weight development. In Dutch and high SES children we observed a decreased weight development, while in non-Dutch and low/middle SES children weight development increased. Across the range of bodyweight categories at age 5, we observed a conversion to normal weight, which was stronger in Dutch and high SES children but less pronounced in non-Dutch and low/middle SES children. Dutch and high SES children were more often underweight or normal weight, at both ages and less often overweight/obese compared to non-Dutch and low/middle SES children. Contrary to our expectations, high healthy pattern scores were positively associated with weight development in Dutch, Moroccan and all SES categories of children and high full-fat pattern scores were negatively associated with weight development in Dutch and high SES children.

In line with our results, other studies also showed ethnic [8, 32] and SES [24, 33] differences in overweight and obesity. Prevalence of overweight/obesity was nearly double in children of non-western origin compared to children of western origin [8, 32]. However in our study, we also observed clear differences in the prevalence of overweight/obesity within the non-native group. At age 10, 44% of the children from Turkish origin was overweight/obese while 30% of children of African Surinamese and 24% of Moroccan origin were overweight/obese. Ethnicity also carries information about SES. Maternal educational level (in our study used as a proxy for SES) explains part of the ethnic differences in childhood overweight [14]. Non-native groups are more often from lower SES groups than native groups. In our study, 23% of Dutch children was from the low/middle SES group, compared to 69% in African Surinamese, 87% in Turkish, 82% in Moroccan children and 43% in children of "other" ethnicities. Despite comparable SES levels, we clearly observed that Turkish children developed more often overweight/obesity between the age of 5 and 10 years (44%) than Moroccan children (24%). These results suggest that the non-native group is a diverse group with possibly different causes and mechanisms that contribute to childhood overweight/obesity in each ethnic group.

We observed a higher tendency to underweight and normal weight in Dutch and high SES children. Another Dutch study also observed higher percentages of underweight in Dutch children, while percentages of underweight in children of Turkish and Moroccan origin were at most only half as high [34]. But unlike our results, this study did not observe SES differences in underweight rates [34]. A study in 4-5 year old children in Norway, found comparable percentages of underweight between children of European (10.4%) and Middle East/North African origin (12.7%) [32]. These differences could be possibly due to unintended side effects of current obesity prevention programs, and current delivery of these programs to lower SES groups is either not adequately reaching into these groups [35].

Additionally we examined weight development per ethnic and SES group, stratified by BMI category at age 5. We observed a conversion to normal weight in most groups, which is not in line with a study in 6-12 year old Norwegian children, where they found that overweight children tended to gain more weight than normal-weight children [24]. But the conversion to normal weight differed per ethnic and SES group. It was stronger in Dutch and high SES children that were more likely to experience negative weight development, regardless of BMI category at age 5. Observing weight development stratified per BMI category at age 5, showed that none of the children switched from underweight to overweight/obesity or from overweight/obesity to thinness. We also obtained more specific information of the differences in weight development between the non-native groups. Weight development of Moroccan children, seemed to be more in line with the structure of weight development in Dutch and high SES children. In normal weight Dutch and high SES children, weight development was negative while in normal weight African Surinamese, Turkish, "other" ethnicities and low/middle SES children, weight development was positive. In normal weight Moroccan children, weight decreased; however results were not statistically significant. In overweight/obese children, we observed a further increase of weight in Turkish children and children of "other" ethnicities.

Our results indicate that a healthy dietary pattern at age 5 is positively associated with weight development whereas a full-fat dietary pattern at age 5 is negatively associated weight development. Oellingrath et al. [23] also observed a positive association between dietary patterns identified as healthy (a 'varied Norwegian' pattern characterized by intakes of fish and meat for dinner, brown bread, regular white or brown cheese, lean meat, fish spread, and fruit and vegetable) and BMI. In this study, 9 year old children with high scores on this 'varied Norwegian' pattern were more likely to be overweight or obese at 9 years of age [23]. Another Dutch birth cohort observed that better diet quality at age 1 and 8 years was associated with higher height, weight, and FFMI, but not with body fatness up to age 10 years. This was independent of diet quality at an earlier or later time point [36]. We did not find other studies in the literature that observed an association between a dietary pattern comparable to our full-fat pattern (high intakes of full-fat cheese and full-fat spreads, low intakes of low-fat cheese, low-fat spreads and low-fat dairy) and BMI. In line with other studies [23, 37, 38, 39, 40], we did not observe a clear association between the snacking pattern (a dietary pattern characterized by snacking items) and weight development. Overall, the observed patterns of association between dietary patterns and weight development were mixed, also after analyses were stratified by BMI category at age 5. We observed only a few statistically significant associations, mainly within the larger groups (e.g. Dutch, low/middle SES and high SES). Therefore based on these results, we cannot draw any conclusions about the role of dietary patterns at the age of 5 in weight development over the next 5 years.

Childhood obesity is a complex construct. A diversity of factors contribute as biological- and lifestyle factors but also the social- and obesogenic environment [41]. There is also interest in the role of dietary patterns in early childhood as a determinant of obesity risk [18]. Few studies observed associations between dietary patterns and overweight [22, 23, 24]. In our analyses we considered sex, children's exact age at the 5-years health check, screen time at age 5 and maternal BMI at age

5 as major determinants that might influence the association between dietary patterns at age 5 and weight development.

Additionally, we studied the role of energy intake in the association between dietary patterns at age 5 and weight development. A previous study by Northstone et al [42] also failed to observe differences in outcome when adjusting for energy intake before entry into the PCA analysis. However, to exclude a possible role of energy intake, we included energy adjusted intake of food groups as an input in the PCA analyses to derive dietary patterns [43]. In sensitivity analyses, we also observed that additionally adjusting for energy intake in the association between dietary patterns at age 5 and weight development did not change the results. In the same Model, we observed that energy intake was not associated with weight development in the ethnic and SES groups.

Results of the association between dietary patterns and weight development stratified by ethnic and SES group, also give information about the possible moderating effect of ethnicity and SES. In another sensitivity analysis, we studied the intermediate effect of dietary patterns on the association with ethnicity / SES on weight development and we observed that the intermediate role of dietary patterns on weight development is limited. However, in our cohort, results were more pronounced in the ethnic groups than in the SES groups.

Methodological considerations

A strength of this study is the population based cohort-design that included a number of 1765 children with complete data on dietary patterns at age 5 and BMI at age 5 and 10 years, of different ethnic and SES groups that are often excluded in epidemiological studies. Analyses stratified per BMI category gave an complete overview of weight development in these groups. Height and weight were measured by a team of trained researchers and health professionals according to standard protocols.

However, interpretation of the association between dietary patterns and weight development is limited due to the cross sectional nature of dietary intake assessment. Dietary tracking, the maintenance of a dietary pattern over a certain time period, has been observed during childhood and from childhood to adolescence [40]. Another limitation of our study is that the FFQ was based on food commonly consumed by the Dutch population as determined by the Food Consumption Survey 1997–1998 [44]. The FFQ was validated with the gold standard of doubly labelled water in a group of 4 to 6-year-old children, although this validation study did not include non-Dutch groups [45]. Thus the FFQ may not reflect the food intake of ethnic minority children. To account for this we included an open question at the end of the FFQ, asking participants to note commonly eaten foods that were missing from the questionnaire. However, in the analysis we decided to not include the food items mentioned in the open item section because it was used only by a few mothers and it was unclear whether the mentioned items were additional to what was already included in the FFQ. In sub-analysis we found that energy intake related to energy requirements (based on Schofield resting metabolism) was not different between Dutch and non-Dutch groups, implying that the FFQ is able to capture total food intake in this population. Smaller numbers in ethnic groups is inherent to the ABCD cohort design but it is possible that some biases may have been introduced into the analyses, particularly as the non-responders tended to come disproportionately from lower SES and ethnic minority groups. Response rates per ethnic and SES group were 27% for Dutch, 12% for African Surinamese, 10% for Turkish, 13% for Moroccan, 13% for other ethnicities, 11% for low/middle SES and 38% for high SES. A nonresponse analysis determining the degree of selective response and selection bias between pregnancy and birth outcomes, indicated that selective non-response was present in the ABCD cohort, but selection bias was acceptably low and did not influence the studied birth outcomes [46].

Conclusions

We observed ethnic and SES differences in weight development between age 5 and 10 years in a multi-ethnic, population-based cohort of 5-10 year old children in The Netherlands. Our results indicate that each ethnic and SES group follows its own path of weight development. Results of the role of dietary patterns in weight development were mixed, limiting our ability to draw conclusions regarding the exact role of dietary patterns in ethnic and SES differences in weight development. Overall, however, our results indicate that a healthy pattern is positively associated, and a full-fat pattern is negatively associated with weight development.

List of abbreviations

BMI: Body Mass Index
ABCD cohort: Amsterdam Born Children and their Development cohort
SES: socio-economic status
FFQ: Food Frequency Questionnaire
PCA: Principal Component Analysis
SD: standard deviations
e.g: for example

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Supplemental Table 4.1. Mean (SD) BMI z-scores per BMI category at age 5 and 10 years by ethnicity and SES in the ABCD study population (n=1 765).

		Ethnicity (n=1 765)					SES (n= 1 759)	
		Dutch (n=1 399)	African Surinamese (n=78)	Turkish (n=46)	Moroccan (n=96)	Other (n=146)	Low/middle (n=557)	High (n=1 202)
BMI category								
Underweight, n (%)	**Age 5**	-1.36 (0.39)	-1.44 (0.46)	-1.74 (0.69)	-1.57 (0.42)	-1.47 (0.36)	-1.44 (0.05)	-1.35 (0.34)
	Age 10	-1.20 (0.82)	-0.88 (1.09)	-1.47 (0.33)	-0.82 (0.91)	-1.04 (0.90)	-0.99 (1.00)	-1.25 (0.74)
Normal weight, n (%)	**Age 5**	0.05 (0.57)	0.18 (0.70)	0.29 (0.49)	0.29 (0.55)	0.04 (0.60)	0.14 (0.58)	0.04 (0.57)
	Age 10	-0.04 (0.85)	0.51 (1.15)	0.67 (1.06)	0.26 (0.92)	0.19 (0.88)	0.32 (0.96)	0.08 (0.83)
Overweight/obesity, n (%)	**Age 5**	1.77 (0.49)	2.27 (0.72)	1.91 (0.57)	2.14 (0.63)	1.68 (0.47)	2.02 (0.59)	1.64 (0.37)
	Age 10	1.44 (0.71)	1.98 (0.72)	1.98 (0.57)	1.85 (0.63)	1.75 (0.76)	1.89 (0.66)	1.25 (0.61)

Ethnicity was based on the country of birth of the pregnant woman and her mother including both first-generation women and second generation women. SES was based on maternal education: low SES (<6y), middle SES (6-10y) and high SES (>10y) post-primary education. BMI categories were based on classification of Cole [7, 26] (n=1 765).

Supplemental Table 4.2. Anthropometric characteristics at age 5 and 10 years by ethnicity, SES and sex in the ABCD study population (n=1 765).

	Ethnicity (n=1 765)						SES (n= 1 759)		
	Dutch (n=1 399)	African Surinamese (n=78)		Turkish (n=46)	Moroccan (n=96)	Other (n=146)	Low/middle (n=557)	High (n=1 202)	
BMI, mean (SD)	**Age 5**	**15.3 (1.3)**	**15.9 (2.3)**	**16.4 (1.7)**	**16.4 (2.0)**	**15.4 (1.4)**	**15.8 (1.8)**	**15.2 (1.2)**	
	Boys	15.3 (1.2)	16.2 (2.0)	16.2 (1.4)	16.3 (2.0)	15.5 (1.5)	15.7 (1.7)	15.3 (1.1)	
	Girls	15.3 (1.4)	15.5 (2.6)	16.6 (2.1)	16.5 (2.2)	15.4 (1.3)	15.8 (2.0)	15.2 (1.3)	
	Age 10	**17.0 (2.2)**	**18.7 (3.8)**	**19.5 (3.2)**	**18.6 (3.2)**	**17.7 (2.6)**	**18.3 (3.2)**	**16.7 (1.9)**	
	Boys	17.0 (2.0)	19.2 (3.6)	19.6 (3.2)	18.4 (3.1)	17.7 (2.7)	18.1 (2.9)	16.9 (1.9)	
	Girls	17.0 (2.4)	18.2 (4.1)	19.3 (3.2)	18.8 (3.3)	17.7 (2.5)	18.5 (3.4)	16.7 (2.0)	
BMI z-score, mean (SD)	**Age 5**	**-0.04 (0.86)**	**0.23 (1.37)**	**0.60 (0.99)**	**0.55 (1.67)**	**0.03 (0.93)**	**0.21 (1.11)**	**-0.06 (0.81)**	
	Boys	-0.06 (0.87)	0.53 (1.31)	0.56 (0.89)	0.54 (1.22)	0.05 (1.02)	0.20 (1.13)	-0.05 (0.83)	
	Girls	-0.02 (0.86)	-0.06 (1.36)	0.65 (1.16)	0.54 (1.11)	0.01 (0.86)	0.21 (1.09)	-0.07 (0.79)	
	Age 10	**-0.11 (1.01)**	**0.49 (1.40)**	**0.89 (1.20)**	**0.52 (1.16)**	**0.21 (1.08)**	**0.38 (1.22)**	**-0.17 (0.96)**	
	Boys	-0.04 (1.01)	0.79 (1.35)	1.00 (1.25)	0.53 (1.19)	0.27 (1.15)	0.39 (1.24)	-0.06 (0.97)	
	Girls	-0.17 (1.01)	0.20 (1.40)	0.75 (1.16)	0.52 (1.15)	0.15 (1.02)	0.36 (1.20)	-0.27 (0.93)	
BMI category									
Underweight, n (%)	**Age 5**	**192 (13.8)**	**17 (21.8)**	**2 (4.4)**	**9 (9.4)**	**17 (11.6)**	**81 (14.5)**	**156 (13.0)**	
	Boys	99 (14.3)	6 (15.8)	1 (3.7)	5 (9.3)	10 (14.9)	44 (15.2)	77 (13.1)	
	Girls	94 (13.3)	11 (27.5)	1 (5.3)	4 (9.5)	7 (8.9)	37 (13.8)	79 (12.8)	
	Age 10	**183 (13.1)**	**7 (9.0)**	**4 (8.7)**	**8 (8.3)**	**14 (9.6)**	**60 (10.8)**	**156 (13.0)**	
	Boys	70 (10.1)	2 (5.3)	3 (11.1)	5 (9.3)	6 (9.0)	29 (10.1)	57 (9.8)	
	Girls	113 (16.0)	5 (12.5)	1 (5.3)	3 (7.2)	8 (10.1)	31 (11.6)	99 (16.1)	
Normal weight, n (%)	**Age 5**	**1 120 (80.0)**	**46 (59)**	**33 (71.7)**	**66 (68.8)**	**114 (78.1)**	**338 (69.7)**	**986 (82.0)**	
	Boys	561 (81.2)	24 (63.2)	22 (81.5)	38 (7.4)	51 (76.1)	205 (70.9)	489 (83.4)	
	Girls	558 (78.8)	22 (55.0)	11 (57.9)	27 (64.3)	63 (79.7)	183 (68.3)	497 (80.7)	

	Age 10	**1 101 (78.7)**	**48 (61.5)**		**22 (47.8)**	**65 (67.7)**	**106 (72.6)**	**368 (66.0)**	**969 (80.6)**
	Boys	567 (82.1)	24 (63.2)		12 (44.4)	36 (66.7)	49 (73.1)	197 (68.2)	489 (83.4)
	Girls	534 (75.4)	24 (60.0)		10 (52.6)	29 (69.0)	57 (72.2)	171 (63.8)	480 (77.9)
Overweight/obesity, n (%)	**Age 5**	**87 (6.2)**	**15 (19.2)**		**11 (23.9)**	**21 (21.8)**	**15 (10.3)**	**88 (15.8)**	**60 (5.0)**
	Boys	31 (4.5)	8 (21.1)		4 (14.8)	11 (20.4)	6 (9.0)	40 (13.8)	20 (3.4)
	Girls	56 (7.9)	7 (17.5)		7 (36.8)	11 (26.2)	9 (11.4)	48 (17.9)	40 (6.5)
	Age 10	**115 (8.2)**	**23 (29.5)**		**20 (43.5)**	**23 (24.0)**	**26 (17.8)**	**129 (23.2)**	**77 (6.4)**
	Boys	54 (7.8)	12 (31.6)		12 (7.4)	13 (24.1)	12 (17.9)	63 (21.8)	40 (6.5)
	Girls	61 (8.6)	11 (27.5)		8 (42.1)	10 (23.8)	14 (17.7)	66 (24.6)	37 (6.0)

Ethnicity was based on the country of birth of the pregnant woman and her mother including both first-generation women and second generation women. SES was based on maternal education: low SES (<6y), middle SES (6-10y) and high SES (>10y) post-primary education. BMI categories were based on classification of Cole [7, 26] (n=1 765).

CHAPTER 5

Diet quality in relation to body composition in childhood: The ABCD study

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To be submitted

Abstract

Introduction

Diet quality in childhood may be an important target in the prevention of adiposity. We aimed to evaluate overall diet quality of children participating in the Amsterdam Born Children and their Development (ABCD) study and to examine associations of diet quality around age 5 years with growth and body composition up to age 12 years.

Methods

We analysed data on diet quality and growth and body composition of 844 children (47.8% were girls). Data on dietary intake were assessed with a food-frequency questionnaire at their median age of 5.6 (IQR 5.3 – 6.0) years. A predefined diet quality score (range 0-10) was calculated, reflecting adherence to age-specific dietary guidelines. Anthropometrics and body composition were assessed around ages 5 and 12 years using bioelectrical impedance analysis. We calculated sex- and age-specific SD-scores for height, weight, body mass index (BMI), fat mass index (FMI), fat-free mass index (FFMI), and body fat percentage (BF%).

Results

We observed a mean (±SD) total diet quality score of the children of 4.8 (± 1.1) out of 10. The highest score was observed for the whole grains component, whereas low scores were observed for sugar-containing beverages and high-fat and processed meat. After adjustment for socioeconomic and lifestyle factors, we observed that a higher diet quality score at age 5 years was associated with a lower weight (-0.49 SDS per 1 point increase in diet quality score, 95%CI -0.80, -0.18), a lower BMI (-0.18 SDS, 95%CI -0.29, -0.07) and a lower FMI (-0.09 SDS, 95%CI -0.17, -0.02) at age 12 years. The observed associations were independent of baseline anthropometric values.

Conclusion

Diet quality of 5-year-old children in the ABCD study was suboptimal. We observed that, independent of sociodemographic and other lifestyle factors, children with a better diet quality at age 5, had lower weight, BMI and body fat mass 7 years later.

Introduction

The prevalence of childhood overweight is increasing rapidly globally and is of great concern because of its adverse health consequences in both childhood and adulthood [1,2]. Diet in childhood is one of the most important modifiable determinants of obesity risk. Not only specific foods or nutrients, but also overall dietary patterns have been related to obesity risk. For example, a review of previous studies in children has shown that high adherence to data-driven 'Western-like' dietary patterns is associated with higher risk of obesity [3], whereas high adherence to data-driven dietary patterns that are labelled as more healthy is linked to a lower obesity risk [3]. However, these data-driven dietary patterns do not necessarily align with guidelines for healthy diets.
A few previous studies have examined predefined diet quality indices reflecting dietary recommendations in relation to BMI or body composition in children. Some studies suggested that children with a higher diet quality at ages ranging from 2 years to 10 years have lower weight [4] or BMI [5]. In contrast, we previously observed among Dutch children participating in the Generation R Study that a higher diet quality in infancy and at age 8 years was associated with a higher BMI up to age 10 years, but that this was fully explained by a higher fat-free mass rather than fat mass [7,8]. The few studies that examined diet quality in relation to detailed body composition in childhood showed inconsistent results with respect to fat and lean mass [4,6,7,8].

As childhood is a period of rapid growth and development, differences between these few studies may be explained by differences in age groups. Therefore, more research is needed to explore associations of diet quality in childhood with detailed measures of body composition. In this study, we aimed to evaluate diet quality of 5-year-old children from a prospective population-based cohort in Amsterdam, and to examine associations of diet quality at the age of 5 years with body composition up to age 12 years.

Methods

Study design and population

This study was embedded in the Amsterdam Born Children and their Development (ABCD) study, an ongoing prospective population-based cohort study in Amsterdam, the Netherlands 9. Between January 2003 and March 2004, all pregnant women living in Amsterdam were invited to participate. Of the 12,373 women approached, 8,266 women filled out a pregnancy questionnaire. Approval of the study was obtained from the Central Committee on Research Involving Human Subjects in the Netherlands, the medical ethics review committees of the participating hospitals, and the Registration Committee of the Municipality of Amsterdam 9. All mothers gave written informed consent for their children.
Around the children's age of 5 years, a food-frequency questionnaire (FFQ) to assess diet in childhood was sent to mothers of 4,488 children, of which 2,851 mothers returned the questionnaire. Valid dietary intake data were available for 2,782 of the children 10. Of these children, a total of 844 children had complete data on growth and body composition at both the ages of 5 and 12 years (Figure 5.1).

Measurements

Diet quality

As described in detail previously 10, dietary intake in childhood was assessed at a median age of 5.6 (IQR 5.3 – 6.0) years using a semi-quantitative FFQ, which was developed for Dutch children and validated for energy intake against the doubly labelled water method 11. This FFQ was filled out by the mother of the child and included questions on food items, frequency of consumption, portion sizes, and type of products consumed, covering the last 4 weeks. Energy and nutrient intakes were calculated using data from the Dutch Food Composition Table (NEVO) 2010 12.

We applied a previously developed predefined diet quality score for school-age children 13, which quantified adherence to dietary guidelines for children aged 4 to 8 years. The ten following components and cut-off values were included in de diet quality score: intake of fruit (≥ 150g/d); vegetables (≥ 125g/d); whole grains (≥ 90g/d); fish (≥ 55g/w); pulses (≥ 84g/w); nuts (≥ 15g/d); dairy (≥ 300g/d); oils and fats (≥ 30g/d); sugar-containing beverages (≤ 150g/d); and high-fat and processed meat (≤ 250g/w). Ratios of reported intakes and recommended intakes were calculated, resulting in a score between 0 and 1 for each component and an overall sum-score ranging from 0 to 10, with a higher score representing a better diet quality 13.

Body composition

At child's mean ages of 5.6 ± 0.5 and 11.8 ± 0.4 years, we assessed anthropometrics of the children. Height was determined to the nearest millimeter using a Leicester portable height measure (Seca, Hamburg, Germany) and weight was measured to the nearest 100 g using a Marsden MS-4102 weighing scale (Oxfordshire, United Kingdom). At the 5.6 and 11.8 year measurements, we additionally measured fat mass with arm-to-leg bioelectrical impedance analysis (BIA) (Bodystat 1500 MDD machine (Bodystat Inc, Douglas, UK)). For both time points, we calculated BMI (weight(kg)/height(m)2), fat-free mass index (FFMI) (fat-free mass(kg)/height(m)2), fat mass index (FMI) (fat mass(kg)/height(m)2), and body fat percentage (BF%) (fat mass as percentage of total body weight). For all outcomes, we created age- and sex-adjusted standard deviation scores (SDS) based on children with data within the ABCD Study.

Covariates

We assessed several socioeconomic and lifestyle factors of the children and their mothers. Information on sex and date of birth of the children was obtained using questionnaires. Ethnicity was based on the country of birth of the mother and her mother, for which information was obtained from questionnaires, and was categorized into five categories (Dutch; Surinamese; Turkish, Moroccan; other). Information on child's physical activity around the age of 5 years was obtained with a questionnaire and included questions on frequency and duration of playing outside, sports participations, and walking and biking to and from school. Responses were combined and averaged into a continuous variable indicating average amount of time being physically active per day (<1 h/d; 1 – 2 h/d; >2 h/d) 15. Information on screen time was also obtained using a questionnaire and reflects time spent watching TV or using a computer (<1 h/d; 1 – 2 h/d; >2 h/d) 15. Information on pubertal developmental stage (tanner stage) of the child was obtained using a questionnaire around the age of 12 years 16,17. At the age of 5 years, questionnaires were used to obtain information on maternal educational level (low; high (higher vocational education or university)).

Statistical analyses

We used linear regression models to analyse associations of diet quality at the age of 5 years with body composition at ages 5 and 12 years separately. Diet quality was analysed both as a continuous variable and categorized into quintiles. Potential confounders for all analyses were selected based on literature. Model 1 included child's sex, age at dietary assessment and for outcomes at age 12 also corresponding baseline anthropometric values. The second model was additionally adjusted for several socioeconomic and lifestyle factors: ethnic background, physical activity, screen time and maternal educational level. To examine whether associations of diet quality and body composition were independent of energy intake, model 3 was additionally adjusted for total calorie intake. Finally, model 4 was additionally adjusted for pubertal status to examine whether associations were independent of development stage. To examine whether associations of diet quality with body composition differed by child's sex, an interaction term was included in the models.

To reduce potential bias due to missing values on covariates (ranging from 0 to 3.0%), these were multiple imputed (n=10 imputations). Results were based on pooling of the effect estimate of the imputed datasets and considered statistically significant at P<0.05, two-sided alpha error. The statistical analyses were carried out using SPSS statistics version 24.0 (IBM Inc., Armonk, NY, USA) and R version 3.4.1 (The R Foundation for Statistical Computing, Vienna, Austria).

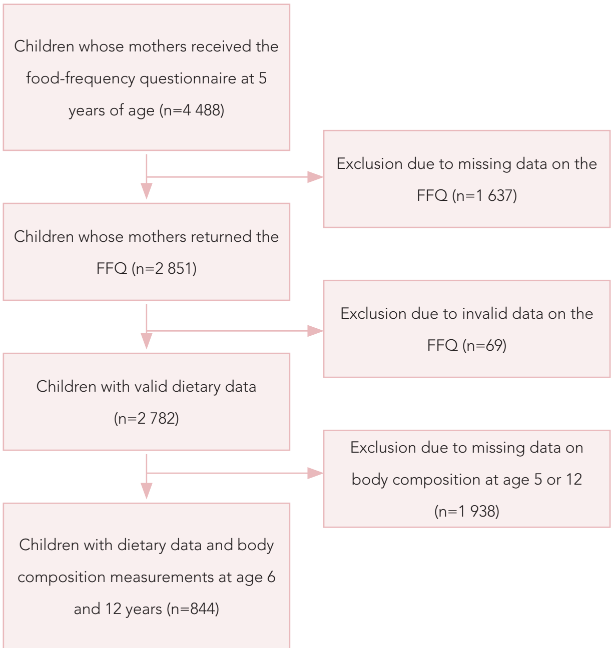

Figure 5.1. Flow chart of participants included in the study.

Results

Population characteristics

Characteristics of the children and their mothers are presented in Table 5.1. Most of the children had a Dutch ethnic background (76.2%) and 47.8% were girls. Median total energy intake was 1503 (IQR 1305 – 1700) kcal per day. Median BMI of the children was 15.3 kg/m2 (IQR 14.6 – 16.0) at the age of 6 years and 17.1 kg/m2 (IQR 15.8 – 18.7) at the age of 12 years. Children with a higher diet quality score more often had a mother with a higher educational level, were more physically active, and spent less time using screens (Supplemental Table 5.1).

Diet quality

Mean (± SD) diet quality of the children was 4.8 (± 1.1) on a theoretical range from 0 to 10. Children with higher diet quality scores on average had higher daily energy intakes (Supplemental Table 5.1). Table 5.2 shows the median scores for the individual diet quality components. We observed a median score of 1.00 (IQR 0.80 – 1.00) for whole grains component, a score of 0.75 (IQR 0.52 – 1.00) for fruit, and a score of 0.68 (IQR 0.18 – 1.00) for fish. The lowest scores were observed for pulses (0.21 (IQR 0.00 – 0.63), sugar-containing beverages 0.00 (IQR 0.00 – 0.02), and high-fat and processed meat 0.00 (IQR 0.00 – 0.35).

Table 5.1. Characteristics of the study participants (n=844).

	N	Mean ± SD, median (IQR), or %
Child characteristics		
Sex		
Girls	403	47.8
Ethnicity		
Dutch	643	76.2
Surinamese	34	4.0
Turkish	10	1.2
Moroccan	29	3.4
Other	128	15.2
Screen time		
Less than 1 hour/day	340	40.3
1 to 2 hours per day	395	46.8
More than 2 hours per day	109	12.9
Physical activity		
Less than 1 hour/day	60	7.1
1 to 2 hours per day	319	37.8
More than 2 hours per day	466	55.2
Maternal educational level		
High	616	73.0
Child dietary assessments		
Age at dietary assessment (y)		5.6 (5.3 – 6.0)
Total energy intake (kcal/d)		1503 (1305 – 1700)
Diet quality (score)*		4.8 ± 1.1
Child growth and body composition		
At baseline (5 years)		
Age at 5 years measurement (y)		5.6 ± 0.5
Height (cm)		116.5 (112.5 – 120.5)
Weight (kg)		20.8 (18.8 – 22.7)
Body mass index (kg/m2)		15.3 (14.6 – 16.0)
Fat mass (kg)		4.0 (3.2 – 5.1)
Fat-free mass (kg)		16.6 (15.4 – 17.8)
Body fat percentage		19.5 (16.3 – 23.3)
At follow-up (12 years)		
Age at 12 years measurement (y)		11.8 ± 0.4
Height (cm)		153.7 (148.5 – 158.1)
Weight (kg)		40.5 (36.1 – 45.6)
Body mass index (kg/m2)		17.1 (15.8 – 18.7)
Fat mass (kg)		9.0 (7.3 – 11.4)
Fat-free mass (kg)		31.5 (28.1 – 34.8)
Body fat percentage		23.0 (19.4 – 26.8)

Values are medians (IQR) for continuous variables with a skewed distribution or means ±SD for continuous variables with a normal distribution and percentages for categorical variables.

** theoretical range 0-10, a higher score reflects a better diet quality.*

Table 5.2. Cut-off values of the diet quality score components and intakes, and scores of the different diet quality score components (n=844).

Component	Cut-off values	Unit	Intake g/d	Score
Fruit	≥ 150	g/d	112 (78-169)	0.75 (0.52-1.00)
Vegetables	≥ 125	g/d	64 (40-96)	0.51 (0.32-0.77)
Whole-grains	≥ 90	g/d	99 (72-130)	1.00 (0.80-1.00)
Fish	≥ 55	g/w	38 (10-75)	0.68 (0.18-1.00)
Pulses	≥ 84	g/w	18 (0-53)	0.21 (0.00-0.63)
Nuts	≥ 15	g/d	5.4 (1.1-10.7)	0.36 (0.07-0.71)
Dairy	≥ 300	g/d	159 (61-279)	0.53 (0.20-0.93)
Oils and soft or liquid fats	≥ 30	g/d	11 (6-17)	0.37 (0.19-0.56)
Sugar-containing beverages	≤ 150	g/d	244 (147-362)	0.00 (0.00-0.02)
High-fat and processed meat	≤ 250	g/w	280 (162-416)	0.00 (0.00-0.35)

Values are median (IQR). Maximum score per component: 1 (van der Velde LA, Nguyen AN, Schoufour JD, et al. Diet quality in childhood: the Generation R Study. Eur J Nutr. 2018.).

Because for some food components, the guidelines include a range rather than fixed number, we used the mean of this range, as mean age of the children in our study at dietary assessment was around 6 years.

Diet quality and growth and body composition

After adjustment for sex, age, and baseline anthropometric values (model 1), results from linear regression models showed that higher diet quality at age 5 years was associated with lower weight, BMI, FMI, and BF% at age 12 years (model 1: β= -0.69 SDS (95%CI: -0.99, -0.40) for weight; β= -0.28 SDS (95%CI: -0.38, -0.17) for BMI; β= -0.16 SDS (95%CI: -0.23, -0.09) for FMI; and β= -0.46 SDS (95%CI: -0.71, -0.21) for BF%) (Table 5.3). After additional adjustment for socioeconomic and lifestyle factors (model 2), total calorie intake (model 3), and pubertal stage (model 4), associations of diet quality with body composition outcomes slightly attenuated but remained statistically significant for weight, BMI and FMI (model 4: β= -0.49 SDS, (95%CI: -0.80, -0.18) for weight; β= -0.18 SDS (95%CI: -0.29, -0.07) for BMI; β= -0.09 SDS (95%CI: -0.17, -0.02) for FMI; and β= -0.24 SDS (95%CI: -0.50, -0.03) for BF%) (Table 5.3). In the adjusted models (model 4), diet quality was not associated with height, FFMI, or BF%.

We found a statistically significant interaction of diet quality with child's sex for the association with FFMI (p-for-interaction = 0.04), but not with other outcomes (p-for-interaction > 0.05). After stratifying our analyses for boys and girls, we observed that girls with a higher diet quality score had a lower FFMI (β= -0.12 SDS (95%CI: -0.22, -0.02), whereas in boys, diet quality was not associated with FFMI (β= 0.01 SDS (95%CI: -0.08, 0.11).

Associations for the diet quality score in quintiles were generally similar to those for the diet score as continuous variable (Supplemental Table 5.2). Children with a diet quality score in the highest quintile at age 5 years had a 1.74 SDS lower weight (95%CI -2.84, -0.65) at age 12 years compared to children in the lowest quintile. For BMI and FMI we observed associations in the same direction, but with smaller effect estimates (β= -0.67 SDS (95%CI: -1.07, -0.27) for BMI; and β= -0.33 SDS (95%CI: -0.60, -0.06) for FMI).

For outcomes at the age of 5 years, we observed that children with a diet quality score in the highest quintile had a 0.38 SDS higher BMI (95%CI 0.09, 0.67) compared to children in the lowest quintile (Supplemental Table 5.3). No associations were observed for diet quality with other body composition outcomes at the age of 5 years.

Discussion

We evaluated diet quality in children around the age of 5 years and examined associations with body composition after a 7-year follow-up in a large population-based cohort of children. We observed that diet quality in our study population was suboptimal. Intake of whole grains was generally in line with dietary guidelines, but intakes of sugar-containing beverages, and high-fat and processed meat were almost always higher than recommended. We also observed that a higher diet quality in childhood was associated with a lower weight, BMI and fat mass at age 12 years but not with height. Associations with fat free mass differed by child sex.

Table 5.3. Associations of diet quality at the age of 5 years with body composition at the age of 12 year.

	BMI (SDS)	FMI (SDS)	FFMI (SDS)	BF% (SDS)	Height (SDS)	Weight (SDS)
	B 95%CI	B 95%CI	B 95%CI	B 95%CI	B 95%CI	B 95%CI
Model 1	**-0.28 (-0.38, -0.17)**	**-0.16 (-0.23, -0.09)**	**-0.09 (-0.16, -0.03)**	**-0.46 (-0.71, -0.21)**	-0.09 (-0.30, 0.12)	**-0.69 (-0.99, -0.40)**
Model 2	**-0.17 (-0.28, -0.06)**	**-0.11 (-0.18, -0.03)**	-0.03 (-0.10, 0.04)	**-0.31 (-0.56, -0.05)**	-0.09 (-0.31, 0.13)	**-0.45 (-0.75, -0.15)**
Model 3	**-0.18 (-0.29, -0.07)**	**-0.09 (-0.17, -0.02)**	-0.05 (-0.12, 0.02)	-0.24 (-0.51, 0.03)	-0.12 (-0.35, 0.11)	**-0.49 (-0.81, -0.17)**
Model 4	**-0.18 (-0.29, -0.07)**	**-0.09 (-0.17, -0.02)**	-0.05 (-0.12, 0.02)	-0.24 (-0.50, 0.03)	-0.13 (-0.35, 0.09)	**-0.49 (-0.80, -0.18)**

Values are regression coefficients and 95% confidence intervals based on linear mixed models and reflect differences in growth per 1 point higher diet quality score. **Bold** values indicate statistically significant effect estimates ($p<0.05$).

Model 1 is adjusted for sex, age, and baseline values

Model 2 is additionally adjusted for ethnic background, maternal educational level, screen time, and physical activity

Model 3 is additionally adjusted for total energy intake

Model 4 is additionally adjusted for tanner stage

Interpretation and comparison with previous studies

Diet quality was suboptimal in our population of children. On average, only half of the dietary guidelines were met. This is in line with diet quality observed in other population-based studies among children in the Netherlands 13 and the US 18. Although the majority of the children in this cohort has a sufficient intake of whole grains, with 64.1% of the children reaching the maximum score for this component (i.e., fully adhering to the guideline), most children do not meet recommendations for intakes of several other components. Especially the intake of pulses was generally much lower than recommended, whereas intakes of sugar-containing beverages and of high-fat and processed meat were generally much higher than recommended. Previous studies have shown that consumption of sugar-containing beverages and high-fat meat is associated with higher risk of obesity and type 2 diabetes [19-21]. It has also been shown that dietary intake tracks from childhood to adulthood 22,23, emphasizing the need to improve intake of these dietary components in childhood to prevent the development of chronic diseases later in life.

In our study, we indeed also observed that higher diet quality in childhood was associated with a lower weight, BMI, and fat mass 7 years later. These associations were especially pronounced for diet quality score in the highest quintile compared to the lowest quintile. We observed that children in the highest quintile of diet quality also had the highest total energy intake per day. Total energy intake and diet quality are not necessarily correlated, as the high energy intake could also be obtained from unhealthy food products, which are not included in the diet quality score. Still, our findings were independent of total energy intake, suggesting that not only the quantity, but also the quality of the diet may be an important factor in lowering risk of overweight in childhood.

Our findings are in line with previous studies reporting lower BMI or fat mass in children with a higher diet quality [4,5], although previous analyses in the Generation R Study using the same diet quality score found associations no associations with a lower fat mass but with a higher fat-free mass 7,24. This suggests that higher diet quality in childhood may be associated with lower risk of adiposity and a better body composition (i.e., lower body fat mass and/or a higher lean mass) in children. Further studies are needed to explore associations of diet quality with detailed measures of body composition at different ages across childhood.

Strengths and limitations

Strengths of this study include its large sample size, the population-based, longitudinal design, and the availability of data on several potential confounders. Another strength is that we evaluated overall dietary intake rather than one single nutrient or food and we used age-specific dietary guidelines. The advantage of studying overall diet is that it takes the correlations between foods and nutrients into account [28]. As BMI only is not an accurate measure of adiposity, it is important to examine detailed measures of body composition, especially in growing children. We therefore assessed detailed measures of body composition using BIA. In addition, we studied prospective associations with later childhood body composition, adjusted for the baseline values of outcome measures.

Several limitations should be taken into account as well. Dietary intake was assessed with a FFQ, which may be subject to measurement errors. However, the FFQ that we used showed reasonable to good validity for estimating energy intake in a previous validation study against the doubly labelled water method [11]. Another potential limitation is that we calculated age- and sex-specific SD-scores for the outcomes based on children within the ABCD study, because no external standard reference values are available for body composition. Therefore, if body composition of the whole study population would shift in the same direction between the two time points, individual changes could not be detected. Our findings may not begeneralizable to all children, since the majority of our study participants were highly educated. Finally, a higher diet quality may be a proxy for an overall healthy lifestyle, which could potentially confound associations of diet with adiposity. Although we had data on a large number of potential confounders such as physical activity, we cannot rule out unmeasured or residual confounding.

Conclusion

In conclusion, we observed that diet quality in a population-based sample of Dutch children was suboptimal. Generally, intake of whole grains was sufficient, whereas intake of pulses was too low and intake of sugar-containing beverages and high-fat and processed meat were higher than recommended. Higher diet quality was associated with lower weight, BMI, and fat mass up to the age of 12 years. Our findings emphasize the importance of diet quality in childhood in the prevention of an unhealthy body composition in childhood.

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Supplemental Table 5.1. Characteristics of study participants in quintiles of diet quality score.

	Mean ± SD, median (IQR), or %				
	Diet score quintile 1 (n=168)	Diet score quintile 2 (n=169)	Diet score quintile 3 (n=169)	Diet score quintile 4 (n=169)	Diet score quintile 5 (n=169)
Child characteristics					
Sex					
Girls	49.9	43.2	50.3	51.5	44.4
Ethnicity					
Dutch	70.2	81.7	76.3	75.7	76.9
Surinamese	6.0	2.4	4.7	5.9	1.2
Turkish	3.0	0.6	0.6	1.8	0.0
Moroccan	2.4	3.6	1.8	3.6	5.9
Other	18.5	11.8	16.6	13.0	16.0
Screen time					
Less than 1 hour/day	26.2	37.3	46.2	44.4	47.3
1 to 2 hours per day	54.2	52.1	37.9	47.9	42.0
More than 2 hours per day	19.3	10.7	16.0	7.7	10.0
Physical activity					
Less than 1 hour/day	8.3	7.1	5.3	7.1	7.7
1 to 2 hours per day	40.5	46.7	36.7	32.5	32.0
More than 2 hours per day	51.2	46.2	58.0	60.4	60.4
Maternal educational level					
High	57.7	74.0	73.4	76.3	83.4

Child dietary assessments					
Age at dietary assessment (y)	5.6 (5.3 – 5.9)	5.6 (5.3 – 6.1)	5.5 (5.3 – 6.1)	5.6 (5.3 – 6.0)	5.6 (5.3 – 6.0)
Total energy intake (kcal/d)	1364 (1224 – 1545)	1492 (1301 – 1665)	1492 (1308 – 1670)	1556 (1343 – 1766)	1598 (1427 – 1798)
Diet quality (score)*	3.1 ± 0.6	4.2 ± 0.2	4.8 ± 0.2	5.4 ± 0.2	6.3 ± 0.5
Child growth and body composition					
Age at 6 years measurement (y)	5.7 ± 0.4	5.6 ± 0.5	5.6 ± 0.5	5.6 ± 0.5	5.7 ± 0.5
Length (cm)	116.7 (111.8 – 120.1)	117.2 (112.6 – 121.1)	116.5 (112.3 – 120.7)	116.0 (112.1 – 119.5)	116.5 (113.6 – 120.5)
Weight (kg)	20.8 (18.6 – 22.3)	21.0 (18.9 – 23.4)	20.5 (18.2 – 22.7)	20.5 (18.6 – 22.5)	21.2 (19.7 – 22.7)
Body mass index (kg/m2)	15.1 (14.4 – 15.8)	15.4 (14.7 – 16.1)	15.0 (14.4 – 15.9)	15.3 (14.5 – 16.0)	15.4 (14.7 – 16.2)
Fat mass (kg)	4.0 (3.1 – 5.1)	4.1 (3.2 – 5.3)	3.8 (3.0 – 4.9)	4.0 (3.1 – 5.0)	4.3 (3.4 – 5.2)
Fat-free mass (kg)	16.3 (15.3 – 17.5)	16.8 (15.4 – 18.2)	16.7 (15.0 – 17.9)	16.5 (15.3 – 17.5)	16.9 (15.8 – 18.0)
Body fat percentage	19.6 (16.2 – 24.3)	19.7 (16.7 – 23.6)	19.1 (15.9 – 21.6)	19.3 (16.3 – 23.2)	19.6 (17.2 – 23.8)
Age at 12 years measurement (y)	11.8 ± 0.4	11.8 ± 0.4	11.9 ± 0.3	11.8 ± 0.4	11.8 ± 0.4
Length (cm)	153.6 (148.3 – 159.6)	153.6 (148.5 – 158.7)	153.8 (149.2 – 157.9)	152.7 (147.6 – 157.1)	154.2 (148.9 – 158.1)
Weight (kg)	41.0 (36.0 – 47.7)	40.7 (35.9 – 46.1)	39.5 (36.0 – 45.2)	39.7 (35.8 – 44.5)	40.5 (36.8 – 45.1)
Body mass index (kg/m2)	17.4 (16.1 – 19.5)	17.2 (16.0 – 19.0)	16.8 (15.7 – 18.6)	16.9 (15.7 – 18.7)	17.2 (15.8 – 18.4)
Fat mass (kg)	9.4 (7.5 – 12.7)	8.9 (7.1 – 11.5)	8.8 (7.0 – 11.1)	8.9 (7.3 – 11.6)	9.0 (7.2 – 10.8)
Fat-free mass (kg)	31.8 (28.1 – 35.8)	31.9 (27.8 – 35.4)	31.1 (28.4 – 34.6)	31.2 (27.7 – 33.7)	31.9 (28.8 – 34.4)
Body fat percentage	23.8 (20.2 – 28.5)	22.9 (19.6 – 26.8)	22.4 (19.1 – 26.6)	23.3 (19.5 – 27.1)	22.1 (18.8 – 25.7)

Values are medians (IQR) for continuous variables with a skewed distribution or means ±SD for continuous variables with a normal distribution and percentages for categorical variables.

* theoretical range 0-10, a higher score reflects a better diet quality.

Supplemental Table 5.2. Associations of diet quality at the age of 6 years with body composition at the age of 12 years (in quintiles).

	BMI (SDS)	FMI (SDS)	FFMI (SDS)	BF% (SDS)	Height (SDS)	Weight (SDS)
	B 95%CI	B 95%CI	B 95%CI	B 95%CI	B 95%CI	B 95%CI
Q1	Reference	Reference	Reference	Reference	Reference	Reference
Q2	-0.46 (-0.84, -0.08)	-0.14 (-0.40, 0.12)	-0.13 (-0.36, 0.10)	-0.18 (-1.08, 0.72)	-0.15 (-0.87, 0.57)	-1.12 (-2.17, -0.08)
Q3	-0.34 (-0.72, 0.04)	-0.14 (-0.40, 0.12)	-0.19 (-0.42, 0.04)	-0.34 (-1.23, 0.56)	-0.04 (-0.76, 0.68)	-0.92 (-1.96, 0.12)
Q4	-0.45 (-0.84, -0.06)	-0.11 (-0.38, 0.15)	-0.23 (-0.47, 0.01)	-0.01 (-0.93, 0.91)	-0.52 (-1.28, 0.23)	-1.34 (-2.42, -0.26)
Q5	-0.67 (-1.07, -0.27)	-0.33 (-0.60, -0.06)	-0.17 (-0.41, 0.07)	-0.83 (-1.78, 0.11)	-0.33 (-1.08, 0.43)	-1.74 (-2.84, -0.65)

Values are regression coefficients and 95% confidence intervals based on linear mixed models and reflect differences in growth compared to Q1. Bold values indicate statistically significant effect estimates ($p<0.05$).

Adjusted for sex, age, baseline values, ethnic background, maternal educational level, screen time, physical activity, total kcal intake, and tanner stage (model 4).

Supplemental Table 5.3. Associations of diet quality at the age of 6 years with body composition at the age of 6 years (in quintiles).

	BMI (SDS)	FMI (SDS)	FFMI (SDS)	BF% (SDS)	Height (SDS)	Weight (SDS)
	B 95%CI	B 95%CI	B 95%CI	B 95%CI	B 95%CI	B 95%CI
Q1	Reference	Reference	Reference	Reference	Reference	Reference
Q2	0.42 (0.01 0.70)	0.30 (0.07, 0.55)	0.11 (-0.05, 0.28)	1.18 (-0.01, 2.38)	0.20 (-0.82, 1.23)	0.69 (-0.10, 1.28)
Q3	0.02 (-0.25, 0.30)	-0.04 (-0.28, 0.20)	0.06 (-0.10, 0.23)	-0.33 (-1.53, 0.86)	-0.52 (-1.55, 0.50)	-0.13 (-0.72, 0.46)
Q4	0.25 (-0.04, 0.53)	0.13 (-0.12, 0.37)	0.12 (-0.05, 0.29)	-0.31 (-0.91, 1.53)	-0.46 (-1.51, 0.59)	-0.18 (-0.42, 0.79)
Q5	0.38 (0.09, 0.67)	0.25 (-0.000, 0.50)	0.13 (-0.04, 0.30)	1.01 (-0.25, 2.27)	0.23 (-0.85, 1.31)	0.57 (-0.05, 1.19)

Values are regression coefficients and 95% confidence intervals based on linear mixed models and reflect differences in growth compared to Q1. Bold values indicate statistically significant effect estimates ($p<0.05$).

Adjusted for sex, age, ethnic background, maternal educational level, screen time, physical activity, and total kcal intake (model 3).

CHAPTER 6

Dietary Patterns by Level of Maternal Education and Their Contribution to BMI, Fat Mass Index, and Fat-Free Mass Index at Age 5 and the Longitudinal Association with BMI at Age 10

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Abstract

Background

Our aim was to identify dietary patterns by the level of maternal education that contribute to BMI, fat mass index (FMI), and fat-free mass index (FFMI) in children at age 5 and to assess if these dietary patterns are related to BMI at age 10.

Methods

Per group (low/middle/high level), Reduced Rank Regression (RRR) was used to derive dietary patterns for the response variables BMI z-score, FMI, and FFMI in 1728 children at age 5 in the Amsterdam Born Children and their Development (ABCD) cohort. Regression analyses were then used to determine the association with BMI at age 10.

Results

In each group, pattern 1 was characterized by its own cluster of food groups. Low: water/tea, savoury snacks, sugar, low-fat meat, and fruits; middle: water/tea, low-fat cheese, fish, low-fat dairy, fruit drink, low-fat meat, and eggs; and high: low-fat cheese, fruits, whole-grain breakfast products, and low-fat and processed meat. Additionally, in each group, pattern 1 was positively associated with BMI z-scores at age 10 (low: $\beta = 0.43$ [95% CI = 0.21; 0.66], $p < 0.001$, middle: $\beta = 0.23$ [0.09; 0.36], $p \leq 0.001$, and high: $\beta = 0.24$ [0.18; 0.30], $p < 0.001$).

Conclusions

The dietary patterns stratified by the level of maternal education are characterized by different food groups. But in all the groups, pattern 1 is positively associated with BMI at age 10.

Introduction

Differences in BMI and body composition in children are unequally distributed across socio-economic status (SES) groups and these differences already start at an early age [1,2]. Underweight as well as overweight and obesity are risk factors for the development of diseases [3,4]. Dietary patterns are important determinants of BMI and body composition in childhood [5], and they are associated with SES [6]. In several birth cohort studies, a higher consumption of a healthy dietary pattern in young children was associated with a higher SES, while a higher consumption of an unhealthier/junk pattern was associated with a lower SES [7,8]. We observed similar findings in the Amsterdam Born Children and their Development (ABCD) cohort, where data on dietary intake was available at age 5 [9].
A number of studies have observed cross-sectional or longitudinal associations between dietary patterns and BMI and body composition in children from Western European countries [10–14]. Surprisingly, some studies have observed that the consumption of 'healthy' dietary patterns increased levels of overweight or obesity [10,11]. Also, the consumption of dietary patterns high in processed foods decreased the prevalence of overweight or obesity [10]. We also observed this tendency in the ABCD cohort [13]. When children were 5 years old, higher scores on a healthy dietary pattern were associated with increased weight development, and higher scores on a full-fat dietary pattern were associated with decreased weight development between the ages of 5 and 10 years [13]. Crucially, these described dietary patterns were obtained via an a posteriori method (PCA) or an a priori method (diet score). To understand which dietary components are most associated with BMI and body composition in children, we applied Reduced Rank Regression (RRR) analysis. RRR combines the a posteriori and a priori methods. Dietary patterns are identified in an exploratory way but are based on a priori knowledge in the form of pre-selected response variables that are thought to link dietary patterns to disease risk [15]. Few studies have derived dietary patterns using RRR that were related to BMI and body composition. However, these RRR-derived dietary patterns were obtained in a different age category [16] or nutrient intakes were used as response variables [17].
Deriving dietary patterns that explain most of the variation in BMI, fat mass index (FMI), and fat-free mass index (FFMI) cross-sectionally will enable us to identify high-risk dietary patterns that are associated with BMI later in life (longitudinally). In addition, deriving dietary patterns stratified by the level of maternal education as a proxy for SES will provide us with information about differences in food items that contribute to the explained variation in BMI and measures of body composition across the different groups. This information might give health care professionals starting points for targeted interventions.
Therefore, it is of interest to (1) identify dietary patterns stratified by the level of maternal education which explain most variance in BMI, FMI, and FFMI at age 5, and (2) to assess to which extent these dietary patterns are related to BMI and weight status at age 10.

Materials and Methods

Study design and population

This study was part of the ABCD cohort, a large ongoing community-based birth cohort (http://www.abcd-study.nl/ (accessed on 3 August 2024)). The design of the cohort study has been described previously [18]. Between January 2003 and March 2004, all pregnant women who were living in Amsterdam were invited to participate in the ABCD cohort at their first parental care visit. Of the 12,373 women that were approached, a number of 8266 women filled out a 'pregnancy questionnaire'. At age 5, the addresses of 6161 mothers were retrieved from the Youth Health Care registry. A '5-year questionnaire' was sent to the woman's home address and a number of 4488 questionnaires were filled out by the mothers. These woman's received an invitation for a 'health check' which was attended by 3321 children and a self-administered Food Frequency Questionnaire (FFQ). A number of 2851 mothers completed the FFQ. At age 10, the parents received an invitation for a preventive health check of their child, arranged by Youth Health Care part of the Public Health Service Amsterdam, carried out at their primary school. A number of 1728 children had valid data on diet at age 5; BMI, FMI, and FFMI at age 5; maternal education; and BMI at 10 years, and were included in the present analyses (Figure 6.1).

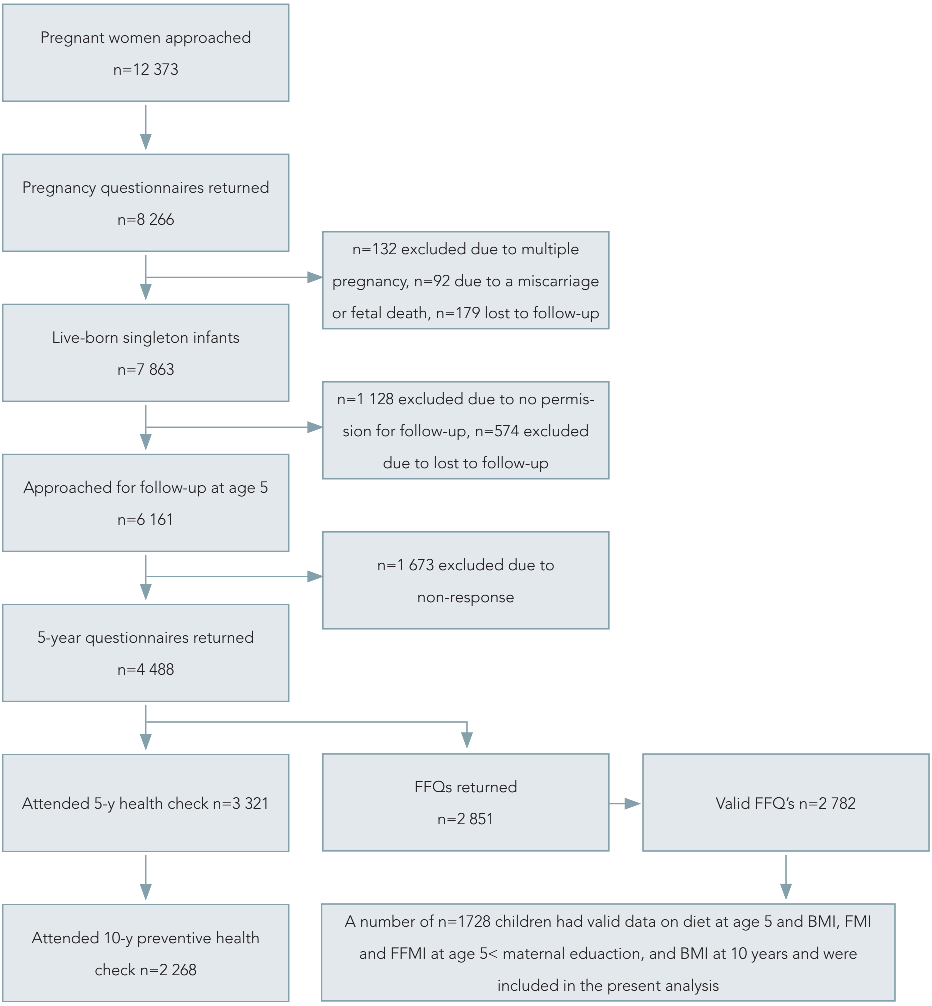

Figure 6.1. Flow chart of the participants included in the present analyses (n = 1728).

Assessment of dietary intake and patterns

When the children were 5 years old, their mother completed a 71-item FFQ that was developed and validated by TNO Food (Zeist, the Netherlands) [19]. Per food item, the consumption frequency, type of product, and portion size consumed during the previous 4 weeks were reported. The given frequency options were 'never', 'less than once a week', 'once a week', '2–3 times a week', '4–5 times a week', and '6–7 times a week'. Based on the data clearance protocol developed by TNO Food, the returned FFQs were scanned. Data on the amounts (g/day) of products consumed and energy intake was calculated using the Dutch Food Composition Database (NEVO) 2010 [20]. A number of 41 food groups were composed and per food group, the energy-adjusted intake (g/d) was calculated [9].

Reduced Rank Regression (RRR) analyses identify dietary patterns in an exploratory way, but use pre-selected response variables that are thought to link dietary patterns to disease risk [15]. For the first research objective, RRR was used to identify dietary patterns for the response variables BMI z-score, FMI, and FFMI at age 5. This analysis was conducted separately per level of maternal education. Initially, three dietary patterns were derived that explained the maximal variance in the response variables. As the third RRR-derived dietary pattern contributed <10% to the total variance explained, it was left out of the subsequent analyses. RRR analyses produce a continuous score for each dietary pattern per individual, which represents the extent to which the dietary intake adheres to the dietary pattern.

Assessment of BMI

When the children were 5 years old, height and weight were measured during the ABCD 'health check'. The children were measured by trained researchers according to standard protocols using a Leicester portable height measurer (Seca, Kettering, United Kingdom) and a Marsden weighing scale (model MS-4102, Advanced Health Products, London, United Kingdom). When the children were 10 years old, height and weight were measured by a health professional during the preventive health check at the children's primary school. During all the measures, the children wore light clothing. Height and weight were calculated into BMI scores [weight (kg)/height (m)2]. To categorize BMI scores into underweight, normal weight, and overweight/obesity, age- and sex-specific BMI cut-offs from the International Obesity Task Force [3,21] were used. Also, the BMI scores were converted to age- and sex-specific BMI z-scores (SD scores) by comparison with the 'World Health Organization standards' [22].

Assessment of FMI and FFMI

When the children were 5 years old, components of body composition were measured to calculate FMI and FFMI during the ABCD 'health check' where children were measured by trained researchers according to standard protocols. Fat mass (FM) with arm-to-leg bioelectrical impedance analysis (BIA) was measured (Bodystat 1500 MDD machine (Bodystat Inc., Douglas, UK)), fat-free mass (FFM) was measured (weight (kg)—FM), and fat mass index (FMI) (fat mass (kg)/height (m)2) and fat-free mass index (FFMI) (fat-free mass (kg)/height (m)2) were calculated.

Assessment of Socio-Economic Status

The level of maternal education was obtained via the '5-year questionnaire' and was used as a proxy for SES. It was defined as the number of years of post-primary education and categorized as low (<6 yrs), middle (6–10 yrs), and high (>10 yrs) [9,23].

Assessment of Potential Confounders

Potential covariates that might influence the association between dietary patterns and BMI, underweight, and overweight/obesity at age 10 were the children's exact age at the 5-year height and weight measurement, sex, maternal BMI, screen time, and ethnicity. Maternal BMI and screen time were collected via the '5-year questionnaire'. Maternal BMI (kg/m2) was based on mothers' self-reported height and weight when the child was 5 years old. Screen time (h/day) was based on the duration in hours that the child spent watching TV or using a computer or console per day at age 5 [24]. Ethnicity was defined using data from the 'pregnancy questionnaire' and was based on the country of birth of the pregnant woman and her mother, including both first-generation women (born outside the Netherlands) and second-generation women (born in the Netherlands but whose mother was born in another country). We defined five groups: Dutch, Turkish, African Surinamese, Moroccan, and "other" ethnicities (mostly of non-Western origin).

Statistical Analysis

Population and anthropometric characteristics were described in numbers with percentages or means with standard deviations (SDs) for each maternal education level separately. ANOVA and post hoc Bonferroni were applied to show differences by maternal education group.

For the second research objective, linear regression was used to determine to which extent the RRR-derived dietary patterns at age five were associated with the BMI z-scores at age 10. Logistic regression was used to determine to which extent the RRR-derived dietary patterns were related to underweight and overweight/obesity at age 10. Of each dietary pattern, the individual pattern score was used as the continuous independent variable and the BMI z-score at age 10, underweight at age 10, and overweight/obesity at age 10 were used as the dependent variables (Model 1; crude). In the adjusted model (Model 2), the association was adjusted for children's exact age at the 5-year height and weight measurement, sex, maternal BMI at age 5, screen time at age 5, and ethnicity. The RRR analyses were performed in SAS® OnDemand for Academics version STAT 15.2. The other analyses were performed in IBM SPSS Statistics version 28 for Windows. The level of statistical significance was 0.05.

Results

Population Characteristics

Table 6.1 presents the characteristics of the study population (n = 1728) stratified by the level of maternal education. Most children (68.3%) had higher-educated mothers, 19.8% middle and 11.8% had mothers with a lower education level. Mean (SD) age was 5.9 (0.5) in the low, 5.7 (0.5) in the middle, and 5.6 (0.4) years in the children of higher-educated mothers at the 5-year health check. The highest BMI z-scores at age 5 were observed in the group of lower (0.42 SD 1.21) and middle-educated mothers (0.08 SD 1.04) and the lowest BMI z-scores were observed in the group of higher-educated mothers (−0.06 SD 0.81).

Table 6.1. Population characteristics of the ABCD study population at age 5 and 10 years by maternal education level (n = 1 728).

		Maternal Education Level [a]		
		Low (n = 204)	Middle (n = 343)	High (n = 1 181)
Age, in years, mean (SD)	Age 5	5.9 (0.5) *	5.7 (0.5) *	5.6 (0.4) *
	Age 10	10.6 (0.4)	10.7 (0.4)	10.6 (0.4)
Sex, n (%) boys		108 (52.9)	178 (51.9)	574 (48.6)
Screen time, in h/day [b],				
mean (SD)	Age 5	2.30 (1.21) *	1.79 (1.04) *	1.17 (0.75) *
Maternal BMI, in kg/m2 [c],				
mean (SD)		26.6 (5.7) *	24.9 (5.0) *	22.9 (3.3) *
Ethnicity, n (%)				
Dutch		83 (40.7) *	235 (68.5) *	1053 (89.2) *
African Surinamese		18 (8.8) *	34 (9.9) *	24 (2.0) *
Turkish		22 (10.8) *	16 (4.7) *	6 (0.5) *
Moroccan		44 (21.6) *	32 (9.3) *	17 (1.4) *
Other ethnicities		37 (18.1) *	26 (7.6) *	81 (6.9) *
BMI z-score, mean (SD)	Age 5	0.42 (1.21) *	0.08 (1.04)	−0.06 (0.81)
	Age 10	0.64 (1.29) *	0.23 (1.16) *	−0.17 (0.96) *
FFMI, in kg/m2, mean (SD)	Age 5	12.19 (0.84)	12.25 (0.83)	12.26 (0.80)
FMI, in kg/m2, mean (SD)	Age 5	3.97 (1.84) *	3.32 (1.43) *	3.01 (1.03) *

[a] level of maternal education was defined as the number of years of post-primary education: low (<6 yrs), middle (6–10 yrs), and high (>10 yrs); [b] data on screen time was missing for n = 7 subjects; [c] data on maternal BMI was missing for n = 88 subjects.

* significant ($p < 0.05$) with all the groups.

RRR-derived dietary patterns by maternal education

In each group, the first dietary pattern was positively associated with the BMI z-score and FMI. In the children with higher-educated mothers, pattern 1 was also positively correlated with FFMI. The explained variances in response variables were 15.4%, 12.2%, and 4.9% for the low, middle, and high maternal education groups, respectively. We observed differences as well as similarities in food groups characterizing the RRR-derived dietary patterns between each group (Table 6.2). Food groups that are typical for children of lower-educated mothers were water/tea with sugar, savoury snacks, low-fat meat and fruits (positive loadings), and sweet sandwich toppings, tomato sauce, peanut butter, whole-grain warm meals, healthy snacks, and high-fat meat (negative loadings). Water/tea, low-fat cheese, fish, low-fat dairy, fruit drinks, eggs and low-fat meat (positive loadings), and boiled potatoes and healthy snacks (negative loading) were typical for children of middle–high-educated mothers. For the children of higher-educated mothers, typical food groups included low-fat cheese, fruits, whole-grain breakfast products, low-fat and processed meat (positive loadings), and full-fat dairy and tomato sauce (negative loading). Water/tea, low-fat meat, low-fat cheese and fruits (positive loadings), and tomato sauce for pasta and healthy snacks (negative loadings) were representative of RRR-derived pattern 1 in multiple groups. For comparison reasons, Supplemental Table 6.1 provides an overview of all the factor loadings on the RRR-derived dietary pattern 1 in the total ABCD cohort (n ≤ 1728) as well as in each level of maternal education.

The second dietary pattern was positively associated with FFMI in all the groups, and negatively associated with FMI in the higher maternal education group. The explained variances in the response variables for the second pattern were 8.09% (low), 3.70% (middle), and 1.57% (higher maternal education level). The food groups characterizing RRR-derived pattern 2, stratified by the level of maternal education, are shown in Supplemental Table 6.2. Additionally, Supplemental Table 6.3 provides an overview of all the factor loadings on the RRR-derived dietary pattern 2 in the total ABCD cohort (n ≤ 1728) and in each group separately.

Table 6.2. Food groups with factor loadings > 0.20 on the RRR-derived dietary pattern 1 with the BMI z-score, FMI, and FFMI at age 5 as response variables in the ABCD cohort (n = 1 728).

Maternal Education Level					
Low (n = 204)		Middle (n = 343)		High (n = 1 181)	
Food Group	Load	Food Group	Load	Food Group	Load
Positive loadings					
Water/tea	0.25	Water/tea	0.35	Low-fat cheese	0.37
Savory snacks	0.24	Low-fat cheese	0.32	Fruits	0.33
Sugar	0.22	Fish	0.28	Whole grain breakfast products	0.22
Low-fat meat	0.20	Low-fat dairy	0.28	Low-fat meat	0.21
Fruits	0.20	Fruit drink	0.25	Processed meats	0.21
		Eggs	0.24		
		Low-fat meat	0.24		
Negative loadings					
Sandwich toppings sweet	−0.33	Boiled potatoes	−0.22	Full-fat dairy	−0.40
Tomato sauce for pasta	−0.27	Healthy snacks	−0.21	Tomato sauce for pasta	−0.23
Peanut butter	−0.23				
Whole-grain warm meals	−0.21				
Healthy snacks	−0.21				
High-fat meat	−0.20				
Variance explained in food intake, %	2.64		2.79		3.06
Variance explained in response variables, %	15.39		12.21		4.90

RRR-Derived dietary patterns related to BMI Z-scores and weight status at age 10

In the children of lower- and middle-educated mothers, the mean BMI z-score at age 10 was higher (M = 0.64 [SD ≤ 1.29] and M = 0.23 [1.16], respectively) compared to age 5, while in the children of higher-educated mothers, the mean BMI z-score was lower at age 10 (M = −0.17 [0.96]).
In all the groups, the percentage of children with overweight or obesity at age 10 was higher compared to age 5, although the percentage was highest in the children of lower-educated mothers (34.8% vs. 16.9% in middle and 6.4% in high at age 10 and 25% vs. 11.5% in middle and 5.1% in children of higher-educated mothers at age 5).
In the children of lower and middle-educated mothers, the percentage of underweight children at age 10 was lower than at age 5 (13.2% and 15.1%, respectively, at age 5 and 10.3% and 11.1%, respectively, at age 10) while the percentages of underweight children in higher-educated mothers were 12.9% at both age 5 and 10.
In all the groups, pattern 1 was associated with higher BMI z-scores at age 10 and higher odds of being overweight or obese at age 10 with the strongest associations observed in the children of lower-educated mothers (β = 0.43 [95% CI = 0.21; 0.66], $p \leq 0.001$ for BMI z-score and OR overweight/obesity = 2.21 [1.32; 3.72], $p \leq 0.003$), and with a lower odds of being underweight (Table 3). However, these associations were only statistically significant in children of higher-educated mothers (OR underweight = 0.66 [0.53; 0.81], $p \leq 0.001$). Pattern 2 was mainly associated with lower odds of being overweight/obese at age 10 (OR = 0.66 [0.52; 0.83], $p \leq 0.001$) in children of higher-educated mothers only (Supplemental Table 6.4).

Table 6.3. The association between the RRR-derived dietary pattern 1 at age 5 and BMI z-score and weight status at age 10 by the level of maternal education (n = 1 728).

	BMI Z-Score		Underweight		Overweight/Obesity	
Level of Maternal Education:	B (95%-CI) [a]	p-Value	OR (95%-CI)	p-Value	OR (95%-CI)	p-Value
Low (n=204)						
Model 1: crude	0.50 (0.28; 0.72)	<0.001	0.45 (0.25; 0.81)	0.008	2.57 (1.65; 4.00)	<0.001
Model 2: adjusted [b]	0.43 (0.21; 0.66)	<0.001	0.52 (0.26; 1.03)	0.06	2.21 (1.32; 3.72)	0.003
Middle (n=343)						
Model 1: crude	0.40 (0.27; 0.53)	<0.001	0.60 (0.39; 0.93)	0.02	2.06 (1.50; 2.83)	<0.001
Model 2: adjusted [b]	0.23 (0.09; 0.36)	0.001	0.73 (0.46; 1.16)	0.18	1.52 (1.06; 2.19)	0.02
High (n = 1181)						
Model 1: crude	0.26 (0.20; 0.32)	<0.001	0.65 (0.53; 0.78)	<0.001	1.76 (1.37; 2.25)	<0.001
Model 2: adjusted [b]	0.24 (0.18; 0.30)	<0.001	0.66 (0.53; 0.81)	<0.001	1.81 (1.37; 2.38)	<0.001

[a)] regression coefficients reflect a change in the BMI z-score at age 10 for a 1-unit increase in dietary pattern score;

[b] model 2 is adjusted for children's exact age at the 5-year height and weight measurement, sex, maternal BMI, screen time at age 5, and ethnicity; because of missing values, n= 635 subjects (low n=173, middle n= 26, and high n=1 136) were included in the adjusted analyses.

Discussion

In a large population-based cohort study in young children, we used RRR to derive dietary patterns stratified by the level of maternal education that explain the variation in BMI z-score, FMI, and FFMI at age 5. We observed similarities as well as differences in the food groups that characterized each dietary pattern. Yet, RRR-derived pattern 1 was positively associated with BMI z-scores and higher odds of being overweight or obese at age 10 in all the groups.

Interpretation and comparison with previous studies

In each group, we identified a dietary pattern that was correlated with BMI and FMI and a dietary pattern that was correlated with FFMI. To the best of our knowledge, we did not find other studies deriving dietary patterns in children stratified by the level of maternal education. Generally, dietary patterns are derived within the total population and subsequently associated with (measures of) SES [5,7–9]. As differences in BMI are unequally distributed across SES groups [1,2], the derived dietary patterns could potentially give insight into which food groups contribute to the variance in BMI, FMI, and FFMI in young children from mothers with different education levels. Indeed, our analysis indicates that although there were some similarities, different food groups contributed to the dietary pattern associated with increased body weight at the follow-up (age 10). In our study, the consumed food items were reduced to 41 food groups based on culinary use and nutritional value [9]. Each food item in the Food Frequency Questionnaire was linked with at least one food item in the Dutch Food Composition Database [20]. It might be possible that food items are consumed in different combinations implicating possible different classifications of food groups than used in our study. For example, the food group 'sugar' consist of sugar consumed as a sweetener in yogurt or cereals, but also as a sweetener consumed in tea. In the children of lower-educated mothers, both the intake of water/tea (0.25) and sugar (0.22) were of importance for pattern 1. In the middle group, however, the intake of water/tea was of importance (0.35) while the intake of sugar (−0.10) did not characterize pattern 1. Sensitivity analyses show that in the children of lower-educated mothers, more children consumed sugar as a sweetener in tea (75%) compared to 67% in the middle- and 40% in the children of higher-educated mothers, and that the average intake was highest in consumers in the lower (2.55 (2.70) compared to the middle (2.18 (2.60)) and higher maternal education groups (1.47 (2.12)). These observations possibly reflect the different culinary uses of the food items between the different groups. In the children of lower-educated mothers, the possible use of tea and sugar in tea as a sweetener could be combined in a food group 'sugar-sweetened beverages'. However, interestingly, we observed in all the groups that pattern 1 was mainly characterized by a high intake of food items generally considered as healthy which could not be further explained by the possible differences in culinary use between the groups. In the lower maternal education group, these items were water/tea, savoury snacks, sugar, low-fat meat, and fruits. In the middle group, these items were water/tea, low-fat cheese, fish, low-fat dairy, fruit drinks, eggs, and low-fat meat and in the higher maternal education group, these items were low-fat cheese, fruits, whole-grain breakfast products, low-fat meat, and processed meat (Table 2). The Dutch Generation R cohort has also derived a dietary pattern associated with a higher FFMI (high intakes of whole-grain products, pasta, rice, fruit, dairy, vegetable oils and fats, and non-sugar-containing beverages) and a dietary pattern that was associated with both FMI and FFMI (high intakes of refined grain products, potatoes, meat, fish, soups, sauces, and sugar-containing beverages) [16]. However, these patterns were derived at age 1 and unlike our results, the FMI pattern was not characterized with food items generally considered as healthy. It might be possible that parents provide their children with more 'healthy food items' when children are already overweight, which possibly indicates reverse causality. From birth, the weight development of children is monitored through Youth Health Care (YHC). Possibly, the YHC gave nutritional advice if the weight development of children was suboptimal, which could have resulted in adjusted nutritional habits. Sensitivity analyses showed that in all the groups, all the food items that were positively related to pattern 1 were consumed in higher amounts by the children with higher BMI z-scores at age 5 (BMI z-scores > 1) than by the children with lower BMI z-scores (BMI z-scores < 1). Food items that were negatively related to pattern 1 were consumed in lower amounts by the children with higher BMI z-scores. Food items that were positively related to pattern 2 did not show a clear pattern. In the total population and in children of higher-educated mothers, 'traditional healthy bread items', e.g., whole-grain breakfast products and full-fat spreads, were related to the variation in FFMI.

The longitudinal results showed that in each group, a positive association was found between the RRR-derived pattern 1 and BMI z-scores and the risk of overweight or obesity at age 10, which was strongest in the lower maternal education group, while only in the higher maternal education group, the RRR-derived pattern 2 was associated with lower odds of being overweight/obese at age 10. We observed increasing associations with decreasing levels of maternal education (pattern 1: low (β = 0.43 [95% CI = 0.21; 0.66] and high (β = 0.24 [95% CI = 0.18; 0.30] and pattern 2: low (β = 0.22 [95% CI = −0.01; 0.46] and high (β = −0.05 [95% CI = −0.10; −0.005]) which is in line with, and could be partly explained by the observed increasing percentages of the explained variances of the response variables in the lower maternal education group. Our results underline that the derived food patterns at age 5 are strongly associated with the risk of overweight development at age 10 in children of lower-educated mothers than children in other groups. The observed longitudinal results are in line with earlier results in our cohort that showed that higher scores on a PCA-derived 'healthy' pattern at age 5 (also associated with high intakes of water/tea, fruits, and fish and low intakes of sweet sandwich toppings) were also associated with significantly higher BMI z-score at age 10 in all the SES groups [13]. Higher scores on a 'full-fat' pattern at age 5 (also high intakes of full-fat spreads) were associated with significantly lower BMI at age 10 in high SES children [13]. These findings are also in line with results from the Generation R cohort, where the FFMI pattern was positively associated with FFMI at age 6 but not with FMI [16] and these associations remained up to age 10 [25]. A higher diet quality at the age of 1 and 8 years old was (independent of diet quality of the other time point) associated with higher BMI until the age of 10 years and was explained by a higher FFMI [25]. Unlike few studies [16,25,26] but in line with another study [27] we did not observe indications that the association between 'healthy dietary patterns' and BMI in children would be explained by the amount of FFMI rather than FMI.

In our cohort, interestingly, only in children of higher-educated mothers, pattern 2 was associated with lower BMI z-scores at age 10 and lower FMI at age 12 (Supplemental Tables S5 and S6). These results suggest that in this group of children, possibly other protecting mechanisms are present that prevent the development of overweight at age 10. The results in our cohort also show that in the children of higher-educated mothers, the mean BMI z-score at age 10 was lower than in the children of lower and middle high educated mothers, which is in line with general observations [28,29].

Methodological Considerations

A strength of this study is the population-based cohort-d/esign that included a number of 1728 children with complete data on diet, maternal education, BMI, FMI, and FFMI at age 5 and BMI at age 10 years. In other studies using RRR, generally, nutrients [17] or disease-specific intermediates [30] were used as response variables. As childhood obesity is unequally distributed across socio-economic status (SES) groups, we target this public health problem by using BMI as well as FMI and FFMI as the response variables. Body mass includes fat mass, lean mass, and bone mass [31,32]. Therefore, increased BMI could be caused by increased fat mass or increased lean mass, or a combination [33]. Analyses stratified per level of maternal education, used as a proxy for SES, gave an overview of dietary patterns that explain the differences in the variation in BMI and other measures of body composition in each group.

Height, weight, and components of body composition were measured by trained researchers and health professionals using standard protocols. Data on BMI were available when children were 5, 10, and 12 years old. FMI and FFMI were not available at age 10, but were available at age 5 and in a select population at age 12. Longitudinal analyses describing the observed associations between the dietary patterns and BMI, FMI, and FFMI in each group were conducted as sensitivity analyses. We observed comparable associations at age 10 and age 12. In each group, pattern 1 was positively associated with FMI at age 12 while pattern 2 was negatively associated with FMI at age 12 in the children of higher-educated mothers. The results are shown in Supplemental Tables S5 and S6.

There are also a few possible limitations. Possibly, some biases may have been introduced into the analyses, especially because the non-responders came more often from lower maternal education groups. Response rates per SES group were 11% for the low plus middle SES group combined and 38% for the high SES group. A non-response analysis determining the level of selective response and selection bias between pregnancy and birth outcomes indicated that selective non-response was present in the ABCD cohort, but that the observed selection bias was acceptably low and did not influence the studied birth outcomes [34]. Also in our cohort, children from lower-educated mothers came disproportionally from non-native ethnicities (Table 1). Despite the fact that ethnicity and SES are correlated, we observed in previous research that the effect of maternal education level is not only driven by ethnicity [9,13]. We observed that both ethnicity and maternal education explained differences in dietary pattern scores between groups at age 5 y which may suggest that both are relevant for the adherence to a specific dietary pattern [9]. Previous results also showed different prevalences of overweight and obesity within the non-native group despite comparable SES levels [13]. For example, children of Turkish origin (87% low-/middle-educated mothers) developed more often (44%) overweight and obesity between the ages of 5 and 10 years than children of Moroccan origin (24%; 82% low-/middle-educated mothers).

Dietary intake was obtained using an FFQ, which may be subject to measurement errors. Mothers were asked to report all that their child had eaten or drunk in the last four weeks. In the Netherlands, parents provide their children with all the consumed foods and drinks while attending primary school. If children were looked after by a childminder or went to after-school care, mothers were asked to ask the person responsible what their child ate or drank there. Nevertheless, mothers may not be fully aware of their children's exact consumption at all times during the last 4 weeks. The FFQ that we used showed reasonable to good validity for estimating energy intake in a previous validation study against the doubly labelled water method [19]. Longitudinal analyses were adjusted for important confounding factors such as children's exact age at the 5-year height and weight measurement, sex, maternal BMI, screen time, and ethnicity. However, in addition, there may be more potential confounding factors (e.g., maternal age, health-conscious behaviour of the mother during pregnancy, parity, breastfeeding, and complementary feeding) that are possibly associated with early life nutrition [35,36].

Conclusions

Our results indicate that the observed dietary patterns stratified by the level of maternal education contribute to the variation in BMI, FMI, and FFMI at age 5 and are relevant for longitudinal BMI and the odds of being overweight or obese at age 10. However, our results also indicate that the possibility of reversed causality could not be ruled out. To investigate whether parents possibly provide their children with more 'healthy food items' when children are already overweight, it is relevant to have nutritional, weight, and body composition data below the age of 5 years old. In further analyses, also the use of additional potential confounding factors could be investigated to study the association between dietary patterns and BMI and body composition in younger children. We observed that each dietary pattern was characterized by both similar and different food groups. However, these patterns were also characterized by only a few food groups and one may argue if these food groups actually represent a dietary pattern. Despite the observed results in our study, the observed dietary patterns do not necessarily give insights for practical implementations.

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Supplemental Table 6.1. Overview of factor loadings on the RRR-derived dietary pattern 1 with BMI z-score, FMI and FFMI at age 5 as response variables in the ABCD cohort (n=1 728).

		Level of maternal education		
Food group	Total cohort (n=1 728)	Low (n=204)	Middle (n=343)	High(n=1 181)
Fruits	0.14	0.20	0.03	0.33
Vegetables	0.01	0.07	0.13	0.15
Refined breakfast products	0.11	-0.13	0.01	0.00
Whole grain breakfast products	-0.07	0.17	0.03	0.22
Low-fat spreads	0.00	0.06	-0.16	0.17
Full-fat spreads	-0.15	-0.15	-0.02	-0.07
Low-fat cheese	0.32	0.18	0.32	0.37
Full-fat cheese	0.04	-0.13	0.02	0.14
Processed meats	0.02	0.10	-0.13	0.21
Peanut butter	-0.23	-0.23	-0.11	-0.11
Sandwich toppings (sweet)	-0.32	-0.33	-0.17	-0.13
Low-fat dairy	0.14	0.05	0.28	0.16
Medium-fat dairy	-0.01	0.02	-0.09	0.09
Full-fat dairy	-0.17	-0.17	-0.08	-0.40
Unhealthy meals	0.04	0.07	-0.08	0.05
Healthy meals	0.07	-0.03	-0.03	0.16
Tomato sauce (for pasta)	-0.23	-0.27	0.02	-0.23
Refined grain products	-0.02	-0.19	0.14	-0.17
Whole grain products warm meal	-0.12	-0.21	-0.15	0.04
Fried potato products	0.02	-0.06	-0.09	-0.16
Boiled potatoes	-0.02	0.09	-0.22	-0.08
Sauces	0.25	0.08	0.13	0.05
Pulses	0.14	0.11	0.17.	-0.05
Fish	0.23	0.09	0.28	0.16
Eggs	0.21	0.16	0.24	0.05
Low-fat meat	0.29	0.20	0.24	0.21
High-fat meat	-0.13	-0.20	-0.07	-0.09
Meat alternatives and soy products	-0.03	0.00	-0.05	0.08
Granola bars	0.01	0.19	0.03	-0.06
Biscuits and pastries	0.12	-0.03	0.12	0.06
Ice cream	-0.01	0.02	-0.09	-0.11
Chocolate and candy	0.04	0.05	-0.03	-0.10
Healthy snacks	-0.09	-0.21	-0.21	0.06
Savory snacks	0.27	0.24	0.09	-0.05
Nuts	0.06	0.08	0.12	-0.04
Sugar sweetened sodas	0.06	0.17	-0.06	-0.07
Artificially sweetened beverages	0.12	0.05	0.16	0.09
Fruit drink	0.18	0.18	0.25	-0.17
Fruit drink concentrate	-0.19	0.04	-0.18	-0.02
Water and tea	0.30	0.25	0.35	0.16
Sugar	0.04	0.22	-0.10	-0.13

Supplemental Table 6.2. Overview of food groups with factor loadings > 0.20 on the RRR derived dietary pattern 2 with BMI z-score, FMI and FFMI at age 5 as response variables in the ABCD cohort (n=1 728).

Level of maternal education					
Low (n=204)		Middle (n=343)		High (n=1 181)	
Food group	Load	Food group	Load	Food group	Load
Positive loadings					
Tomato sauce for pasta	0.32	High-fat meat	0.31	Granola bars	0.28
Fried potato products	0.33	Vegetables	0.27	Whole grain breakfast products	0.27
		Fruit drink concentrate	0.23	Sandwich toppings sweet	0.25
		Granola bars	0.21	Full-fat spreads	0.20
		Medium-fat dairy	0.21		
		Sauces	0.20		
Negative loadings					
Eggs	-0.34	Tomato sauce for pasta	-0.34	Savory snacks	-0.35
Low-fat meat	-0.33	Biscuits/pastries	-0.21	Biscuits/pastries	-0.31
Full-fat dairy	-0.23	Low-fat meat	-0.20	Sauces	-0.28
Pulses	-0.23	Unhealthy meals	-0.20	Sugar sweetened sodas	-0.20
				Sugar	-0.20
				Artificially sweetened beverages	-0.20
Variance explained in food intake, %	2.35		2.43		3.79
Variance explained in response variables, %	8.09		3.70		1.57

Supplemental Table 6.3. Factor loadings on the RRR-derived dietary pattern 2 with BMI z-score, FMI and FFMI at age 5 as response variables in the ABCD cohort (n=1 728).

	Level of maternal education			
Food group	Total cohort (n=1 728)	Low (n=204)	Middle (n=343)	High(n=1181)
Fruits	0.25	0.12	0.09	0.11
Vegetables	0.21	0.16	0.27	0.03
Refined breakfast products	-0.06	-0.04	0.07	-0.09
Whole grain breakfast products	0.30	0.18	-0.08	0.27
Low-fat spreads	0.07	-0.15	0.07	0.03
Full-fat spreads	0.10	-0.02	-0.09	0.20
Low-fat cheese	0.15	0.14	-0.17	0.00
Full-fat cheese	0.05	-0.07	0.13	-0.02
Processed meats	0.19	-0.10	0.11	0.15
Peanut butter	0.05	-0.12	-0.08	0.17
Sandwich toppings (sweet)	0.09	-0.08	-0.09	0.25
Low-fat dairy	0.08	-0.05	0.05	0.01
Medium-fat dairy	0.17	0.17	0.21	0.06
Full-fat dairy	-0.32	-0.23	-0.18	-0.06
Unhealthy meals	-0.03	0.07	-0.20	-0.02
Healthy meals	0.07	0.17	0.13	-0.11
Tomato sauce (for pasta)	-0.15	0.32	-0.34	-0.12
Refined grain products	-0.21	-0.14	-0.06	-0.17
Whole grain products warm meal	0.00	0.04	-0.16	0.01
Fried potato products	-0.10	0.33	-0.15	-0.16
Boiled potatoes	-0.11	0.11	-0.04	-0.12
Sauces	-0.11	-0.02	0.20	-0.28
Pulses	0.00	-0.23	0.18	0.03
Fish	-0.06	-0.08	0.03	-0.18
Eggs	-0.18	-0.34	-0.02	-0.16
Low-fat meat	-0.08	-0.33	-0.20	0.03
High-fat meat	0.10	0.11	0.31	0.00
Meat alternatives and soy products	0.06	0.10	-0.13	0.05
Granola bars	0.23	0.11	0.21	0.28
Biscuits and pastries	-0.23	-0.01	-0.21	-0.31
Ice cream	-0.13	0.11	-0.08	-0.17
Chocolate and candy	-0.18	0.07	-0.15	-0.17
Healthy snacks	0.14	0.17	0.18	0.03
Savory snacks	-0.24	-0.17	0.19	-0.35
Nuts	-0.11	-0.02	-0.12	-0.09
Sugar sweetened sodas	-0.22	-0.14	0.00	-0.20
Artificially sweetened beverages	-0.10	-0.07	-0.01	-0.20
Fruit drink	-0.06	-0.02	0.08	0.01
Fruit drink concentrate	0.14	0.16	0.23	0.05
Water and tea	-0.11	-0.13	-0.12	-0.14
Sugar	-0.28	-0.17	-0.13	-0.20

Supplemental Table 6.4. The association between RRR-derived dietary pattern 2 at age 5 and BMI z-score and weight status at age 10 by level of maternal education (n=1 728).

	BMI z-score		Underweight		Overweight/obesity	
Level of maternal education	B (95%-CI) [a]	p-value	OR (95%-CI)	p-value	OR (95%-CI)	p-value
Low (n=204)						
Model 1: crude	0.09 (-0.14; 0.33)	0.44	0.65 (0.35; 1.21)	0.17	1.08 (0.74; 1.59)	0.69
Model 2: adjusted [b]	0.22 (-0.01; 0.46)	0.07	0.40 (0.17; 0.93)	0.03	1.16 (0.74; 1.82)	0.52
Middle (n=343)						
Model 1: crude	0.13 (-0.01; 0.27)	0.07	0.61 (0.41; 0.90)	0.01	1.13 (0.82; 1.57)	0.45
Model 2: adjusted [b]	0.11 (-0.03; 0.24)	0.13	0.60 (0.38; 0.96)	0.03	1.08 (0.75; 1.54)	0.69
High (n=1181)						
Model 1: crude	-0.06 (-0.11; -0.002)	0.04	1.02 (0.87; 1.20)	0.81	0.64 (0.52; 0.78)	<0.001
Model 2: adjusted [b]	-0.05 (-0.10; 0.005)	0.08	1.03 (0.85; 1.24)	0.77	0.66 (0.52; 0.83)	<0.001

[a] Regression coefficients reflect a 1-unit change in BMI z-score at age 10 for each increment in dietary pattern score; [b] Model 2 is adjusted for sex, children's exact age at the 5-years height and weight measurement, screen time at age 5, maternal BMI at age 5 and ethnicity, because of missing values n=1635 subjects (low n=173, middle n=326, high maternal education level n=1 136) were included in the adjusted analyses.

Supplemental Table 6.5. The association between RRR-derived dietary pattern 1 at age 5 and BMI z-score, body composition and weight status at age 12 by level of maternal education (n=525).

	BMI z-score	FMI	FFMI	Underweight	Overweight
Level of maternal education	B (95%-CI) [a]	B (95%-CI) [a]	B (95%-CI) [a]	OR (95%-CI)	OR (95%-CI)
Low (n=48)					
Model 1: crude	0.31 (-0.15; 0.77)	0.80 (0.01; 1.58)	0.27 (-0.48; 1.02)	2.85 (0.56; 14.5)	2.21 (0.97; 5.00)
Model 2: adjusted [b]	0.20 (-0.24; 0.65)	0.78 (0.01; 1.55)	0.07 (-0.65; 0.79)	8.85 (0.06; inf)	2.70 (0.87; 8.38)
Middle (n=106)					
Model 1: crude	0.37 (0.13; 0.61)	0.79 (0.35; 1.23)	0.24 (-0.09; 0.57)	0.52 (0.19; 1.45)	2.25 (1.28; 3.95)
Model 2: adjusted [b]	0.18 (-0.08; 0.43)	0.52 (0.06; 0.99)	0.03 (-0.31; 0.37)	1.14 (0.29; 4.50)	1.76 (0.82; 3.75)
High (n=370)					
Model 1: crude	0.20 (0.08; 0.31)	0.16 (0.02; 0.30)	0.16 (0.01; 0.31)	0.64 (0.47; 0.89)	1.08 (0.60; 1.94)
Model 2: adjusted [b]	0.17 (0.05; 0.28)	0.21 (0.07; 0.34)	0.08 (-0.07; 0.22)	0.64 (0.46; 0.89)	1.06 (0.58; 1.92)

[a] Regression coefficients reflect a 1-unit change in BMI z-score, FMI and FFMI at age 12 for each increment in dietary pattern score; Data on FMI and FFMI was missing for n=7 subjects (n=1 middle SES, n=6 high SES)[b] Model 2 is adjusted for sex, children's exact age at the 5-years height and weight measurement, screen time at age 5, maternal BMI at age 5 and ethnicity, because of missing values n=505 subjects (lown=45, middle n=105, high maternal education level n=355) were included in the adjusted analyses.

Supplemental Table 6.6. The association between RRR-derived dietary pattern 2 at age 5 and BMI z-score, body composition and weight status at age 12 by level of maternal education (n=525).

	BMI z-score	FMIb	FFMIb	Underweight	Overweight
Level of maternal education	B (95%-CI)a	B (95%-CI)a	B (95%-CI)a	OR (95%-CI)	OR (95%-CI)
Low (n=48)					
Model 1: crude	0.06 (-0.39; 0.51)	-0.27 (-1.05; 0.51)	0.44 (-0.26; 1.15)	1.08 (0.26; 4.44)	1.33 (0.65; 2.72)
Model 2: adjusted [c]	0.06 (-0.39; 0.50)	-0.22 (-1.03; 0.60)	0.34 (-0.37; 1.05)	11.4 (0.12; inf)	1.67 (0.62; 4.48)
Middle (n=106)					
Model 1: crude	-0.11 (-0.37; 0.16)	-0.18 (-0.67; 0.31)	0.06 (-0.29; 0.41)	0.94 (0.40; 2.19)	1.28 (0.70; 2.37)
Model 2: adjusted [c]	-0.01 (-0.64; 0.24)	0.10 (-0.37; 0.57)	0.05 (-0.28; 0.39)	0.53 (0.12; 2.36)	1.56 (0.73; 3.34)
High (n=370)					
Model 1: crude	-0.04 (-0.14; 0.05)	-0.20 (-0.32; -0.08)	0.08 (-0.05; 0.21)	1.05 (0.82; 1.34)	0.89 (0.55; 1.44)
Model 2: adjusted [c]	-0.04 (-0.14; 0.06)	-0.14 (-0.26; -0.03)	0.06 (-0.06; 0.18)	1.07 (0.82; 1.40)	0.85 (0.50; 1.47)

[a] Regression coefficients reflect a 1-unit change in BMI z-score, FMI and FFMI at age 12 for each increment in dietary pattern score; [b] Data on FMI and FFMI was missing for n=7 subjects (n=1 middle SES, n=6 high SES) [c] Model 2 is adjusted for sex, children's exact age at the 5-years height and weight measurement, screen time at age 5, maternal BMI at age 5 and ethnicity, because of missing values n=505 subjects (low n=45, middle n=105, high level of maternal education n=355) were included in the adjusted analyses.

CHAPTER 7

General discussion

Aims

The three research questions in this thesis were: 1 to derive dietary patterns in children at age 5, using three different methods, 2: to examine associations with ethnicity, maternal education and other socioeconomic determinants and 3: to examine associations with longitudinal BMI and measures of body composition. The studies of this thesis were embedded in the Amsterdam Born Children and their Development (ABCD) study, a prospective community-based cohort study. The current chapter provides a brief summary of the main findings, a general discussion of the major findings per research question and methodological considerations, followed by public health implications and directions for further research.

Main findings

Dietary patterns in childhood

Main findings:

- Using the three major methods to derive dietary patterns, we identified dietary patterns that can be labelled as healthy, unhealthy, traditional and a pattern in which intakes of full- and low-fat food groups were relevant (Chapters 2, 5 and 6).

Comparison of the identified dietary pattens

We observed that children in the ABCD-cohort consume dietary patterns that can be labelled as healthy, unhealthy, traditional and a pattern in which intakes of full-and low-fat food groups were relevant. This can to a large part be compared to results in the literature where data-driven dietary patterns identified in children are generally labelled as healthy, unhealthy and, less frequently, as traditional (1-7). Names of data-driven patterns are chosen subjectively and comparable diet scores can reflect adherence to different food groups.

In our cohort, both the a posteriori derived data-driven Principal Component Analyses (PCA) and hybrid Reduced Rank Regression (RRR) method provided a dietary pattern that was characterized by high intakes of food groups perceived as healthy (Table 7.1). Also, pre-defined diet quality score components with the highest scores can reflect elements of a healthy dietary pattern (Table 7.1). We observed that among the three different methods used, similar food groups are of importance in dietary patterns labelled as healthy. In line with our results, most of the data-driven healthy patterns were mainly characterized by high intakes of fruit and vegetables (2), but also whole grains (8), fish and pulses (1) were relevant in data-driven healthy patterns in children, indicating that both in our cohort but also in the literature, it is unequivocal which food groups are of importance in healthy dietary patterns.

Using the data-driven PCA method, we also derived a snacking pattern which can be labelled as an unhealthy pattern (Table 7.1). The a priori diet quality score accounted for unhealthy food intake, by reverse scoring for the intake of a number of unhealthy foods (Table 7.1). However, the score did not include all potentially unhealthy foods such as savoury snacks, refined breakfast products, ice cream, sauces, chocolate and candy (9), which have been identified as being important contributors to unhealthy dietary patterns in children (2, 7, 8, 10). Also, healthy food groups of which the intakes did not meet the recommended intakes contribute to a lower diet quality score.

In our cohort, we additionally observed two dietary patterns in which intakes of full-fat and low-fat food groups were of importance (Table 7.1). Using the data-driven method, we observed a full-fat pattern which was not previously identified as such in the literature. In contrast, using the RRR-derived method, we observed that the first pattern that explained most of the variation of the response variables BMI z-scores and FMI, was characterized by high intakes of low-fat food groups which makes it of interest to observe the role of low- and high fat food groups in dietary patterns.

Table 7.1: Overview of the identified dietary patterns in 5-year old children in the ABCD cohort.

Used method	PCA (chapter 2; table 2)	RRR (chapter 6; table 2)	Diet quality score [a] (chapter 5; table 2)
Label: healthy			
Name of the dietary pattern	Healthy	Pattern 1 [b]	
Characteristic food groups	Water and tea, vegetables, fish, fruits, whole grain products for the warm meal, nuts and pulses	Water and tea, low-fat cheese, fruits, fish, low-fat dairy, whole grain breakfast products, low-fat meat and eggs	Whole grains, fruit, fish, dairy and vegetables
Label: unhealthy			
Name of the dietary pattern	Snacking		
Characteristic food groups	Savory snacks, refined breakfast products, ice cream, sauces, chocolate and candy, fruit drinks and full-fat dairy		Sugar-containing beverages, high-fat and processed meat, pulses, nuts, oils and soft or liquid fats [c]
Label: low-fat and full-fat			
Name of the dietary pattern	Full-fat	Pattern 1	
Characteristic food groups	Full-fat spreads, full-fat cheese, pasta dishes with tomato sauce and low intakes of low-fat spreads and low-fat cheese	Water and tea, low-fat cheese, fruits, fish, low-fat dairy, whole grain breakfast products, low-fat meat and eggs	

[a] For each food group, ratios of reported intakes and recommended intakes were calculated, resulting in a score between 0 and 1 and an overall sum-score ranging from 0 to 10, with a higher score representing a better diet quality (9)
[b] Pattern 1 explained most of the variation of the response variables BMI z-scores and FMI at age 5.
[c] Food groups of which the intakes did not meet the recommended intakes

Socioeconomic determinants of dietary patterns at age 5

Ethnicity

Main findings

- Ethnicity contributed independently to the differences in dietary patterns (Chapter 2).
- Children from non-Dutch origin had predominantly a higher adherence to both the data-driven snacking and healthy pattern (Chapter 2).
- We observed that each group of non-Dutch origin has their own characteristic dietary habits (Chapters 2 and 5).

Up to now, there is limited evidence about the association between ethnicity and dietary patterns of children. In line with our observations, studies in Asia, the USA and among adolescents in Belgium observed that children originating from low- and middle-income countries consumed more often both a healthy and an unhealthy dietary pattern (3, 11-14). Partly in line with our observations, a healthy pattern was related with non-white ethnicity at age 2 (15) and non-white ethnicity was associated with lower diet quality (16) in two European cohorts. Contrary to our results, the British ALSPAC cohort observed that a 'junk' pattern was related to white ethnicity at age 4 and 7 (17). However, the distinction between ethnic groups as white/non-white does not do justice to the diversity of ethnicities in Europe. Unlike our results, some cohort studies in Australia and New Zealand observed that young children of non-Australian and New Zealand-born mothers tended to consume core foods less frequently than those with Australian-and New Zealand-born mothers (18, 19), while children of Asian born mothers were reported to consume less discretionary foods compared to children of Australian-and UK-born mothers (20-22).

In line with our observations, a study in Germany observed considerable differences in dietary habits in children and adolescents by different ethnicities (23). Also, one study in the Netherlands observed higher intakes of fruit and vegetables in 9-10 year old children from non-Dutch origin compared to children of Dutch origin (24). Also, higher intakes of snacking items and soft drinks were observed in Germany in children originating from low- and middle-high income countries, mainly of Turkish origin (23, 25) and in in children originating from low- and middle-high income countries in the USA (26). Results from the Dutch National Food Survey's reported that intake of fat and full-fat dairy products is high among adults from Turkish origin (27, 28).

We divided our study population into major ethnic groups relevant in the Netherlands (29), specifically Amsterdam, and observed that each ethnic group has their characteristic dietary habits which included both healthy and unhealthy components (Chapter 2: Table 2.3 and Figure 2.2. Chapter 5: supplemental Table 5.1).

Our results indicate ethnic differences in dietary patterns however, due to the small number of children in the non-Dutch origin groups in our study, we could not further specify these differences. With larger numbers of children of non-Dutch origin, we would have run RRR analyses separately for each ethnic group, to better understand which food groups explain most of the variation in BMI and measures of body composition in each ethnic group.

Maternal education

Main findings

- The level of maternal education was related to dietary patterns (Chapters 2, 5 and 6).
- Children of lower educated mothers were prone to have unhealthy dietary patterns, however we observed mixed and unexpected results in the association between maternal education and healthy dietary patterns (Chapters 2, 5 and 6).

In the majority of the studies in this thesis, we have used the level of maternal education as a proxy for SEP which is considered as the strongest socioeconomic factor of dietary intake of young children (15, 30). Our results are in line with other studies that observed that maternal education level was related to dietary patterns (4, 6, 15, 17, 30-33) and the large amount of literature that observed that children of lower educated mothers consume more often unhealthy dietary patterns (17, 19, 31, 34, 35). Also, the most recent Dutch National Food Consumption Survey (36) reported statistically significant higher consumption of potatoes, meat, savoury snacks, sauces and seasonings and non-alcoholic beverages in children of lower educated mothers compared to children of higher educated mothers (1-17 years old). These food groups are also relevant in our data-driven 'unhealthy' and 'traditional' dietary pattern.

Our results are however only partly in line with literature that observed that higher maternal education levels are associated with healthy dietary patterns (2, 6, 15, 35, 37-39). We observed that children with higher diet quality scores had more often a mother with a higher educational level (Chapter 5; table 2). On the other hand, we did not observe that maternal education was related to the data-driven healthy pattern (Chapter 2; table 2) or that intakes of healthy food groups were exclusively important in the RRR-derived dietary pattern 1 in children of high educated mothers only (Chapter 6; table 2). Possibly, some of these observed differences can be related to the inclusion of different food groups per used method. For example, the intake of the food group water and tea was not included in the diet quality score. Another possible explanation might be that in our cohort, only the intakes of the healthy food groups vegetables, fruits and whole grains were significantly higher in children of higher educated mothers while intakes of nuts, pulses and water and tea were significantly higher in children of lower educated mothers. Additionally, we have assessed the level of maternal education in two different ways throughout the conducted analyses in our cohort which makes it difficult to compare and interpret the results of the different analyses clearly. The diet quality score was associated with two categories of maternal education level defined as 'completed higher vocational education' or 'university' (Chapter 5) while the PCA (Chapter 2) and RRR derived dietary patterns (Chapter 6) were associated with three categories of maternal education level defined as the number of years of post-primary education. The advantage of assessing three categories of maternal education is that we could better observe possible differences in educational level.

Other socioeconomic factors

Main findings

- Lower level of paternal education, lower level of household finance and lower neighbourhood SES were independently associated with a higher risk of unhealthy dietary patterns, although maternal education conferred the highest risk (Chapter 3).
- A lower level of household finance was an extra risk of unhealthy dietary patterns within the group of middle-high educated mothers (Chapter 3).

We choose to assess the association and possible moderation of maternal education and other socioeconomic indicators on the data-driven snacking pattern score (Chapter 3) because of the strong association between the data-driven snacking pattern and the level of maternal education (Chapter 2) and the possible adverse associations with health. In Chapters 2, 5 and 6 however, we also observed that the association between maternal education and the adherence to healthy dietary patterns showed unexpected results which underlines the complexity of the role of socioeconomic determinants in dietary patterns.

SEP is a multidimensional construct and there is a number of socioeconomic determinants that affect children's health at multiple levels (40, 41). We studied SEP at both an individual level (maternal and paternal education, household finance) as well as at the less frequently studied neighbourhood level (neighbourhood SES) (42), which are the commonly used indicators in public health research that are related to dietary patterns in children. We observed that all the studied socioeconomic determinants were relevant (Chapter 3), which is in line with results in the literature that observed associations between one or more of the determinants and dietary intake (31, 42-45). There are various pathways through which each of these socioeconomic determinants can affect children's dietary pattern intake, which broadly occur through knowledge, attitudes (46), parent modelling (47, 48), the financial ability to purchase healthy foods (49-52), the level of exposure to unhealthy food establishments (49, 53) and the degree of food advertising (54).

Our results also indicate that the level of maternal education is the strongest associated socioeconomic determinant of unhealthy dietary patterns in children, which is in line with results in other studies (15, 55). However, our results underline the importance of a sufficient level of household finance, that can overrule the effect of a middle high maternal education level (Chapter 3).

While not all studies have included determinants at both an individual and neighbourhood level, our results underline that all of these determinants are relevant for dietary pattern intake of young children. In general, the observed associations between socioeconomic determinants and dietary patterns could provide directions for public health interventions to specifically target children from lower SEP groups, especially children from lower educated mothers that are most at risk of unhealthy dietary patterns, and these interventions should take along the possible accumulation of disadvantage socioeconomic determinants.

Associations between dietary patterns and longitudinal BMI, FMI and FFMI

Main findings

- The identified dietary patterns were associated with longitudinal development of BMI and measures of body composition, however we observed unexpected results in this association (Chapters 4, 5 and 6).
- While the association between healthy dietary patterns and longitudinal BMI and measures of body composition showed mixed results (Chapters 4, 5, 6), the data-driven full-fat dietary pattern was negatively associated with weight development.
- Our results indicate that each ethnic and SEP group follows its own path of weight development, and that the association between dietary patterns and weight development might be different within each group.

Our observations in Chapter 5 are in line with the majority of the results in the literature, that report that higher diet quality scores and higher adherence to healthy (data-driven) dietary patterns are associated with lower BMI z-scores and/or a lower prevalence of overweight and obesity (2, 3, 56-68).

However, opposing associations were observed using the data-driven (Chapter 4) and hybrid method (Chapter 6). A few other studies have observed inconsistent (38, 58, 69-72), or no associations between higher diet quality scores or other hypothesis-driven dietary patterns as mKIDMED score/DASH/HEI and longitudinal 'healthy weight' (73-76) or in line with our results, a higher prevalence of overweight and obesity in children consuming dietary patterns labelled as healthy (7, 77). A Norwegian study observed in cross-sectional analyses in 9-10 year old children that a adherence to a 'junk/convenient' dietary pattern had a significantly lower likelihood of being overweight whereas children adhering to a 'varied Norwegian' or a 'dieting' pattern (artificially sweetened soft drinks, low fat cheese and fat- and sugar-reduced yoghurt), had a significantly higher likelihood of being overweight (7). The researchers suggest possible parental modification of the diets of overweight children. It might be possible that parents provide their children more 'healthy food items' when children are already overweight, which possibly indicates reverse causality. This could not be ruled out in our cohort as well based on both the cross-sectional and longitudinal results described in Chapters 4 and 6. In the Netherlands, from birth on, weight development from children is periodically monitored through Youth Health Care (YHC). Probably, the YHC gave nutritional advices if weight development of children was suboptimal which could have resulted in adjusted nutritional habits by the parents before the age of 5 years old.

Few other studies described the possibility of reversed causality. In the UK ALSPAC cohort, full-fat dairy intake at age 10 was associated with a reduced risk of excess total body fat mass and a suggestion of a reduction in overweight at 13-years old. Furthermore, the highest vs. lowest consumers of full-fat products had smaller gains in BMI at 13-years old (78). Also, in the UK ALSPAC cohort, a small positive correlation was observed between diet soft drink consumption, but not SSB consumption at age 5 and 7 and fatness at age 9, which was explained by existing overweight status at ages 5 and 7-year old (79) while no evidence was observed between SSB consumption at age 5 or 7-year old and fatness. The researchers of these studies suggested that parents had possibly provided this type of drink to their children in the hope of limiting weight gain (65, 79).

Considering the higher prevalence of childhood obesity in children originating from low- and middle-high income countries and lower SEP children (80-84) (Chapter 4) and the evidence of a growing prevalence of underweight/thinness in children originating from high-income countries (85-88), a relevant further step in our analyses was to study the role of dietary patterns in weight development per group separately. Although the number of subjects in some ethnic groups was limited, our results indicate that the association between dietary patterns and weight development might differ per group and that it would be relevant to (further) study the role of both ethnicity and SEP in this association.

Although it is convincing that there is an association between dietary patterns and weight and weight development in young children, and that this association might differ for each ethnic and SEP group, our results about these associations are mixed. Yet, childhood obesity is a complex construct. A diversity of factors contribute as biological- and lifestyle factors (89) but also the social- and obesogenic environment (90). Possibly there are different mechanisms that contribute to childhood overweight/obesity in each ethnic and SEP group. It would be relevant for future research to further study this association and for public health implications to contribute to the development of healthy weight in children.

General methodological considerations

Dietary pattern analysis

Dietary pattern analyses is an approach used in nutritional epidemiology, to examine the risk between diet and chronic diseases. In general, dietary patterns reflect a combination of food groups that highlight a broader picture of food and nutrient consumption than looking at individual nutrients or foods (8, 91-93). In this thesis, we used the three main methodological approaches to study overall diet (92, 94) which allowed us to study the dietary pattern intake in 5-year old children in the ABCD-cohort, from different perspectives. Each method however has its own advantages and disadvantages (92, 94). The main advantage of the data-driven PCA method is that the observed dietary patterns reflect the maximum of variation in food group intake, and therefore reflect combinations of food groups that are frequently consumed together (6, 94). This allowed us to study the actual dietary pattern intake independent of other factors. The main advantage of the hypothesis-driven diet quality score is that this score reflects the dietary intake according to the dietary guidelines. The applied diet quality score in this thesis was composed to assess to which extent the intake of 10 food groups met the Dutch Dietary Guidelines for children aged 4 to 8 years (95, 96). The results gave therefore direct information on which dietary habits in children complied least with the recommendations (95, 96) and need to be improved (Chapter 5; table 2). Although diet quality scores are applied most frequent in the literature (97), they do not reflect a complete picture of dietary intake as not all food items and food groups are included in the score. The hybrid RRR method is a less frequently studied method (97). Similar to the data-driven PCA method, the RRR-derived dietary patterns reflect total dietary intake. Additionally, the RRR-derived dietary patterns also reflect the combinations of food groups that explain the maximum variation in health markers, in our research we used BMI, FFMI and FMI at age 5 as response variables. Using RRR, therefore, allowed us to understand which combinations of food groups, as part of the total dietary intake, were relevant in cross-sectional weight development and measures of body composition in children.

Assessment and interpretation of food groups and dietary patterns

The hypothesis-driven diet quality score used a different classification of food groups compared to thedata- driven and hybrid method. Some food groups were not included in the diet quality score as only food items were included that are part of the recommended intakes for children aged 4 to 8 years (9, 95, 96). Therefore for example, the food groups water and tea and low-fat meat were excluded from the analyses. But also food groups were classified differently, for example the food group low-fat cheese was included in the dairy component in the hypothesis-driven diet quality score. Yet, these food groups were of importance in the PCA and RRR-derived 'healthy' dietary patterns which limits an optimal comparison between the derived dietary patterns identified using different methods.

Also, it might be possible that food items are consumed in different combinations implicating possible different classification of food groups than used in our study. For example, the food group 'sugar' consists of sugar consumed as a sweetener in yogurt or cereals, but also as a sweetener consumed in tea. We observed that children from lower educated mothers consumed sugar more often as a sweetener in tea compared to children from middle and higher educated mothers, therefore possibly the use of tea and sugar in tea as a sweetener could be combined in a food group 'sugar sweetened beverages' (Chapter 6).

We considered component loadings of ≥0.3 in the PCA analyses and ≥0.2 in the RRR analyses important for the interpretability of the dietary patterns. Lower component loadings indicate smaller positive or negative correlations between the food group and the dietary pattern. Including lower component loadings were not useful for a better interpretation of the observed results and were in line with the overall picture of the pattern.

The role of potential confounding factors

The dietary patterns derived within the lower maternal education group, explained higher levels of variances in response variables compared to the middle and higher maternal education group (resp. 15.4, 12.2 and 4.9% for Pattern 1) (Chapter 6). Although levels of explained variances are generally low in nutritional research, these observations indicate that particularly in children of lower educated mothers, the role of dietary patterns in explaining differences in BMI and measures of body composition is higher compared to children of middle and higher educated mothers. These observations suggest that the potential role of dietary patterns is higher in children of lower educated mothers and therefore underline the importance of targeting children from lower educated mothers to develop healthy dietary patterns.

We adjusted for several potential confounding factors in the association between dietary patterns and longitudinal BMI and measures of body composition. However, residual confounding may still be present. For example, we did not have data on growth spurts as a variable, and we used the variable children's exact age at the 5-years height and weight measurement' to correct for the variation in age in months, during the 5-year measurements. Tanner stage was measured in our cohort at age 12 and in pre-analyses only relevant in our population at age 12, but not at age 10, based on the a significant change (≥10%) effect estimated on the dietary patterns. Initially, we choose the variable 'screen time' as a proxy for sedentary behaviour in the association between the PCA and RRR-derived dietary patterns at age 5, and longitudinal weight development. Possibly, we could have also adjusted for physical activity in theses associations. In the literature, both screen time as well as physical activity levels are described as important and independent variables in the association with BMI. Although, in analyses assessing the association between diet quality score with body composition at age 5 and 12 years, we adjusted for both screen time and physical activity.

Public health implications and further research

The results presented in this thesis add to the existing literature on the topic of dietary pattern analysis in different ethnic and socioeconomic groups of children and their association with longitudinal measures of body composition. Our results also provide directions for future research and for public health strategies, which will be suggested in this paragraph.

Implications of the findings for further research

1: Study the association between healthy, full- and low-fat dietary patterns and weight development

In this thesis, we were unfortunately not able to further explain the observed mixed and unexpected results between dietary patterns and both cross-sectional and longitudinal weight(development) (Chapters 4 and 6) because we could not rule out the possibility of reversed causality in our cohort. In the Netherlands, weight development of children is monitored by the Youth Health Care (YHC) between birth and the age of 4 years old as standard practice. It may be possible that the advice provided by professionals may have modified children's diets, or have resulted in socially desirability when filling out the FFQs.

Adherence to the data-driven full-fat pattern can be in line with the focus on dairy consumption in the age between 1 and 4 years old. Although the intake of low- and medium fat dairy is recommended (96), parents might receive inconsistent advises and subsequently choose for full-fat dairy options in younger children. To better understand the association between dietary patterns characterized by full-fat and low-fat food groups and longitudinal weight in further research, it might be relevant to also include relevant possible mediating variables, for example the level of satiety. Currently more literature is available that observed higher levels of satiety and possibly weight loss in children by intakes of full-fat dairy products compared to intakes of low-fat and semi-skimmed dairy products (98). Also, in adults a dietary pattern high in ultra-processed foods unconsciously increased energy intake compared to a unprocessed food pattern (99), possibly due to differences in meal eating rates. These results underline the relevance to include the number of eating moments per day, satiety, absorption and digestion of nutrients in studying the association between dietary patterns and weight development.

Additionally, we did not have information about the dietary pattern intake at age 10 or 12 years, whichlimits us to understand how dietary patterns would have developed over time in our cohort and how the dietary intake at age 10 or 12 years old would have influenced weight development at age 10 or 12. Although literature suggests that dietary patterns developed in childhood track into adolescence (100-104), other studies suggest that periods of change can be apparent during childhood (10) and that associations between behaviour factors including food group intake and BMI at different age points in childhood might become stronger with age (105). Further research could possibly investigate dietary patterns at more time points and therefore further investigate the role of dietary patterns in longitudinal weight and measures of body composition.

2: Because of the observed mixed results regarding the role of maternal education in healthy dietary patterns, our results indicate that it is relevant to use a more fine-grained definition of maternal education

Because we have observed mixed and unexpected associations between the level of maternal education and healthy dietary patterns (Chapters 2, 5 and 6), it is relevant to further study the role of maternal education and include multiple levels of maternal education. In our cohort however, our group of children of middle high educated woman (6-10 years of post-primary education) possibly also represented children from a higher maternal education level (graduation level: university of applied sciences). It would be relevant for future research to apply the most suitable definition (e.g. based on the level of education or the number of years of post-primary education) and grouping of maternal education, based on the country of birth and educational background of the study population.

3: Include larger numbers of children from relevant ethnic groups to study their specific dietary patterns

Results in Chapters 2, 4 and 5 underline the relevance to further explore the role of ethnicity in dietary patterns in children, which is especially relevant concerning the higher prevalence of overweight among children originating from low- and middle-income countries (106-109), and the observed differences in weight development between the ethnic groups in our cohort (Chapter 4). Our results add to the limited amount of research available about the role of ethnicity, dietary patterns and weight development and measures of body composition. In further research, these associations should be studied within each ethnic groups. Therefore, it would be necessary to include larger numbers of children from relevant ethnic groups, which can however be challenging in cohort studies. Also in the ABCD cohort, non-respondents were more often from low- and middle high income countries (110). Researchers acknowledge the 'need' of including larger numbers of children from relevant ethnic groups, and it would require a lot of time in approaching groups that do not usually participate in (intensive) cohort research. Due to the predominantly smaller numbers of children per ethnic group in studies, researchers might choose to merge groups. While results in this thesis, underline the relevance to study the dietary patterns per group separately, as we observed for example different eating habits between Turkish and Moroccan children, groups that are often merged in research.

In general, less ethnic-specific data is available. For example, the results of the Dutch National Food Consumption Survey (36) presented by the National Institute for Public Health and the Environment (RIVM), are currently reported by gender, age and gender groups, maternal education level, region, urbanisation and body mass index but would ideally also be described per ethnic group and the registration of ethnic origin does not extend beyond the second generation by the Central Office of Statistics (CBS). The availability of ethnic specific data is however crucial for public health care professionals to apply in their daily practice and practical interventions to target groups that are most at risk. Because the literature does not fully allow us to make the distinction between ethnic groups, it would be relevant for further research to consider the best way to distinguish, define, and include children from relevant ethnic groups, for example through self-identification by the (parents of the) participants. When ethnicity is studied in its role as a cultural determinant, the classification of ethnicity by self-indication can depend on de study topic, setting and study population.

4: Study the possible interaction between ethnicity and socioeconomic position more extensively

With larger numbers within relevant ethnic groups, future research should also study the possible interaction between ethnicity and socioeconomic position (111). For example, our data-driven healthy pattern was associated with ethnicity but not with maternal education level (Chapter 2) and it might be possible that the observed association between maternal education level and the healthy pattern was partly driven by Turkish and Moroccan children, that were predominantly from lower and middle maternal education level groups. To gain more insight in the association and separate the effects, it would be relevant for further research to study the associations of SEP with dietary patterns more stratified, within each ethnic group and the other way around. Furthermore, it might be possible that other factors are relevant for the possible interaction between ethnicity, SEP and dietary patterns, for example the level of acculturation, perceived level of discrimination or living conditions (112-1154). Currently, additional nutritional data from children aged 0-4 years old, is available within the Amsterdam based Sarphati cohort (https://www.sarphaticohort.nl), and further analyses within this cohort could possibly provide additional information on this topic. Given that the level of maternal education was the most important socioeconomic factor for children in our cohort at age 5. It would be however relevant for further research to study whether other SEP factors would be possibly more relevant in other age categories.

Implications of the findings for policy and practice

1: Ongoing public health strategies should (continue to) focus on healthy weight and healthy weight development in children, targeting children of non-Dutch origin and/or lower SEP in the prevention of overweight and obesity

The prevention of overweight requires an system approach (115), and the observed socioeconomic and ethnic inequalities in weight and weight development (Chapter 4) and adherence to unhealthy dietary patterns (Chapters 2, 3 and 5) underline the importance of ongoing public health strategies to focus on healthy weight and healthy weight development in children, targeting children from non-Dutch origin and/or lower SEP. However, we have observed differences in weight and weight development and adherence to unhealthy dietary patterns between these groups which should be taken into account. However, the focus on overweight and obesity should not detract from identifying children at risk of thinness, which may also present a risk for health (116-121). In our study we observed that thinness was more prevalent in children of Dutch origin and/or high SEP.

Considering these inequalities, and given the relevance of diet for weight development, gaining further insight in the role of dietary patterns (in each of these groups) could be even more relevant for policy and practice. The aim of this thesis was to provide practical information that could be used in targeting groups in order to contribute to the prevention of childhood overweight. Potentially, the derived dietary patterns could contribute to the required knowledge of which foods and beverages contribute to BMI and measures of body composition, within the specific ethnic and SEP groups. However, we were not able to fully investigate the role of multiple SEP factors in all derived dietary patterns and the possible interaction between ethnicity and SEP. Nevertheless, our results add to the existing literature that with decreasing SEP, an upward trend in adherence to snack and unhealthy eating patterns can be seen. This underlines the fact that current intervention programs should continue targeting children from non-Dutch origin and lower SEP groups which more often live in neighbourhoods with an unhealthy food environment (122), and take into account possible differences in applicability and acceptability of these intervention strategies between different SEP groups (123).

As differences between SEP groups are already present at a young age and remain stable throughout early childhood (30), it is relevant and possibly also more cost-effective, to target these children from an early age onwards to promote healthy eating habits. Also, results of the most recent Dutch National Food Consumption Survey (36) that are presented by level of maternal education, can be relevant for public health care professionals to apply in their daily practice to target children from lower educated mothers.

Additionally, results in our cohort (Chapters 2 and 5) also indicate that children from each non-Dutch origin group have diverse dietary habits which both include healthy and unhealthy elements. It would be relevant to maintain and emphasize these diverse habits and, more importantly, the healthy aspects in each group in public health interventions. For example, the intervention Simple Fit! aims to combat overweight and obesity in children aged 0-12 with a Turkish or Moroccan background in the Netherlands (124). Although this intervention is evaluated (125) and there are indications of differences in the level of cultural adaptation of obesity interventions (126, 127). Additionally, it is of importance to also include relevant individual obesity related factors that fit each target group. Parents function as a role model (128) and it would be important that they are supported in that role by public health interventions. Besides the relevance of the studied factors, literature underlines the importance of, for example, a healthy parental weight (80, 129) which is more often sub-optimal in parents originating from low- and middle-income countries or the perception of children's weight and growth which can differ between mothers of Dutch and non-Dutch origin (130).

2: Given the dietary intake in our cohort, the current food environment for children needs to be adapted

In our cohort, but also in another cohort in the Netherlands (9), and internationally (37, 131), the diet quality in children is suboptimal and should be improved. Except for the intake of whole grains, nutritional intake did not meet the recommendations that were developed (95, 96). Either the consumed amount of the food item was insufficient, or the nutritional composition did not met the criteria (e.g. were too high in level of saturated fat or salt or contained added sugar). Although in recent years, the Dutch children have been eating more according to the guidelines (36) and nutritional composition of processed food items have been improved, intakes of vegetables, fruits, fish, nuts, pulses need to be increased whereas intakes of red and processed meat and sugar-sweetened beverages need to be decreased (36).

It is important to ensure that this nutritional advice is also in line with current guidelines regarding food education (128). Diet is a major factor for healthy weight development and a higher intake according to dietary guidelines may have a beneficial impact on growth and body composition throughout childhood (Chapter 5). Although we have observed mixed and unexpected associations between dietary patterns and healthy weight development in our cohort (Chapters 4 and 6), and although there are still many topics to include in further research, the importance of stimulating a healthy dietary intake for healthy development in young children is unequivocal.
Given the current food environment, it is not surprising that children, mainly from non-Dutch origin and/

or lower maternal education groups, consume according to unhealthy snacking patterns or have suboptimal diet quality scores. Food choices are either made consciously and driven by knowledge, attitudes or skills or made unconsciously and sensitive to influences from the current food environment (132-135). Despite the major role of maternal education level in our cohort of 5-year old children (Chapter 3) (136), our results underline the importance of higher neighbourhood SES for healthy dietary intakes in children (Chapter 3)(137). Neighbourhood SES reflects the food environment by the type of foods that are available (54, 138) and advertisements that are present in the neighbourhood (139). A variety of organizations, such as schools, after-school cares, sport clubs, supermarkets, food establishments but also online influences have a role in creating a healthy food environment and it is crucial that all of these settings take their responsibility (115, 140). Currently, many primary schools in the Netherlands implement school-based interventions and several have shown positive effects. For example the "EU-Schoolfruit- en groenteprogramma" increases the fruit and vegetable intake in 4-12 year-old children and contributes to the improvement of healthy eating habits (141), and "Smaaklessen" increases the level of knowledge about consuming a healthy, sustainable and varied dietary pattern in 4-12 year-old children (142). School-based interventions have also shown positive effects on increasing the fruit and vegetable intake in children with migration background (143). Additionally, many primary schools evaluate the use of birthday treats and attempt initiatives as collective and healthy school lunches, which can be -if tailored to the preference of children, parents and the school staff- a promising strategy to promote healthier dietary habits among children (144). By doing so, primary schools clearly contribute to the healthy development of children (145) unlike other stakeholders within the current food environment of children that lag behind. The "National Preventieakkoord" aims to reduce the prevalence of overweight (146) does not yet seem to achieve the expected goals. The Healthy Youth, Healthy Future (JOGG) approach targets children (0–18 years) in the Netherlands by creating an environment that encourages healthy dietary habits and physical activity aiming to prevent obesity. Literature underlines the contribution of JOGG in local stakeholder connecting and mobilisation and shifts in social norms toward healthier lifestyles in the community. However, the contribution to individual health outcomes remains unclear (147). To conclude, it is important that all policies and environments make healthy food options readily available and appealing for children and their parents, and thus make the healthy choice the easy choice.

General conclusion

By using three main approaches to study dietary patterns, we observed that 5-year old children in the ABCD-cohort consume dietary patterns that can be labelled as healthy, unhealthy, traditional and a pattern in which intakes of full- and low-fat food groups were relevant. Children of non-Dutch origin and/or from lower educated mothers were most prone to unhealthy dietary patterns. Additionally, we have indications that children of non-Dutch origin also had higher adherence to a healthy dietary pattern and that each of these groups has their own characteristic dietary habits. Unlike results in the literature, we did not observe a clear association between the level of maternal education and healthy dietary patterns. Healthy diets are considered as a major determinant for optimal weight development in children and the observed dietary patterns were relevant for longitudinal weight development and measures of body composition. In line with our expectations, a higher diet quality score was associated with lower weight, lower BMI and lower FMI at age 12. However, opposing and unexpected associations were observed using the data-driven and hybrid method, where adherence to the data-driven healthy pattern was positively, and adherence to the full-fat pattern was negatively associated with weight development between age 5 and 10. Similar associations were observed using the hybrid method were a pattern characterized by food groups perceived as healthy, was positively associated with BMI z-scores and FMI, regardless of the level of maternal education. The results observed in this thesis do underline that the role of nutrition in health- and weight development related topics is complex and highlights the need for interventions that account for the complexity of inteactions between dietary patterns and weight development.

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Summary

In the Netherlands and many other high-income countries, the prevalence of childhood overweight and obesity is higher in children originating from low- and middle-income countries and in children with a lower socioeconomic position (SEP). Healthy diets are considered a major determinant for optimal weight development in childhood and healthy weight later in life. However, there is limited knowledge about ethnic and socioeconomic differences in dietary patterns of children and how these dietary patterns contribute to BMI and measures of body composition over time (**Chapter 1**). Therefore, this thesis addressed the following questions, using data from the Amsterdam Born Children and their Development (ABCD) study, a large, prospective and population-based birth cohort in the Netherlands (http://www.abcd-study.nl):

1. Which dietary patterns can be defined in 5-year old children using an a posteriori derived (data-driven) method (Chapter 2), an a priori derived method (Chapter 5) and a hybrid method (Chapter 6).
2. Which ethnic and socioeconomic determinants are associated with the derived dietary patterns? (Chapters 2, 3 and 5).
3. To which extent are the derived dietary patterns associated with BMI and measures of body composition over time? (Chapters 4, 5 and 6).

In **Chapter 2** we describe the four dietary patterns that were derived using the data-driven Principal Component Analyses (PCA) method: a snacking (high intakes of savoury and sweet snacks, fruit drinks, refined breakfast products and low intakes of whole-grain breakfast products), full-fat (high intakes of full-fat spreads, full-fat cheese, pasta dishes and low intakes of low-fat spreads and low-fat cheese), meat (high intakes of low- and high-fat meat, sauces, potatoes and refined grain products for warm meals) and healthy (high intakes on the food groups water and tea, vegetables, fish, fruits and whole grain product for warm meals) dietary pattern. Children of non-Dutch origin scored high on the snacking and healthy pattern. We observed that children of Turkish origin scored high on the full-fat pattern and children of African Surinamese origin high on the meat pattern. Children of lower educated mothers scored above all high on the snacking pattern, high on the meat pattern and low on the full-fat pattern.

In **Chapter 3**, we further studied the strong association between the level of maternal education and the PCA-derived snacking pattern. We observed that also other indicators of SEP, that is a lower level of paternal education, lower level of household finance and lower neighbourhood socioeconomic status (SES) were associated with higher snacking pattern scores. Yet, a lower maternal education level conferred the highest risk. We also observed that a lower level of household finance was an additional risk factor for higher snacking pattern scores within the group of middle-high educated mothers.

In **Chapter 4**, we describe how the four PCA-derived dietary patterns were associated with weight development between age 5 and 10 years, stratified by ethnic groups and level of maternal education. Children of Dutch origin and higher educated mothers were more often normal weight at age 5, and they developed more often normal weight at age 10 if they were underweight or overweight at age 5, compared to children of non-Dutch origin and lower and middle high educated mothers. Overall, higher scores on the healthy dietary pattern were unexpectedly positively associated with weight development in most groups, regardless of ethnic origin and maternal education level, whereas higher scores on the full-fat pattern were negatively associated with weight development.

In **Chapter 5,** we applied an a priori diet quality score, which reflects the extent to which the intake within 10 product groups complies with the age-specific Dutch food-based dietary guidelines for children aged 4 to 8 years. We observed an average score of 4.8 (± 1.1) out of a possible 10 points, indicating that in our cohort, about half of the age-specific dietary guidelines were met. Only the intake of whole-grains met the recommendation. The intake of fruits, vegetables, fish, pulses, nuts, dairy, oils and soft or liquid fats, sugar-containing beverages and high-fat and processed meat did not meet the recommendations. We observed that children with higher diet quality scores had more often a higher educated mother. We further described how a higher diet quality score was associated with a lower body weight, lower BMI and a lower body fat mass at age 12 years.

Because of the observed differential weight development per ethnic and socio-economic group and the unexpected and mixed results between the derived dietary patterns and weight development, we choose to further study which dietary patterns were relevant for BMI and measures of body composition at age 5 stratified by maternal educational level. We applied the hybrid Reduced Rank Regression (RRR) method in **Chapter 6**, and derived dietary patterns that explained the maximum of variation in BMI, body fat mass and body fat-free mass at age 5. Pattern 1 was characterised by high intakes of low-fat and healthy food items in all maternal education level groups, and explained the maximum of variation in BMI and body fat mass, in our cohort at age 5. Higher scores on pattern 1, were associated with higher BMI and a higher odds of being overweight or obese at age 10, and higher body fat mass at age 12 in all maternal education level groups.

Lastly, **Chapter 7** provides a general discussion of the studies described in this thesis. The main answers to the research questions, including the implications for future research and policy and practice are:

1. We applied three methods deriving dietary patterns at 5-year old children in the ABCD-cohort, which can overall be labelled as healthy, unhealthy and traditional, and a pattern in which in takes of full- and low-fat food groups were relevant. Compared to the age-specific Dutch guidelines, the dietary intake in our cohort was suboptimal, which underlines the need for improvement of the current food environment for children.

2. We observed that children of non-Dutch origin, lower educated mothers, lower educated fathers, lower level of household finance and lower neighbourhood socioeconomic status (SES) were most prone to unhealthy dietary patterns. Ongoing public health strategies should there fore (continue to) focus on healthy weight and healthy weight development in children, focussing on children of non-Dutch origin and/or lower SEP in the prevention of overweight and obesity.

   We have indications that children from each ethnic group consume their own characteristic dietary patterns. In our cohort however, the number of children of non-Dutch origin was small. Therefore, it would be relevant for further research to include larger numbers of children from relevant ethnic groups in the Netherlands, to further study their specific dietary patterns and the possible interaction between ethnic origin and socioeconomic position more extensively.

   We did not observe clear associations between maternal education level and healthy dietary patterns. Therefore, it would be relevant for further research to use a more fine-grained definition of maternal education.

3. We also observed opposing and unexpected associations between dietary patterns and BMI and measures of body composition over time. This prompts for further research to investigate the association between healthy, full- and low-fat dietary patterns and weight development.

The results observed in this thesis underline that the role of nutrition in health- and development related topics is complex. However, consuming healthy foods is important for everyone regardless of ethnic background and SEP, and it is essential that healthy foods are convenient, affordable and available for all children and their parents.

Samenvatting

Overgewicht en obesitas komen vaker voor onder kinderen van niet-Nederlandse afkomst en met een lagere sociaaleconomische positie (SEP). Een gezond voedingspatroon draagt bij aan een gezonde gewichtsontwikkeling als kind, en een gezond gewicht als volwassene. Er is echter nog weinig bekend over etnische en sociaaleconomische verschillen in voedingspatronen van kinderen en hoe deze voedingspatronen het lichaamsgewicht en de lichaamssamenstelling op latere leeftijd beïnvloeden (**Hoofdstuk 1**). Daarom zijn in dit proefschrift de volgende onderzoeksvragen opgesteld, welke worden beantwoord middels gebruik van data uit de Amsterdam Born Children and their Development (ABCD)-studie, een grootschalig en langlopend geboortecohort in Nederland (http://www.abcd-study.nl)

1. Welke voedingspatronen kunnen bij 5-jarige kinderen worden gedefinieerd met behulp van verschillende methoden: een (data gestuurde) a posteriori methode (Hoofdstuk 2), een a priori methode (Hoofdstuk 5) en een hybride methode (Hoofdstuk 6).
2. Welke etnische en sociaaleconomische determinanten zijn geassocieerd met de gedefinieerde voedingspatronen? (Hoofdstuk 2, 3 en 5).
3. In welke mate hangen de gedefinieerde voedingspatronen samen met BMI en lichaamssamenstelling op latere leeftijd? (Hoofdstuk 4, 5 en 6)

In **hoofdstuk 2** beschrijven we de vier voedingspatronen die vaak voorkomen bij de 5-jarige kinderen in het ABCD-cohort. Deze patronen zijn gedefinieerd met behulp van de a posteriori Principal Component Analyse (PCA)-methode. We vonden een snack patroon (hoge inname van hartige en zoete snacks, fruitsappen en geraffineerde ontbijtproducten en een lage inname van volkoren ontbijtproducten), een volvet patroon (hoge inname van margarine/roomboter, volvette kaas en pastagerechten en een lage inname van halvarine en magere kaas), een vlees patroon (hoge inname van vetarm en vetrijk vlees, sauzen, aardappelen en geraffineerde graanproducten voor warme maaltijden) en een gezond voedingspatroon (hoge inname van water en thee, groenten, vis, fruit en volkoren graanproducten bij de warme maaltijd). Kinderen van niet-Nederlandse afkomst aten vaker volgens het snack- en het gezonde voedingspatroon. We zagen ook dat kinderen van Turkse afkomst vaker aten volgens het volvette patroon en kinderen van Afrikaans-Surinaamse afkomst vaker volgens het vlees patroon. Kinderen van lager opgeleide moeders aten vooral vaker volgens het snack patroon, en vaker volgens het vleespatroon en minder vaak volgens het volvette patroon.

In **hoofdstuk 3** hebben we de sterke associatie tussen opleidingsniveau van de moeder en het a posteriori gedefinieerde snack patroon verder onderzocht. We zagen dat ook andere sociaal economische indicatoren sociaaleconomische, te weten een lager opleidingsniveau van de vader, een lager niveau van huishoudfinanciën en een lagere sociaaleconomische status (SES) van de buurt de kans op een snack patroon vergrootte, hoewel een lager opleidingsniveau van de moeder de sterkste risicofactor was. We zagen dat kinderen van een middelhoog opgeleide moeder vaker aten volgens een snack patroon als het niveau van huishoudfinanciën te laag of net voldoende was, dan wanneer er ruimte was om geld over te houden.

In **hoofdstuk 4** beschrijven we vervolgens hoe de vier a posteriori gedefinieerde voedingspatronen geassocieerd waren met gewichtsontwikkeling tussen de leeftijd van 5 en 10 jaar, uitgesplitst naar etnische groep en opleidingsniveau van de moeder. Kinderen van Nederlandse afkomst en hoog opgeleide moeders hadden vaker een gezond gewicht op 5-jarige leeftijd en indien zij dat niet hadden, ontwikkelde zij vaker een gezond gewicht op 10-jarige leeftijd. Een hoge score op het gezonde voedingspatroon, leidde in de meeste groepen verassend tot een hogere gewichtsontwikkeling, ongeacht etnische achtergrond en hoogte van het opleidingsniveau van de moeder, terwijl een hoge score op het volvette voedingspatroon leidde tot een lagere gewichtsontwikkeling.

In **hoofdstuk 5** pasten we een a priori gedefinieerde voedingskwaliteitsscore toe. Deze score geeft weer in hoeverre de inname van 10 productgroepen overeenkomt met de leeftijdsspecifieke Nederlandse Richtlijnen Goede Voeding voor kinderen van 4 tot en met 8 jaar. In ons cohort werd een gemiddelde score behaald van 4,8 (± 1,1) uit een mogelijke score van 10, wat aangeeft dat de helft van de leeftijdsspecifieke voedingsrichtlijnen werd gehaald. Alleen de inname van volkorenproducten voldeed aan de aanbevelingen. De inname van fruit, groenten, peulvruchten, vis, nootjes, zuivel, olie en vloeibare vetten, suikerhoudende dranken en vetrijk en bewerkt vlees voldeed niet aan de aanbevelingen. We zagen dat kinderen met een hogere score vaker een hoger opgeleide moeder hadden, en dat zij op 12-jarige leeftijd vaker een lager gewicht, een lagere BMI en een lagere vetmassa hadden.

We zagen dat de gewichtsontwikkeling van kinderen in ons cohort verschilt, afhankelijk van de etnische achtergrond en het opleidingsniveau van de moeder. We zagen ook onverwachte en wisselende resultaten tussen de voedingspatronen en gewichtsontwikkeling. Daarom wilden we in **hoofdstuk 6** specifieker bekijken welke voedingspatronen het meest voorspellend waren voor de gevonden verschillen in BMI en lichaamssamenstelling van kinderen op 5-jarige leeftijd. We gebruikten hiervoor de hybride Reduced Rank Regression (RRR)-methode en hebben uitgesplitst naar het opleidingsniveau van de moeder, onderzocht welke voedingspatronen het meest voorspellend waren voor de BMI, vetmassa en vetvrije massa op 5-jarige leeftijd. Patroon 1 werd in elke groep gekenmerkt door een hoge inname van vetarme en gezonde voedingsmiddelen en was voorspellend voor een hogere BMI en vetmassa in ons cohort op 5-jarige leeftijd. Kinderen met een hoge score op Patroon 1, ontwikkelden een hogere BMI en een hogere kans op overgewicht of obesitas op 10-jarige leeftijd, en een hogere vetmassa op 12-jarige leeftijd, ongeacht het opleidingsniveau van de moeder.

Tot slot biedt **hoofdstuk 7** een algemene discussie van de studies die in dit proefschrift worden beschreven. De belangrijkste antwoorden op de onderzoeksvragen inclusief de implicaties voor toekomstig onderzoek, beleid en praktijk zijn:

1. Wij hebben drie verschillende methoden toegepast om voedingspatronen te definiëren bij 5-jarige kinderen in het ABCD-cohort, en deze voedingspatronen kunnen overkoepelend wor- den gelabeld als gezond, ongezond, traditioneel en een patroon waarin de inname van volle en vetarme productgroepen relevant was. In vergelijking met de geldende voedingsrichtlijnen, is de voedingsinname in ons cohort suboptimaal, wat onder andere pleit voor aanpassingen in de huidige voedselomgeving van kinderen.

2. We observeerden dat kinderen van niet-Nederlandse afkomst, lager opgeleide moeders, lager opgeleide vaders, uit gezinnen met een lager niveau van huishoudfinanciën en een lagere sociaaleconomische status (SES) van de buurt, vaker een ongezond voedingspatroon consumeerde. Daarom is het relevant dat de publieke gezondheid zich (blijft) focussen op een gezond gewicht en een gezonde gewichtsontwikkeling voor kinderen van niet-Nederlandse afkomst en/of een lagere SEP, om overgewicht en obesitas te voorkomen.

We hebben ook aanwijzingen dat er verschillende voedingspatronen worden geconsumeerd per etnische groep specifiek. Binnen ons cohort was het aantal kinderen binnen de groepen met een migratieachtergrond te klein om hier duidelijke uitspraken over te doen. Daarom is het belangrijk dat er grotere groepen kinderen van relevante etnische groepen geïncludeerd worden in toekomstig onderzoek, om hun specifieke voedingspatronen te onderzoeken, plus om de mogelijke interactie tussen etniciteit en SEP uitgebreider te bestuderen.

We vonden in ons cohort geen duidelijke associaties tussen het opleidingsniveau van de moeder en de consumptie van gezonde voedingspatronen. Daarom zou het relevant zijn om in toekomstig onderzoek gebruik te maken van een meer verfijnde definitie van het opleidingsniveau van de moeder.

3. We zagen tegengestelde en onverwachte associaties tussen de voedingspatronen en BMI en lichaamssamenstelling op latere leeftijd. De associatie tussen gezonde, volvette- en vetarme voedingspatronen en gewichtsontwikkeling zou in vervolgonderzoek verder onderzocht kunnen worden.

De resultaten in dit proefschrift benadrukken dat de rol van voeding in gezondheids- en ontwikkeling gerelateerde onderwerpen complex en multivariabel is. Toch is het consumeren van gezonde voeding belangrijk voor iedereen, ongeacht etniciteit en SEP. Het is essentieel dat gezonde voeding aantrekkelijk en beschikbaar is voor alle kinderen en hun ouders.

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About the author

Viyan Rashid was born on December 15, 1979 in Eindhoven in the Netherlands as the oldest child in the family. Favourite subjects at the secondary school were arts and biology. After doubting to study between 'something in arts and design' or 'something medical', she choose to obtain a bachelor's degree in Nutrition and Dietetics at the HAN University of Applied Sciences in Nijmegen (1998-2002).

She wrote her bachelor thesis at the Uppsala University in Sweden. After, she obtained a master's degree in Nutriton and Health with a specialization in Dietary Behaviour and Disease Prevention at the Wageningen University (2002-2004). She wrote her master thesis in Vietnam about dietary patterns, intake and attitudes to soms iron-fortified foods in the diet of primary school children in rural North Vietnam.

Since 2010, she works as a lecturer at the Amsterdam University of Applied Sciences, at the department of nutrition and dietetics were she is responsible for courses in nutrition and the supervision of graduation students. As part of the PhD-program, she took several courses in epidemiology and statistical methods at the NIHES Erasmus Rotterdam and EpidM Amsterdam UMC. She is fascinated by the large amount of scientific developments in the field of nutrition and the role of nutrition in the prevention and treatment of diseases.

Publications and author contributions

Chapter 2

Ethnicity and socioeconomic status are related to dietary patterns at age 5 in the Amsterdam Born Children and their Development (ABCD) cohort.

Rashid V, Engberink MF, van Eijsden M, Nicolaou M, Dekker LH, Verhoeff AP, Weijs PJM. BMC Public Health. 2018 Jan 8;18(1):115.

V.R, M.v.E., P.J.M.W., A.P.V., formulating the research questions and designing the study; V.R., M.v.E., M.F.E., L.H.D. analysing the data; V.R., M.F.E., M.v.E., M.N., L.H.D., P.J.M.W., A.P.V., writing the article; and V.R., M.F.E., P.J.M.W. had primary responsibility for final content. All authors read and approved the final manuscript.

Chapter 3

Beyond maternal education: socio-economic inequalities in children's diet in the ABCD cohort.

Rashid V, Weijs PJM, Engberink MF, Verhoeff AP, Nicolaou M. PLoS One. 2020 Oct 13;15(10):e0240423.

Conceptualization, V.R., P.J.M.W., M.F.E., A.P.V., M.N.; methodology, software and formal analysis V.R., MN.; writing original draft preparation V.R. M.N.; writing – review and editing V.R., P.J.M.W., M.F.E., A.P.V., M.N.; supervision P.J.M.W., M.F.E., A.P.V., M.N.; All authors have read and agreed to the published version of the manuscript.

Chapter 4

Weight development between age 5 and 10 years and its association with dietary patterns in the ABCD cohort.

Rashid V, Streppel MT, Engberink MF, Weijs PJM, Nicolaou M, Verhoeff AP. BMC Public Health. 2020 Apr 1;20(1):427.

V.R., M.E., M.S. formulating the research questions and designing the study; V.R., M.E., M.S., M.N analysing the data; V.R., M.S., M.N., P.J.M.W., A.V. writing the article; and V.R, M.S., M.N. has primary responsibility for final content. All authors read and approved the final manuscript.

Chapter 5

Diet quality in relation to body composition in childhood: the ABCD-study

Anh N. Nguyen, Viyan Rashid, Tanja G.M. Vrijkotte, Peter J.M. Weijs, Mary Nicolaou, Trudy Voortman (To be submitted)

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Chapter 6

Dietary patterns by level of maternal education and their contribution to BMI, Fat Mass Index and Fat Free Mass Index at age 5 and the longitudinal association with BMI at age 10.

Rashid V, Nicolaou M, Verhoeff AP, Weijs PJM, Streppel MT. Nutrients. 2024 Sep 25;16(19):3242.

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