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# Healthy diet in Norwegian children: determinants and associations with body weight. Results from The Norwegian Mother and Child Cohort Study (MoBa)

Kosthold blant norske barn: Påvirkningsfaktorer og assosiasjon mellom kosthold og vektstatus. Resultater fra en studie i den Norske mor- og barn undersøkelsen (MoBa)

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# Acknowledgments

When starting the search for a master's project, I knew I wanted to do a quantitative study. I wanted to improve my statistical skills and be able to learn from and work with experienced researchers within the public health field. I figured that the best way to accomplish this goal was to look for a potential ongoing project at the FHI (Norwegian Institute of Public Health). After sending an e-mail with a request to write my thesis on a different (but similar) project, I was lucky enough to get a reply from Eleni Papadopoulou (main supervisor). I was offered to write my thesis on diet quality and children with data from the Norwegian Mother and Child Cohort Study (MoBa). Nutrition has always been a passion of mine, and I believe that knowledge on diet and food is extremely important for human health. This making it an obvious public health interest. Also, the current focus on an increasing overweight and obese child and adolescent population made this topic especially interesting.

I would first like to thank my supervisors Eleni Papadopoulou (PhD) and co-supervisor Anne Lise Brantsæter (PhD) for including me in their research group and giving me the opportunity to work on such an exciting research project. Also, for the privilege to work with MoBa data and the chance to present my research project at the Nutrition and Growth Conference in Paris, May 2018.

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Oslo, May 8th 2018

Line M. N. Sørensen

## Sammendrag

**Bakgrunn/hensikt:** Et sunt kosthold beskytter mot underernæring så vel som mot andre ikke-smittsomme sykdommer, og det er kjent at kostholdsvaner vedvarer i voksen alder. Den økende andelen overvekt og fedme blant barn krever umiddelbare tiltak, og kvaliteten på kostholdet er en nøkkelfaktor. Det er derfor viktig å skaffe mer kunnskap om hvilke faktorer (determinanter) som påvirker kostholdet i denne aldersgruppen. Denne masteroppgaven består av to ulike studier. Først en litteraturstudie, etterfulgt av en kohortstudie. Litteraturstudien ble gjennomført for å identifisere en eller flere kosthold-indekser for bruk i den etterfølgende studien. Hensikten med studien var å undersøke kvaliteten på kostholdet til norske barn og identifisere faktorer som påvirker dette. Deretter var målet å undersøke om kostholds-kvalitet var assosiert med vektstatus ved alder syv år i studiepopulasjonen.

**Populasjon/Metode:** En omfattende litteraturstudie ble utført for å identifisere potensielle kostholds-indekser for videre bruk i kohortstudien. Analysene i studien er basert på 34074 kvinner og barn som deltar i Den norske mor og barn undersøkelsen (MoBa). Kvaliteten på kostholdet ble undersøkt ved i) grad av tilslutning til et middelhavskosthold, definert ved bruk av en matfrekvens-basert middelhavs-kostholds score (fMDS) og ved ii) bruk av en kostholdskvalitets-indeks (DQI), som reflekterer i hvilken grad kostholdsanbefalinger ble fulgt for 34,074 tre-åringer og 18,350 syv-åringer. Kostholdsdeterminantene ble undersøkt ved bruk av trinnvis seleksjon (p-verdi<0.001). Definisjon av overvekt og fedme ved syv års alder var basert på internasjonale kriterier (International Obesity Task Force (IOTF)), og undersøkt ved logistisk regresjon.

**Resultater:** Litteraturstudien resulterte i funn av to kostholds-indekser som egnet seg for bruk i kohortstudien. Disse var DQI (Diet Quality Index) og fMDS (food frequency-based Mediterranean Diet Score). Ved tre og syv år hadde henholdsvis 36% og 34% av barna høy score på middelhavskostholdet (fMDS poengsum: 3-6). Når vi sammenlignet barna ved de to måletidspunktene, var mer enn halvparten av barna (63%) på det samme høye nivået ved begge tidspunkt, mens 18% hadde høyere score ved syv år. Gjennomsnittlige score for DQI var 59% ved begge måletidspunktene, halve studiepopulasjonen (49%) hadde samme kostholdskvalitet ved begge tidspunkt og 26% hadde forbedret kostholdskvalitet ved syv års alder. Når det gjelder determinantene, viste det seg at høy kvalitet på kostholdet hos mor under graviditet, målt ved tilslutning til kostholdsanbefalinger, var en determinant for bedre

kostholdskvalitet hos barnet ved tre og syv år, uavhengig av hvilken metode som ble brukt. Høyt energi inntak (kcal) under graviditet og lengre skjermtid i barndommen var assosiert med en dårligere kvalitet på kostholdet både ved tre og syv år, også her uavhengig av metode. God kostholdskvalitet basert på DQI, var assosiert med lavere risiko for overvekt/fedme ved syv år.

**Konklusjon:** Litteraturstudien viste at de to indeksene DQI og fMDS var best egnet for bruk i kohortstudien. Kohort studien viste at norske barn har moderat til dårlig kostholdkvalitet, og at faktorer tidlig i livet og barndommen påvirker kvaliteten på kostholdet til norske barn. Kvaliteten på kostholdet så også ut til å være av betydning for barns vektutvikling.

# Abstract

**Background/objectives:** A healthy diet protects against malnutrition as well as other non-communicable diseases, and it is well known that dietary patterns track into adulthood. The increasing prevalence of overweight and obesity in children calls for immediate attention, and diet quality is of high importance. The many determinants of diet quality is well worth the attention, as this is a complex phenomenon, especially for this age group. This thesis consists of two different studies. First a literature review, followed by a scientific study. The literature review was performed to identify one or more dietary indices for use in the following scientific study. The aim of the study was to explore the diet quality in Norwegian children and the potential determinants thereof. Last, to explore the association between diet quality and weight status at seven years in the population.

**Subjects/method:** An extensive scientific literature review was performed to identify potential dietary indices for application in the following scientific study. The analysis in the study was based on a sample of children in the prospective population-based Norwegian Mother and Child Cohort Study (MoBa). Diet quality was assessed as i) adherence to a Mediterranean-like diet, estimated using a food frequency-based Mediterranean Diet Score (fMDS) and ii) by the diet quality index (DQI), reflecting compliance to food-based dietary guidelines for 34,074 three-year-old (pre-school age) and 18,350 seven-year-old children (school age). Determinants of diet quality were identified by a stepwise backward selection procedure (p-value<0.001). Overweight and obesity at seven years was determined by International criteria (International Obesity Task Force (IOTF)), and the relationship with diet quality was assessed by logistic regression models.

**Results:** From the literature review, two dietary indices were identified and considered appropriate for use in the following scientific study. These were the DQI (Diet quality Index) and the fMDS (food frequency-based Mediterranean Diet Score). We found that 36% and 34% of the children had high adherence to the Mediterranean diet (fMDS score range: 3-6) at pre-school and school age, respectively. When comparing the two age points, more than half of the children (63%) had the same adherence level at both time points, while 18% improved their adherence over time. The average DQI score was 59% at both age points, half of our study population (49%) retained the same dietary quality level, while 26% increased their DQI from three to seven years. Regarding the determinants, high maternal diet quality during

pregnancy, assessed by the compliance to national food-based recommendations, was a determinant of better child diet quality at three and seven years, regardless of the diet quality assessment method. In addition, high maternal energy intake during pregnancy and longer screen time in childhood were associated with lower diet quality at both ages, regardless of the diet quality assessment method. A good quality diet (high scores on the DQI) was associated with a lower risk of overweight/obesity at seven years.

**Conclusion:** The literature review showed that the DQI and the fMDS were the most coherent dietary indices for application in the cohort study. Results from the study show that children in Norway have a moderate to low quality diet. According to the preliminary analysis, modifiable early-life and childhood factors may affect the diet quality of Norwegian children. Diet quality also seem to have an effect on weight development in the population.

# Abbreviations and explanations

ACARFS – The Australian Child and Adolescent Recommended Food Score

ALES – Índice de Alimentação do Escolar (School Child Diet Index)

BPA – Bisphenol A

BQI – Breakfast Quality Score

BSDS – Baltic Sea Diet Score

β - Beta

C-DQI - Diet Quality Index for Children

CI – Confidence interval

DASH – The Dietary Approaches to Stop Hypertension

DGA – Dietary Guidelines for Americans

DGI-CA – Dietary Guideline Index for Children and Adolescents

DQI – Diet Quality Index

DQI-A – Diet Quality Index-Adolescents

DQI-AM – Diet Quality Index for Adolescents with Meal Index

DQI-I – Diet Quality Index-International

DQI-N – Diet Quality Index-National

EAT – The Raine Eating Assessment in Toddlers score

E-KINDEX - Electronic Kids Dietary Index

FCHEI – Finnish Children Healthy Eating Index

FGs – Food groups

FHI – Folkehelseinstituttet (Norwegian Institute of Public Health)

fMDS – Food frequency-based Mediterranean Diet Score

FVI – Fruit and Vegetable Index

HDHS-A – Healthy Dietary Habits Score for Adolescents

HDI – Healthy Diet Indicator

HEI – Healthy Eating Index

HEI-C – Modified HEI, based on Canadian food guide to healthy eating and nutrients (2005)

HEPI – The Healthy Eating Preference Index

HLD-index – The Healthy Lifestyle-Diet Index

HuSKY – The Healthy Nutrition Score for Kids and Youth

KIDMED - The Mediterranean Diet Quality Index for children and adolescents

LCD – Low Carb Diet score

MDI – Mediterranean Diet Index

MDS – The Mediterranean Diet Score

NCD – Non-communicable diseases

NQI – Nutritional Quality Index

NZDQI-A – New Zealand Diet Quality Index - Adolescents

OR – Odds ratio

RC-DQI – Revised Children-Diet Quality Index

SEADiet – The Southern European Atlantic Diet

SES – Socio Economic Status

TDS – Total Diet Score

The AHA healthy diet score – The American Heart Association healthy diet score

UEI – Unhealthy Eating Index

YHEI – Youth Healthy Eating Index

YHEI-TW – Youth Healthy Eating Index-Taiwan

# 1. Introduction

## 1.1 Structure of the thesis

This thesis is presented in two parts. First a synoptic chapter, followed by an article. Both parts are written in English due to one of the supervisors being of Greek descent and this making the process of supervising easier. Further, the synoptic chapter consists of two different studies. [1)] A scientific literature review to identify one or more dietary indices, for use in the following scientific study. This part includes mainly methods and results. [2)] A scientific study, including a short introduction and summary of methods and results. Finally I will discuss the findings from both the literature review and the scientific study undertaken, and present a conclusion of my work, answering the specific research questions. Both the synoptic chapter and the article are presented as independent products. The article is formatted and written with the aim of publication in the American Journal of Clinical Nutrition, and their author guidelines have been taken into account.

## 1.2 Diet quality in childhood

The important effects of diet on human health have been studied for several decades in several populations worldwide using different methodologies. Beneficial and negative effects of the consumption of single foods and nutrients on human health have been vastly reported (1). Consequently, the research interest was focused on specific parts of the diet, rather than the overall diet and its quality. The main argument for studying diet as a whole, is that people eat complex meals or combinations of foods, not nutrients or single foods. The combined foods we eat may interact and can complicate when investigating associations between single dietary factors and health outcomes (2). There are two main methodologies to assess overall diet, one using a-priori decided criteria and another by a-posteriori data-driven dietary patterns (1). In this thesis we focus on a-priori diet scores in children and adolescents.

A-priori indices evaluate the level of adherence to a specific dietary pattern or the level of adherence to specific dietary recommendations for populations based on current scientific knowledge on nutritional factors important to human health (1, 3). They are developed as tools to measure and quantify what is found to be difficult to measure qualitatively (4). Diet quality is a major determinant for the development of obesity, and has been defined as to what degree it reduces the risk of non-communicable diseases (NCD) (3). There are several a-priori diet indices made specifically for assessing diet quality in children and adolescents (4-6). The use of such indices in this age group is increasing (5), and they can be important tools in evaluating diet quality and its association with several health outcomes (4).

In developed countries there is an increase in overweight and obesity in the child and adolescent population (7). Apart from genetic predisposition to weight gain, increasing adherence to unhealthy diets (low diet quality) and decreasing physical activity in these age groups have a major negative impact on this trend. There is growing evidence that childhood obesity and dietary patterns can track into adulthood (8), and for this reason the diet quality of this generation is an important public health issue (9). A healthy diet fosters growth and development and protects against malnutrition and NCD's such as diabetes, heart disease, stroke and cancer (10). A healthy diet that is characterized by high quality in this age group might therefore help reduce the risk of weight related and other NCD's in the future.

### 1.3 Purpose and objectives

The main aim of this thesis was to study the diet quality of Norwegian children and factors that influence it. Also, the diet quality and its associations with weight status was explored. To achieve this, several sub-tasks were performed, and four specific research questions addressed:

1. Subtask 1: To perform a systematic and extensive review of scientific literature on diet indices among children

1.1 Research question: Which a-priori diet quality indices can be applied in the Norwegian Mother and Child Cohort Study to describe diet quality of Norwegian children at 3 and 7 years?

2. Subtask 2: Application of the a-priori diet indices identified in subtask 1 in data available for children participating in MoBa.

2.1 Research question: What is the diet quality in Norwegian children according to selected dietary quality indices identified in subtask 1?

3. Subtask 3: Explore associations between child characteristics and parental socio-demographic, lifestyle and pregnancy-related characteristics with the child diet quality in Norwegian families in MoBa.

3.1 Research question: How does child characteristics and parental socio-demographic, lifestyle and pregnancy-related characteristics impact dietary quality of the children in MoBa?

4. Subtask 4: Explore the prospective association between diet quality and weight status in children in MoBa.

4.1 Research question: Is child dietary quality associated with weight development in MoBa?

# 2. Literature review

## 2.1 Materials and methods

With the guidance of a librarian from the Norwegian Institute of Public Health a systematic literature search was done to identify studies using a-priori dietary indices used to evaluate diet quality in children (3-12 years) and adolescents (13-17 years). As suggested by the librarian, the search was done in two databases, MEDLINE and Embase. These databases were used as they would cover the field of the search best both in Scandinavia and of all continents.

The two different search terms used for the literature review are presented in the Appendix. The search results from both databases were imported to EndNote. In addition, a hand-search was done amongst relevant articles and systematic reviews to look for relevant studies not found by the automated searches in MEDLINE and Embase.

## 2.2 Quality assessment and data extraction

The inclusion criteria were publications of studies that:

- Used a-priori scores for the evaluation of diet quality, either as adherence to specific dietary guidelines or other distinct dietary patterns (e.g Mediterranean),
- Included participants aged 3-17 years,
- Included human populations, and
- The language of the publication was Norwegian, Swedish, Danish and English so that the author would be able to fully understand the text.

The detailed numbers of included and excluded articles at each step of the screening process are presented in a flow chart (Figure 1). The first elimination of articles was done by removing duplicates, both by using the duplicate search engine available in EndNote, but also going over all articles and checking publications. Second, titles and abstracts were screened for inclusion/exclusion criteria. To ensure all relevant articles were included and limit bias, the thesis supervisor Eleni Papadopoulou, looked over excluded articles from the search based on titles and/or abstracts before proceeding with full text reading. Third, full text screening was performed. The full text reading resulted in 158 included articles which were tabulated in an excel file and the following was recorded: 1st author, year of publication, country, age group, index, dietary assessment method, purpose of index, components of index, scoring, score range and evaluation against health outcomes.

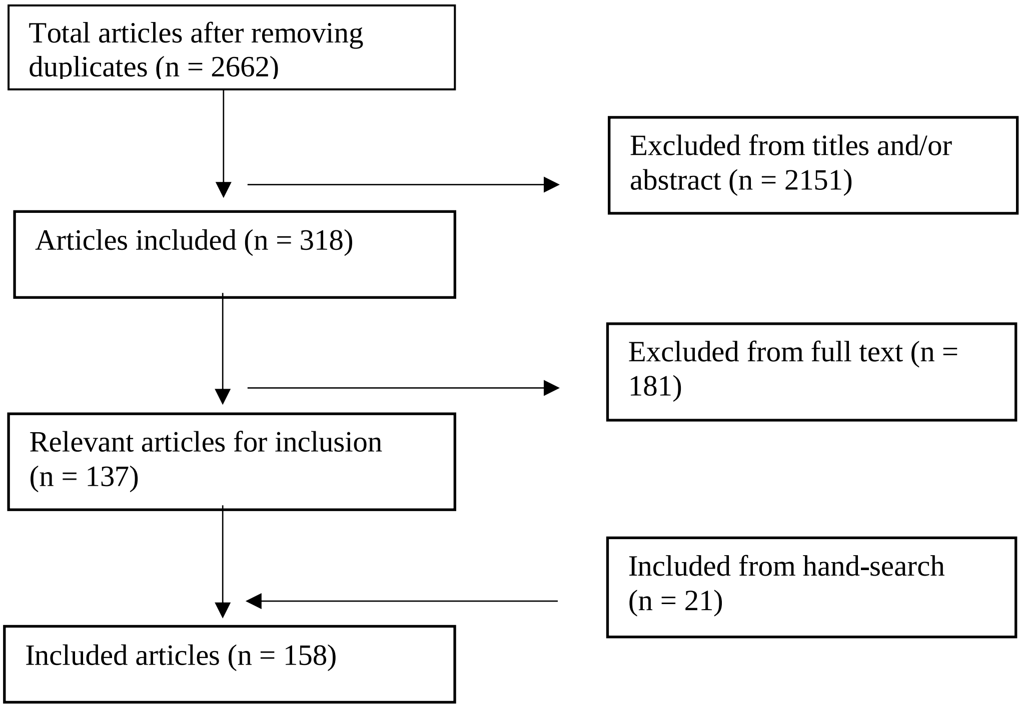


Figure 1. Flow chart of literature review search.

## 2.2 Results

### 2.2.1 A-priori dietary indices to assess diet quality in children and adolescents.

The literature review resulted into 158 relevant articles. I have further described the a-priori indices used in these articles by grouping them based on their content into: indices describing adherence to the Mediterranean diet and indices describing adherence to specific dietary recommendations and others.

Table 1. Overview of the included articles (n=158) by a-priori dietary indices

| **A-priori dietary indices** | **Number of articles** |
|---|---|
| Mediterranean Diet Quality Index for children and adolescents (KIDMED) | 58 |
| Mediterranean Diet Score in children and adolescents (MDS) | 12 |
| Other Mediterranean Diet Scores | 7 |
| Healthy Eating Index in children and adolescents (HEI) | 33 |
| Dietary Quality Index (DQI) for children and adolescents | 19 |
| Dietary Approaches to Stop Hypertension index (DASH) | 11 |
| Other indices | 28 |

The sum of the articles adds up to more than n=158, due to some papers describing more than one index.

### *Indices describing adherence to the Mediterranean diet*

The Mediterranean diet is considered a healthy dietary pattern (11) and several epidemiological and experimental studies have shown correlations between high adherence to the Mediterranean diet and better health, such as lower risk for developing CVDs, cancers and Alzheimer's disease (11). As early as the 1960's it was observed that the Mediterranean countries benefit from lower rates of chronic diseases and have a higher life expectancy than countries with other dietary patterns (12). Under this diet, the food groups recommended to be consumed in high frequency are vegetables and legumes, fruits and nuts, unrefined cereals and olive oil (13). In addition, a moderately high intake of fish, a low-to-moderate intake of dairy products and low intake of saturated fats, meat and poultry is recommended. For adults alcohol is considered beneficial in moderation (mostly wine).

For measuring the adherence to the Mediterranean diet among children and adolescents, several a-priori indices have been used in the literature (14). Their main similarity is that they are based on known foods which are characteristic for the Mediterranean diet. However, these indices vary in the number and type of components, scoring systems and by category classification systems. Out of the 158 studies, 82 included a-priori indices to assess adherence to MD. The KIDMED score is the mostly used a-priori index (n=58, 71%), followed by the Mediterranean Diet Score (MDS) and other modified versions of the MDS (n=24, 29%).

### *KIDMED – the Mediterranean Diet Quality Index for children and adolescents*

The KIDMED score was developed by Serra-Majem, L. et al (11) in 2004, and is based both on principles characteristic of the MD and on those which oppose it. It was developed to evaluate dietary habits among Spanish youth, considering sustainability and challenges regarding the traditional Mediterranean dietary pattern. The calculation of the diet score is based on 16 yes/no questions, ten questions for the consumption of specific food groups and six questions on dietary habits related to breakfast, fast food and sweets (11). The following questions have a positive connotation in relation to MD and are assigned a value of +1 if fulfilled: Takes a fruit or fruit juice every day, has a second fruit every day, has fresh or cooked vegetables regularly once a day, has fresh or cooked vegetables more than once a day, consumes fish regularly (at least 2-3 times per week), likes pulses and eats them more than once a week, consumes pasta or rice almost every day (5 or more times a week), has cereals or grains (bread etc) for breakfast, consumes nuts regularly, uses olive oil at home, has a dairy product for breakfast, takes two yoghurts and/or some cheese (40g) daily. The remaining questions have a negative connotation in relation to the MD are assigned a value of -1 if fulfilled: Goes more than once a week to a fast-food restaurant, skips breakfast, has commercially baked goods or pastries for breakfast, takes sweets and candy several times every day. The total score range is 0-12 (some later studies have modified the score so that it ranges from -4 - 12) (15-31). Usually the score is divided in three categories describing optimal adherence/high diet quality (KIDMED score>8), need of improvement (KIDMED score: 4-7) and poor adherence/low diet quality (KIDMED score ≤3) (11, 15-69).

Out of the total 58 studies used the KIDMED score, 3 used it for measuring population adherence only (28, 52, 56), 17 of the studies explored the association between child's adherence to the Mediterranean diet and weight status (15, 19, 23, 33, 38, 39, 42, 45, 51, 55, 57, 59, 60, 64, 65, 67, 69). Almost half of these studies reported a negative association between the KIDMED score and BMI and/or waist circumference (15, 19, 23, 39, 45, 51, 55, 59). Lazarou, C. et al (51) found adherence to the MD to be inversely associated with weight status and obesity, but reports other determinants to be of greater importance, such as child's physical activity, maternal obesity, and the dietary beliefs and behaviours. Other factors, such as living area, socioeconomic status and parental education appears to be important factors for high KIDMED scores (18, 22, 26, 29-31, 34, 37, 46, 53, 61, 69-71). In addition, the KIDMED score was used to investigate associations between child's diet quality and disease outcomes in eight studies, including asthma, non-alcoholic steatohepatitis, bone health, blood pressure and albuminuria (20, 35, 36, 41, 48, 58, 72). Other associations studied with the KIDMED score included quality of life, academic performance, sleep, nutritional knowledge and interventions related to healthy diet knowledge (18, 21, 27, 43, 45, 60, 62, 64, 66, 73).

### *The Mediterranean Diet Score (MDS)*

The MDS was developed and later revised and modified by Trichopoulou, A. et al (74, 75) and was intended for use in adults. The score consisted of 8 components, namely vegetables, legumes, fruits and nuts, dairy products, cereals, meat and meat products, ethanol and monosaturated:saturated fat ratio (it was also revised in 2002 by Hu, F. B. et al (76) to include fish). A value of 0 or 1 was assigned to each component by the use of sex-specific median intakes as the cut-off value. For components with a positive connotation to the MD a score of 0 would be assigned if the intake was below the median value, and a score of 1 if the intake was at or above the median. For components with a negative connotation to the MD, a score of 1 would be assigned if consumption was below the median value and a score of 0 if at or above the median. The score ranges from 0 (minimal adherence) to 9 (maximal adherence).

In all 12 studies using the MDS in children and adolescents, alcohol was left out or considered detrimental and given a score of 0 (77-88). With a total of eleven studies using the MDS, either in its original form or as slightly modified versions, the index is used as a measurement of diet quality in three studies (80, 81, 89), and as a measurements of adherence to MD in eight (77-79, 82, 84-87). In three studies, the association between the MDS and weight status or obesity is explored (81, 83, 87). Other uses include comparison of the MDS with incidence of asthma, inflammatory markers, cardiometabolic risk factors and reading skills as outcome measures (77-80, 82, 88).

### *Other Mediterranean diet scores*

In seven studies other Mediterranean diet scores were used. In 4 of them a modified version of an MDS index developed for use in the EPIC study (90) was used (91-94). This MDS index was based on 9 components, foods considered beneficial included vegetables, legumes, fruits, cereals and fish, and detrimental, meat, meat products, dairy products, and a final component which was the ratio of monosaturated to saturated lipids. These studies explored association between adherence to MD and asthma (94, 95) and rhinoconjunctivitis (92) and wheezing (91).

Last, Rivas et al (96) investigated the association between child's exposure to Bisphenol A (BPA), a ubiquitous environmental contaminant, and several diet indices. Among these were a Mediterranean diet score, developed by Martinez-Gonzales et al (97), initially developed to explore BMI and MD adherence in adults. The FFQ consisted of 13 questions with the wine consumption component from the original index being left out from the survey due to the intended age group.

### *Healthy Eating Index (HEI) and Dietary Quality Index (DQI)*

Other commonly used a-priori indices to assess diet quality are the Healthy Eating Index (HEI) and the Dietary Quality Index (DQI). Their main similarity is that they are made to describe the combined adherence to national and international dietary recommendations for a healthy diet. The first HEI score was developed in 1995 by Kennedy, T. E. et al (98) based on the dietary guidelines for the American population and was constructed to measure overall diet quality that would incorporate nutrient needs and dietary guidelines into one measure. The index had 10 components. In 2005 the HEI was revised by Guenther, P. M. et al (99) to complement the new Dietary guidelines for Americans. The revised HEI-2005 had 12 components: Total fruit, whole fruit, total vegetables, dark green and orange vegetables and legumes, total grains, milk, meat and beans, oils, saturated fats, sodium and excess calories (from solid fats, alcoholic beverages and added sugars). In 2012, the HEI score was revised, again to be up to date with the new Dietary guidelines for Americans (100). The changes from the HEI-2005 version included: green and beans were replaced with dark greens, orange vegetables and legumes; seafood and plant proteins were added as components; a ratio of poly- and monounsaturated to saturated fatty acids replaces saturated fatty acids and oils; and refined grains replaced total grains. The latest version of the HEI score is the HEI-2015. The main change is that the empty calorie component from the 2005 and 2010 versions is divided into added sugars and saturated fats.

Thirty-three studies from our literature search had used different HEI scores to measure diet quality and adherence to dietary guidelines in children and adolescents. Twenty-five studies used either HEI-2005 or HEI-2012 (2005, 2010), with minor modifications. Three of these studies used the indices to measure adherence to guidelines and diet quality in their respective populations (101-103). Other studies investigated adherence to the guidelines and outcome measures including BMI, physical activity, body composition, metabolic syndrome and other weight-related conditions(104-108), dietary knowledge interventions (109, 110), socioeconomic status (111, 112), intake of certain foods, snacking and feeding practises (110, 113-117). In addition, the HEIs were used in four studies exploring the association between adherence to the guidelines with autism, and also CRP levels in pre-pubertal girls (118-120).

A-priori indices of diet quality that describe adherence to country specific dietary recommendations for children and adolescents include the YHEI (Youth Healthy Eating Index) for the American population(105, 121), the YHEI-TW (Youth Healthy Eating Index-Taiwan) for the Taiwanese population(122), HEI-C (Modified HEI based on Canadian food guide to healthy eating and nutrients) for the Canadian population(123), AHEI (Alternative Healthy Eating Index) that is based on food choices that were associated with chronic diseases and premature mortality (124) and FCHEI (Finnish Children Healthy Eating Index) for the Finish population(79, 80) .

Several DQIs (n=19) have been made to assess the diet quality in the children and adolescent population. Huybrechts et al (125) created a score for use in pre-school children based on the Flemish dietary guidelines, which also has been used in two other studies identified in the literature search (126, 127). The major components of this DQI was dietary diversity, dietary quality (categorized into three groups: preference group, moderation group and low-nutritious, energy-dense group, with points of 1, 0 and -1 allotted respectively), dietary equilibrium and dietary meal patterns. Total DQI = (dietary diversity score + dietary quality score + dietary equilibrium score + meal index)/4, expresses the compliance of the child with the Flemish dietary guidelines (higher compliance gives higher DQI score). Another DQI was developed by Voortman et al (128) in 2015 and was based on Dutch and international dietary guidelines for young Dutch children. This DQI consisted of 10 components: Vegetables, fruits, bread and cereals, rice, pasta, potatoes and legumes, dairy, meat and eggs, fish, oils and fats, candy and snacks, and sugar-sweetened beverages. Cut-offs were calculated from the recommendations in the guidelines.

The DQI-A developed by Vyncke et al in 2013 (129) was an adapted version of the DQI by Huybrechts et al (125) for adolescents. This version of the DQI consisted of three main components, namely quality, diversity and equilibrium, leaving out the meal pattern component. In their study, Vyncke et al investigated the validation of the DQI-A by comparison with biomarkers, nutrient and food intakes. The 3 other studies using the DQI-A were investigating risk factors for insulin resistance, cardiorespiratory fitness and diet, and stress and diet quality respectively (126, 130, 131).

A study by Bel, S. et al (132) investigating self-reported sleep duration and diet quality in adolescents, used the DQI-AM (the Diet Quality Index for Adolescents with Meal Index), which is based on both previously described DQI's, developed for use in adolescents and includes a forth component, the meal index which reflects the frequency of consumption of meals.

The C-DQI (Diet Quality Index for Children) developed by Kranz et al (133) was used to investigate changes in diet quality of American pre-schoolers from 1977 to 1998. The index consisted of 8 components: Added sugar, total fat, saturated fat, grains, fruits and vegetables, dairy products, excessive juice, and iron.

Further, a revised version of this score, the RC-DQI (the Revised Children-Diet Quality Index) was used as an index in three studies. Developed by Kranz et al in 2006 (134) to assess overall diet quality in a nationally representative sample of American pre-schoolers (2-5 years). It was based on the new intake recommendations at the time, regarding nutrients and foods both to be consumed in moderation and adequately, to reduce the risk of deficiencies and obesity in this age group. The index consisted of 13 components, namely added sugar, total fat, linoleic acid, linolenic acid, DHA (docosahexaenoic acid) + EP (eicosapentaenoic acid), grains, whole grains, fruits, vegetables, excess fruit juice, dairy, iron, and the relation between total energy intake and sedentary behaviour (television time). Another study by Kranz et al (135) used the same index to investigate the diet quality in relation to sociodemographic predictors and body weight status. The last study using this index was a study by Cheng, G. et al (136) from 2010 which explored the correlation between diet quality and the timing of puberty onset and body composition at puberty onset.

All studies using the DQI-I (Diet Quality Index - International) (137-139) are based on the DQI-I developed by Kim et al (140). The major categories of the index are dietary variety, dietary adequacy, dietary moderation and overall balance. The variety category has 2 components, the overall food group variety, and within-group variety for protein source. Within the adequacy category, there are 9 components: Vegetables, fruits, grains, fiber, protein, iron, calcium and vitamin C respectively. The moderation category consists of 5 components which are: total fat, saturated fat, cholesterol, sodium and empty calorie foods. The overall balance category calculates macronutrient ratio and fatty acid ration. One of the studies from the literature search (138) used a version of the DQI-I modified by Tur et al(141) to better assess the Andalusia diet (a Mediterranean Spanish region).

Wong, J. E. et al (142) developed the NZDQI-A (Diet Quality Index for NZ Adolescents) reflecting the New Zealand Food and Nutrition Guidelines for Healthy Adolescents. It was developed to better suit the examination of the diet quality for this age group in New Zealand as such a tool was missing. The index was based on adequacy and variety of five major foods groups: Fruit, vegetables, cereals, dairy and meat.

#### *Other diet quality indices*

The DASH (the Dietary Approaches to Stop Hypertension) index has been used in several studies to investigate the associations with several health outcomes, amongst BMI, diabetes, blood pressure and other cardiometabolic risk factors in the child and adolescent population (79, 143-150). In addition, a study done by Haapala et al (2015) (151) explored diet quality and cognition in children using the DASH index. The index consists of 8 components or DASH food groups: Grains, vegetables, fruits, dairy, meat, nuts/seeds/legumes, fats/oils, and sweets (147).

The literature search also identified several other a-priori indices rarely used, and some were only created for use in a specific study. Some of the discovered indices are made for country-specific studies, such as the ACARFS (The Australian Child and Adolescent Food Score)(152), the Chinese Children Dietary Index(153), EAT (The Raine Eating Assessment in Toddlers score)(154), the Australian Recommended food score (155) and the DGAI (Dietary Guidelines for American Adherence Index)(156). Other were for a specific area like the SEADiet (the Southern European Atlantic Diet) (157) and the BSDS (Baltic Sea Diet Score) (80, 151). Others include the ALES (School child diet index)(158), the DGI-CA (Dietary Guidelines Index for Children and Adolescents)(159-161), the HDI (Healthy Diet Indicator)(81), the E-KINDEX(162, 163), the TDS (Total Diet Score)(164), the NQI (Nutritional Quality Index)(136), the LCD (Low Carb Diet score)(165), the HuSKY(166, 167), the HLD-index (the Healthy Lifestyle-Diet Index)(168, 169), The AHA healthy diet score(170), the BQI (Breakfast Quality score)(96), the FVI (Fruit and Vegetables Index)(88), the HEPI (Healthy Eating Preference Index)(171), the UEI (Unhealthy Eating Index)(110) and the HDHS-A (Healthy Dietary Habits Score for Adolescents)(172).

### 2.2.2 Differences by continent and country

A priori indices are mostly used in research for children and adolescents from countries on the European continent. From this literature search we identified 97 studies in European populations, divided between 11 countries. The countries with most studies were Greece and Spain with a total of 33 and 27 studies respectively, followed by Italy and Finland with 12 and

4 studies. Other countries were Belgium, Sweden, the Netherlands, Norway, Portugal and the UK with 1, 2 or 3 studies. In Europe KIDMED, fMDS, MDS, HEI, BQI, DQI, DQI-I, HuSKY, BSDS, FCHEI, DASH, NQI, RC-DQI, DQI-AM, DQI-A, HDI, E-KINDEX, HLD-index and the SEADiet were used, with KIDMED and the MDS being the most frequently applied a-priori indices.

It is also interesting to report a-priori indices that was used to assess dietary quality in multi-country studies. We identified 9 multi-country studies in Europe, using indices based on the DQI, MDS and KIDMED.

In North America, 33 studies have used a priori indices. Twenty-nine studies in the USA, 3 in Canada and 1 in Mexico. The different scores used on this continent were: HEI, C-DQI,RC-DQI, The AHA healthy diet score, DASH, FVI, MDI, HEPI, TDS, YHEI, AHEI, KIDMED, DQI-I, UEI and the HEI-C. In the USA which contributes with most studies, the most frequent index found is the HEI, followed by DASH and different versions of the DQI.

Australia and Oceania had 12 studies, with 9 studies from Australia and 3 from New Zealand. The indices used were DGI-CA, DQI, EAT, The New Zealand Diet Quality Index for Adolescents, ACARFS, The Australian recommended food score, NZDQI-A and HDHS-A.

In Asian populations we identified 11 studies, where 4 is from Iran, 2 from Turkey and 1 from each of China, Israel and Taiwan. Scores used were DASH, HEI, YHEI-TW, LCD, The Chinese Children Dietary Index, KIDMED and DGAI.

The continents with the least studies were South America and Africa with 3 and 1 studies respectively. The 3 studies in South America were from Brazil, Colombia and Peru, whilst the 1 study from Africa was from Tunisia. The indices used in these countries were ALES, KIDMED and MDS in South America and the DQI-N in Tunisia, Africa.

### 2.2.3 The dietary quality indices most suitable for application in Norway

Based on this literature review it was found that simple indices which focus on food groups rather than single nutrients are generally easier to apply, and can be a useful tool for implementation in epidemiological studies. The two indices chosen for the current study are the fMDS by Tognon et al (87) and the DQI by Huybrechts et al (125). The reason for this decision is foremost that both are applicable with regards to available data in MoBa. Second, one is based on dietary guidelines for the age group under study and the other is based on the

Mediterranean dietary pattern, which is known to prevent overweight and other NCDs (11, 15). A more expanded discussion for this choice will follow in the Discussion section (4: Discussion).

# 3. Dietary quality in Norwegian children

### *The Norwegian Mother and Child Cohort Study (MoBa)*

MoBa is a prospective population-based cohort study conducted by the Norwegian Institute of Public Health with the main aim to increase the knowledge base on environmental exposures and disease, thereby help prevent disease and early morbidity in the future(173, 174). The participants were recruited from 1999-2008 and the recruitment included 50 out of Norway's 52 hospitals with maternity units. Together with appointments for ultrasound scanning in week 17–18 of pregnancy, the pregnant women receive a postal invitation that included an informed consent form, the first questionnaire, an information brochure as well as consent form and questionnaire for the father. Forty-one percent of the invited women agreed to participate and gave their consent upon recruitment. The number of recruited participants in the cohort are 114,622 children, 95,369 mothers and 75,618 fathers. In addition, biological material (blood, urine) were collected from the mother and the father was collected during the ultrasound scan visit in the hospital. After birth, cord blood was collected and a second blood sample from the mother.

During pregnancy, the mother responded to three questionnaires and the father to one. After birth, questionnaires were sent out when the child was 6 months, 18 months, 3 years, 5 years, 7 years and 8 years old. Currently, the questionnaire for the 13 year olds are send out. The questionnaires during pregnancy include general background information, and details on previous and present health problems and exposures. Detailed dietary information was obtained through a semi-quantitative food frequency questionnaire (FFQ) send around the 22$^{nd}$ week of pregnancy. Extensive information on the development of the child and the health of both the mother and child, and lifestyle exposures are obtained via questionnaires after birth (6 months, 18 months and 3 years). The questionnaires at ages 5 and 8 years mainly collected information on child's learning, language and neurocognitive development and at age 7 years focused on somatic diseases, mainly on allergies and asthma. Anthropometric data on child weight and development were included in all questionnaires sent out after delivery.

## 3.1 Materials and methods

### 3.1.1 Study design and study population

Our study is a prospective mother-child study that draws resources from the MoBa study. Out of the total MoBa population, 87,720 mother-child pairs were of singleton, live born pregnancies without congenital malformations and chromosomal anomalies and with available information via questionnaire 1 (at recruitment) and questionnaire 2 (at gestational week 22). Of these, 34,074 (39%) mother-child pairs were included for the assessment of dietary quality at 3 years and 18,350 (21%) mother-child pairs for the assessment of dietary quality at 7 years, with available information on child's diet at the two time points and other important characteristics collected in postnatal questionnaires. The current analysis is based on version 9 of the quality-assured data files released for research in 2015.

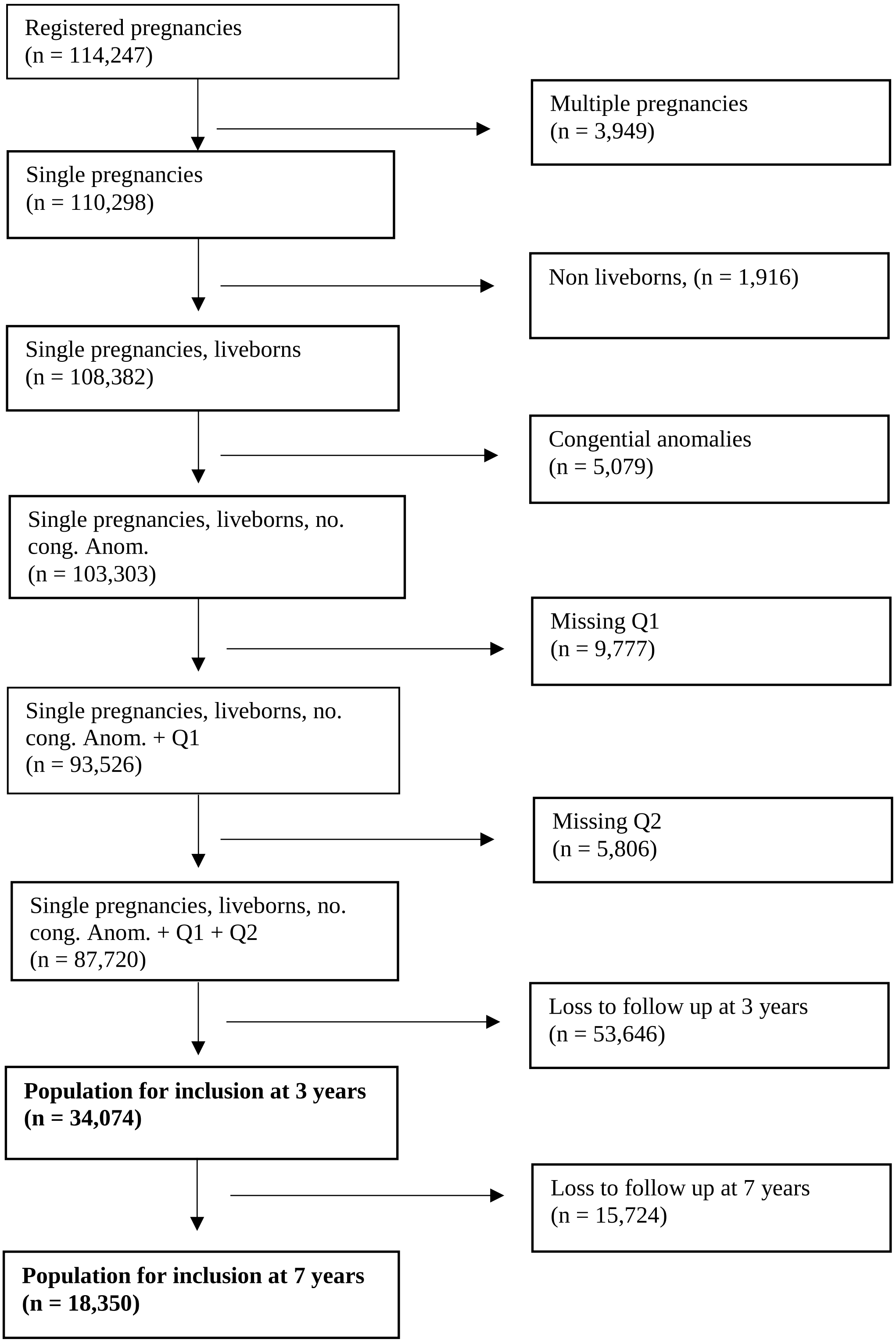


Figure 2. Flow chart of selection of the study population

### 3.1.2 Ethics

The current study is part of the Catch-up project, a research project financed by the Research Council of Norway (NFR, project number 268465) and owned by the Norwegian Institute of Public Health. The overall aim of the Catch-up project is to examine the impact of pre- and postnatal exposure to mixtures of chemicals on catch-up growth, obesity and cardiometabolic health in children.

Informed consent from the MoBa participants was obtained upon recruitment. The establishment and data collection in MoBa was licensed by the Norwegian Data Inspectorate (01/4325) and approved by the Regional Committee for Medical Research Ethics (S-97045, S-95113). The Catch-up study was approved by the Regional Committee for Medical Research Ethics in South-Eastern Norway in 2017 (2017/1299).

### 3.1.3 Assessment of diet quality in Norwegian children

The dietary intake was assessed with the mothers filling in a semi-quantitative food frequency questionnaire (FFQ) in the diet section of the MoBa questionnaires at 6 months, 18 months, 3 years and 7 years. The two questionnaires used to calculate the index scores, were Q6 (at 3 years) which contained 36 food items grouped into categories to fit both indices, and Q8 (at 7 years) covering 50 food items which were grouped into categories in the same way. The information on frequency and serving sizes were converted into grams per day, for more specific details, see table 1 and 2 in article. No vitamin or mineral calculations were included in the study, as the information on these were not accurate enough or not included in the indices to be used to check the diet quality in the population. To be able to check the diet quality in the population, two different indices were used, namely the fMDS and the DQI.

The fMDS (food frequency Mediterranean Diet Score) was developed by Tognon et al (87) and is based on the traditional Mediterranean Diet. The index consisting of 6 food groups has a total score range of 0-6, were >3 is considered a high adherence to the MD. The DQI (Diet Quality Index) used is a modified version of the index developed by Huybrechts et al (125), and is the summary of three major components: Dietary diversity, dietary quality and dietary equilibrium. The index consists of 9 food groups at 3 years and 10 food groups at 7 years. The total score range was -25-100%. The score was further divided into tertiles as lower, medium and upper dietary quality score ranges. For more detailed descriptions of the scores, see article.

### 3.1.4 Potential determinants of diet quality in Norwegian children

We included several characteristics as determinants of the diet quality in children that can be grouped into parental and pregnancy-related and children characteristics. The following variables were included as parental and pregnancy-related characteristics: maternal (continuous) and paternal (30-39, <30, ≥40) age and education (≤12 years, 13-16 years, ≥ 17 years), marital status (living with/not living with partner), maternal pre-pregnancy BMI (continuous) and paternal BMI (normal: 18.5 – 25 kg/m, overweight: 25-30 kg/m, obese >30 kg/m, underweight <18.5 kg/m), gestational weight gain (as recommended, less than recommended, more than recommended), parity (nulliparous/multiparous), mode of delivery (vaginal/caesarean), gestational diabetes (yes/no), gestational hypertension (yes/no), preeclampsia (yes/no), active (no smoking, occasional smoker, daily smoker) and passive (yes/no) smoking during pregnancy, alcohol consumption during pregnancy (yes/no), folic acid supplements use before (yes/no) and during (yes/no) pregnancy, total maternal energy intake during pregnancy (continuous), fiber intake (continuous) and maternal healthy diet (continuous) during pregnancy. Regarding the children characteristics, we explored the following: birth weight (continuous), gestational age (continuous), gender (boys/girls), total breastfeeding duration (>12 months, 9-12 months, 5-8 months, never/0-4 months), timing of introduction of solid foods (<6 months/≥6 months), timing of kindergarten attendance (not going, started before 16 months, started at 16-18 months), dietary supplements use before 3 years (yes/no), sleep duration before 3 years (as recommended/less than recommended), food allergy before (yes/no) and at 3 years (yes/no), screen time (TV) at 3 years (<1 hour or none, 1-2 hours, ≥3 hours), time spent outdoors at 3 years (1-3 hours, >3 hours, seldom/<1 hour). In addition, when exploring potential determinants of diet quality at 7 years, we also explored: sleep duration at 7 years (as recommended, less than recommended, more than recommended), food allergy at 7 years (yes/no), screen time (TV) (≤1 hour/day, >1 hour/day) and leisure physical activity at 7 years (0-2 hours/day, 3-4 hours/day, 5-7 hours/day, ≥8 hours/day).

### 3.1.5 Weight status of Norwegian children at 7 years

Overweight and obesity at 7 years amongst the children in the cohort was determined by the International (International Obesity Task Force; IOTF) Body Mass Index (BMI) Cut-offs from 2012 (175). These are gender and age specific cut-offs. Boys and girls at 7 years with BMI>20.59 kg/m$^2$ and BMI>20.39 kg/m$^2$ respectively, as well as boys and girls of 7.5 years old with BMI>21.06 kg/m$^2$ and BMI>20.89 kg/m$^2$ were defined as overweight (including obese).

### 3.1.6 Statistical analysis

For the statistical analysis Stata SE version 15 was used. First we explored the distribution of each of the diet quality scores at 3 and 7 years (fMDS and DQI), as well as the distributions of the variables explored as potential determinants of diet quality using descriptive statistics. For continuous variables mean and SD were recorded, and for categorical variables percentage was recorded. Further, for the categorical fMDS, t-tests and Chi-square tests were used to test differences between categories of potential determinants of diet quality. For the continuous DQI scores, t-tests and one-way ANOVA test were used to test differences between categories, while Pearson's correlation coefficient was used to examine linearity between continuous variables that were potential determinants of diet quality. In addition, the Shapiro-Wilk test was done as a normality test for all continuous variables, which were all normally distributed, including the DQI scores and the potential determinants of diet quality. The level of significance for all tests was $\alpha$=0.05.

Stepwise backward elimination was performed on the full multivariable model to retain the strongest determinants for the different diet quality scores (with p-value <0.001 as cut-off). Multivariable logistic regression models and linear regression models were fitted for the categorical fMDS and continuous DQI at 3 and 7 years, respectively. The reference group of each categorical variable was chosen based on either being the norm or being the mostly reported category for the respective variable. The number of groups ranged from 2-4 depending on the distribution within that variable. Odds Ratios (ORs) for logistic regression and beta regression coefficients ($\beta$s) for linear regression were recorded alongside with their 95% confidence intervals (95% CI) for each group in respect to the reference group for each variable.

To check for associations between child's diet quality at 3 years and overweight at 7 years, logistic regression models were used. The DQI scores were categorized in tertiles, as low, medium or high adherence. Three different models were defined and adjusted for the following; Model 1: child BMI at 3 years, child gender and maternal education. Model 2: Adding time spent outdoors, sleep and TV time. Model 3: Adding maternal HEI scores and pre-pregnancy BMI.

## 3.2 Results

### 3.2.1 Diet quality in Norwegian children and its determinants

When using the fMDS score at 3 years to assess diet quality we found that 21,925 (64%) children had a low adherence to the MD, whilst 12.150 (36%) had a high adherence. At 7 years 66% had a low adherence and 34% a high adherence, again based on the fMDS. The change between the two ages showed that 47% of the children had persistently low adherence to MD, whilst only 16% remained in the high adherence group at the follow up. Of the children who changed their diet quality from 3 to 7 years, 18% showed a better adherence and 19% showed worse adherence to the MD respectively.

When using the DQI to assess dietary quality, the mean total score was 59.2% (SD 12.2) and 59% (SD 9.9) for the 3 and 7-year olds respectively (Figure 3). Of the three main components of the score, the dietary diversity was higher at 3 than at 7 years with a mean of 73.7% (SD 13.3) vs. 62.4% (SD 16.4), while dietary quality was higher at 7 years with a mean score of 56.6% (SD 43.4) vs 47.9% (SD 20.6) at 3 years. Dietary equilibrium was similar for both ages (3 years: mean (SD)= 58,5% (8,5) and 7 years: mean (SD)= 58.4% (9.8)).

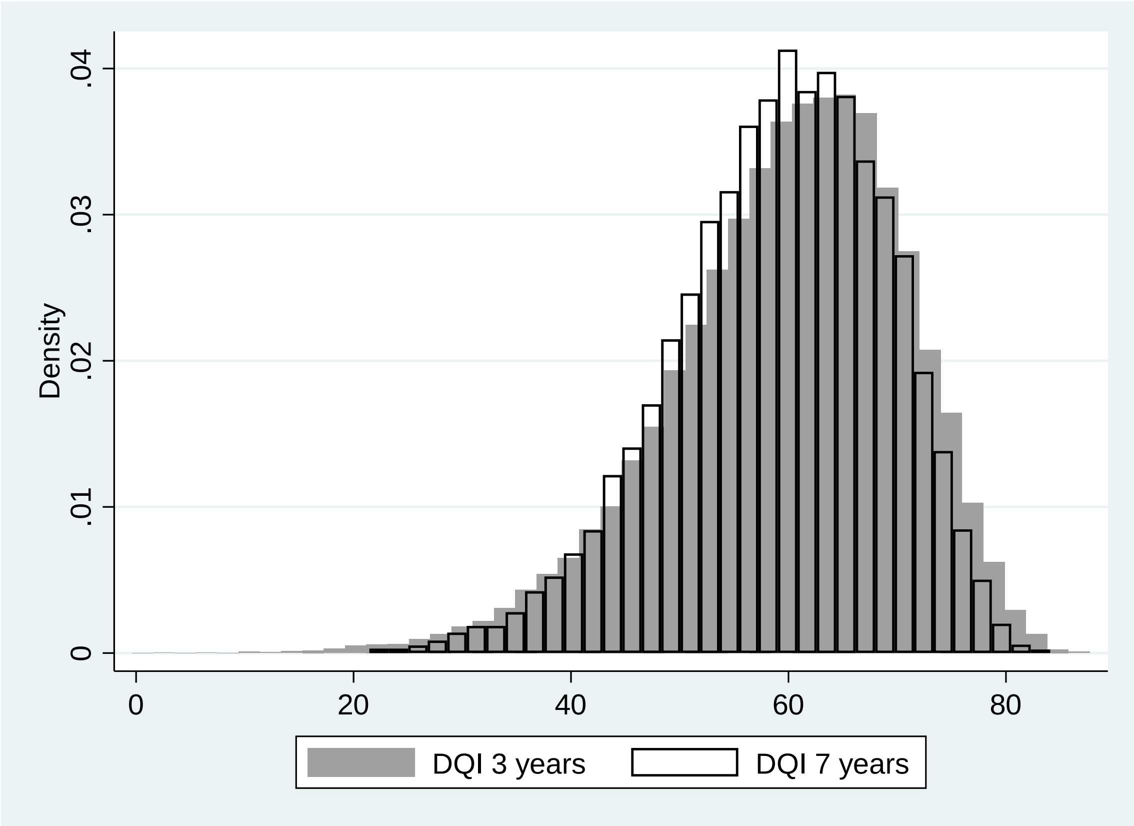

Figure 3. Distribution of the DQI score at 3 and 7 years.

From the various determinants explored with bivariate models several showed to be statistically significant to the child's fMDS and DQI scores. Mothers who were highly educated were more likely to have children with both high fMDS and DQI scores at 3 ($p<0.001$) and 7 years ($p=0.002$). Children with mothers not living with a partner were more likely to have a high fMDS score ($p<0.001$) at both 3 and 7 years, but this was not found with the DQI scores. Mothers smoking daily during pregnancy were less likely to have children with a good diet quality, with low fMDS score at 3 years ($p<0.001$), and low DQI scores at both 3 ($p<0.001$) and 7 years ($p<0.001$). Mothers with higher HEI scores and fiber intake were more likely to have children with both high fMDS and DQI scores at both ages ($p<0.001$). Children with underweight fathers (BMI<18.5kg/m) were more likely to have high fMDS scores at 3 years ($p<0.001$) and 7 years ($p=0.028$), whereas obese fathers (>30kg/m) were more likely to have children with lower fMDS ($p<0.001$ and $P=0.028$, at 3 and 7 years respectively) and DQI scores at both ages ($p<0.001$). Regarding postpartum and children characteristics, low breastfeeding duration (0-4 months) was related with a low diet quality at both ages for both scores ($p<0.001$). Starting daycare before 16 months was associated with a higher quality diet in both fMDS and DQI at 3 years. Having food allergy at 3 years was associated with higher fMDS score at both 3 and 7 years ($p<0.001$), but it had adverse impact on the DQI scores at 3 years ($p<0.001$). Watching TV for ≥3 hours daily and spending ≤1 hour outdoors per day had a negative effect on both the fMDS and DQI scores at both ages ($p<0.001$).

*Determinants of high diet quality at 3 and 7 years*

From stepwise backward selection we observed that high adherence to the MD (high fMDS score) at 3 years was positively associated with maternal fiber intake (OR 1.01; 95%CI 1.00, 1.01), maternal HEI score (OR 1.03; 95%CI 1.03, 1.04) and having food allergy at 3 years (OR 1.69; 95%CI 1.54, 1.85). At 7 years, high adherence to the MD (high fMDS scores) was associated with increased maternal fiber intake (OR 1.01; 95%CI 1.01, 1.02), high maternal HEI scores (OR 1.03; 95%CI 1.03, 1.04), spending more than 3 hours outdoors (at 3 years) (OR 1.16; 95%CI 1.08, 1.24), sleeping less than recommended (OR 1.72; 95%CI 1.35, 2.20) and having food allergy at 7 years (OR 1.24; 95%CI 1.11, 1.38).

For the DQI, a higher number of associations were discovered. Higher DQI score at 3 years was associated with high maternal fiber intake (β 0.10; 95%CI 0.08, 0.12) and high maternal diet quality (HEI score) (β 0.27; 95%CI 0.25, 0.29), average or high maternal education (average: β 1.18; 95%CI 0.87, 1.50 and high: β 1.33; 95%CI 0.95, 1.70) and paternal education (average: β 0.70; 95%CI 0.41, 0.98 and high: β 1.26; 95%CI 0.93, 1.59), female gender (β 1.21; 95%CI 0.89, 1.35), later introduction of solid foods (>=6 months: β 0.77; 95%CI 0.47, 1.07), later kindergarten attendance (> 16-18 months: β 1.30; 95%CI 1.06, 1.53) and longer time outdoors (> 3 hours: β 0.46; 95%CI 0.22, 0.71). At 7 years, higher DQI score was associated with maternal fiber intake (β 0.09; 95%CI 0.07, 0.11), maternal HEI score (β 0.25; 95%CI 0.22, 0.27), average or high paternal education (average: β 0.68; 95%CI 0.33, 1.03 and high: β 1.42, 95%CI 1.04, 1.80), female gender (β 1.25, 95%CI 0.96, 1.55), late introduction of solid foods (≥6 months) (β 1.08; 95%CI 0.69, 1.47), spending more time outdoors at 3 years (β 0.63; 95%CI 0.32, 0.94) and being physically active for 5-7 hours/daily (β 0.89; 95%CI 0.57, 1.21) or for ≥8 hours/daily (β 1.71; 95%CI 1.26, 2.15) at 7 years.

*Determinants of low diet quality at 3 and 7 years*

From stepwise backward selection we observed that lower odds for high adherence to the MD (low fMDS score) at 3 years were associated with maternal age (OR 0.98; 95%CI 0.98, 0.99), maternal total daily energy intake (OR 0.84; 95%CI 0.81, 0.87) and TV watching at 3 years for 1-2 hours (OR 0.88; 95%CI 0.84, 0.93) or for more than 3 hours daily (OR 0.72; 95%CI 0.61, 0.84). At 7 years, lower odds for high adherence to the MD (low fMDS scores) were associated with increased maternal total daily energy intake (OR 0.88; 95%CI 0.83, 0.93), having siblings (OR 0.88; 95%CI 0.88, 0.94) and watching TV for more than 1 hour daily at 7 years, compared to less screen time (OR 0.88; 95%CI 0.75, 0.85).

At 3 years lower DQI score was associated with maternal total daily energy intake (β -1.46; 95%CI -1.65, -1.27), having siblings (β -2.05; 95%CI -2.28, -1.09), maternal second hand smoking during pregnancy (β -0.96; 95%CI -1.38, -0.54), mothers non-users of folic acid supplements before pregnancy (β -0.68; 95%CI -0.92, -0.44) and during early pregnancy (β -1.16; 95%CI -1.47, -0.85) and breastfeeding less than 12 months (9-12 months: β -0.39; 95%CI -0.67, -0.11, 5-8 months: β -1.01; 95%CI -1.30, -0.73 and never/0-4 months: β -1.73; 95%CI -2.12, -1.34). Regarding the child-related characteristics, lower DQI at 3 years was associated with not receiving dietary supplements up to age of 3 (β -1.59; 95%CI -2.08, -1.09), sleeping less than recommended (β -2.14; 95%CI -2.73, -1.55), having food allergy (β -2.56; 95%CI -3.02, -1.55), long screen time (1-2 hours/day: β -2.25; 95%CI -2.49, -2.01 and more than 3 hours/day:β -4.96; 95%CI -5.68, -4.23) and seldom being outdoors (β -3.60; 95%CI -4.26, -2.93). At 7 years, lower DQI scores were associated with increased maternal age (β -0.09; -0.12, -0.05), maternal total daily energy intake (β -1.16; 95%CI -1.40, -0.92), having siblings (β -1.65; 95%CI -1.97, -1.33), maternal second hand smoking during pregnancy (β -0.96, 95%CI -1.51, -0.40), mother non-users of folic acid supplements during early pregnancy (β -1.11; 95%CI -1.49, -0.73), breastfeeding less than 12 months (9-12 months: β -0.86; 95%CI -1.22, -0.50, 5-8 months: β -1.13; 95%CI -1.53, -0.73, never/0-4 months: β -1.17; 95%CI -1.71, -0.64), longer screen time at 3 years (1-2 hours: β -0.92; 95%CI -1.23, -0.60 and 3 or more hours/day: β -2.58; 95%CI -3.54, -1.63) and 7 years (>1hour/day: β -2.19; 95%CI -2.50, -1.88) and seldom being outside at 3 years (β -1.67; 95%CI -2.51, -0.83).

### 3.2.2 Diet quality in Norwegian children and weight status

At 7 – 7.5 years, 12% (4,153) of the children in the cohort were considered overweight or obese by the Extended International (IOTF) Body Mass Index Cut-Offs from 2012. Having high adherence to the MD at 3 years was associated with a lower odds ratio of overweight/ obesity at 7 years when adjusted for child BMI at 3 years, maternal education and child gender (Model 1: OR 0.97; 95%CI 0.87, 1.08), while the association was not significant.

Similar results were observed when further adjusting for physical activity, screen time and sleeping duration at 3 years (Model 2: OR 0.99; 95%CI 0.88, 1.10) and for maternal dietary quality during pregnancy and pre-pregnancy BMI (Model 3: OR 0.98; 95%CI 0.88, 1.10).

Having total DQI score at the middle and upper tertile at 3 years was associated with lower risk for overweight, compared to children with total DQI in the lower tertile, while the associations of the upper vs. lower tertile were more consistent and also significant (model 1: (middle tertile: OR 0.95; CI 0.84, 1.08 and upper tertile: OR 0.81; CI 0.71, 0.92) model 2 (middle tertile: OR 0.99; CI 0.87, 1.13 and upper tertile: OR 0.85; CI 0.74, 0.97) and model 3 (middle tertile: OR 1.02; CI 0.84, 1.16 and upper tertile: OR 0.87; CI 0.75, 0.99)). More specifically, children with the highest diet quality (upper tertile for DQI) at 3 years had 19%, 15% and 13% lower risk for being overweight at 7 years, after adjustment for different confounders.

Further, from running regression analysis on the three main categories of the DQI at 3 years, namely diversity, quality and equilibrium, only dietary quality score was statistically significantly associated with reduced risk of overweight at 7 years (with model 1 (middle tertile: OR 0.82; CI 0.73, 0.93 and upper tertile: OR 0.78; CI 0.68 , 0.89), model 2 (middle tertile: OR 0.85; CI 0.75 , 0.97 and upper tertile: OR 0.81; CI 0.71 , 0.93) and model 3 (middle tertile: OR 0.87; CI 0.76 , 0.99 and upper tertile: OR 0.82; CI 0.71 , 0.93)). The dietary quality score in the middle and upper tertile both being significantly associated with a decreased risk for overweight.

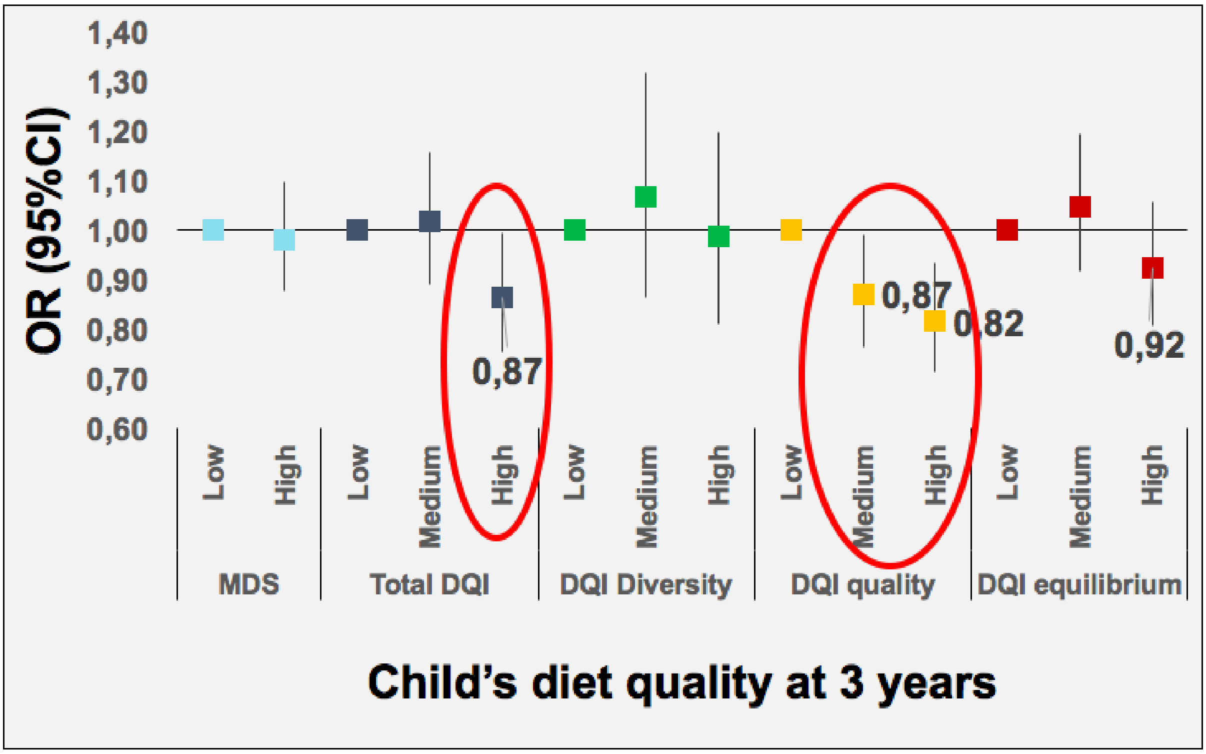


Figure 4: Risk for overweight at 7 years

# 4. Discussion

In this master thesis I have conducted a literature review to identify studies using a-priori indices applied to assess the quality of the overall diet in children and adolescents. I have identified 158 studies, and have summarized them. Following this review, I identified a-priori diet quality indices that could be applied in the Norwegian Mother and Child cohort study to describe diet quality of Norwegian children at 3 and 7 years. Further, I applied the identified indices and described the quality of the overall diet in the MoBa children, including the main parental, sociodemographic and lifestyle determinants of child diet quality. Finally, I have explored the association between diet quality and the risk for overweight in Norwegian children, in a prospective study.

To my knowledge, there is limited research on overall diet quality in Norwegian children. However, current national dietary surveys conclude that, although there is room for improvement, most children follow the dietary recommendations (176, 177). According to the survey results, 4 year olds have an inadequate intake of fruits and vegetables, and an excessive intake of saturated fats in relation to national guidelines. For the 9 and 13 year olds, the same deviations were found. In addition, they had an excessive consumption of sugars and a lack of fish consumption. They also found that for all age groups the intake of vitamin D and iron was too low. Today, approximately 15-20% of Norwegian children and as much as 25% of adolescents are found to be overweight or obese (178), according to the Norwegian Public Health Institute.

### *How to assess the quality of the overall diet in children?*

Choosing the indices to be applied to the MoBa children population was done based on several factors. In general, the development of an index or choosing an appropriate index for a study can be challenging for several reasons. The information needed to use an index and to calculate an index score varies depending on the components included, the level of details needed for calculations, cut-off values and that the methodology should be easy to use, such that it is applicable for other study populations. Indices which include specific healthy and unhealthy foods, might give a good indication of the status of the diet quality of the population. On the other hand, indices that include detailed nutritional information, such as intakes of specific nutrients, can be more burdensome to apply.

From the literature review, we found that the most widely used index was the KIDMED index, which was used in a total of 58 studies. This was followed by different versions of the HEI score, with a total of 33 studies, and the DQI with a total of 19 studies. The KIDMED index is one of the simplest indices to calculate, containing only food items, although some of its components are mostly used in the Mediterranean areas, and might not be the most obvious choice of components to include in questionnaires in non-Mediterranean countries or on other continents. The calculation of the KIDMED score was, as previously mentioned, based on 16- yes/no- questions and was related to amounts of foods which were simple to answer. It differs from the other most commonly used indices in that it was based on a known healthy dietary pattern, and not on national or international dietary guidelines. The HEI scores are based on different versions of the American dietary guidelines, and have more precise cut-off values and therefore more detailed information is needed to calculate a HEI score. It also required the calculation of the fatty acids ratio and total energy from sugars and fats, hence including both food items and nutrients. The DQI included four major components: dietary diversity, dietary quality, dietary equilibrium and dietary meal patterns, and contained both food items and nutrients, while in some versions of the DQI nutrients were not required. The main difference of the DQI and the HEI compared to the KIDMED and other MD scores is that the first two include all the food groups consumed and some nutrients, while the MD type scores are focused in specific food groups and nutrients related to the MD diet.

Based on this literature review I found that simple indices which focus on food groups rather than single nutrients are generally easier to apply. The MoBa questionnaires did not originally include the questions of the KIDMED index and are missing several key elements, and it was therefore not applicable in our study. However, it was preferable to apply an index or multiple indices which were based on food groups, as this could be a useful tool to implement in further epidemiological studies within MoBa. The variety component was also of interest due to the possibility of having to combine several foods in each component. This allows for checking the variety within each food group, and might be an additional indicator of the diet quality of the child and adolescent population in Norway.

Based on the criteria and information available from MoBa, the choice of indices for application in the study was the fMDS and the DQI. They both include applicable components and information of a healthy quality diet which was also attainable from the MoBa questionnaires. This choice gave us the opportunity to measure diet quality based on both a pre-defined known healthy dietary pattern, and a pre-defined score based on dietary guidelines. The DQI score also includes a diversity component which was found to be of interest.

*Exploring the diet quality of Norwegian children-is it associated with overweight?*

When evaluating diet quality of children in our study with both the fMDS and the DQI scores, the results showed moderate to low diet quality. The majority of children had low adherence to the MD at both 3 and 7 years, and the mean DQI score was 59.2% and 59% at 3 and 7 years, respectively (total score range -25-100%). The findings with both scores is lower than what is found in other European countries (87, 125), and is of concern. In the development of an increasingly overweight and obese child and adolescent population, diet quality as a determinant is of high importance (33), although the literature is divided as to whether diet quality alone can be a determinant in this developing trend. Regardless, better diet quality seems to be an important mean in battling this public health issue, as a relatively inexpensive and promising tool (33).

In the present study, we found that a high DQI score was inversely associated with children's weight status at 7 years and a lower risk for overweight. We explored two different diet quality scores in this study. Regardless of the used score, having high diet quality was related with lower risk for overweight in this prospective study. Nevertheless, we found statistically significant results only for the upper tertile of the total DQI and for the diet quality component that is a part of the total DQI.  These results were coherent with that of Jennings et al (179), who found weight status to be inversely associated with high DQI and HDI (the Healthy Diet Indicator) scores, but not with MDS scores when exploring weight status and diet quality amongst 9-10 year old British children. Previous studies have shown similar results, with significant associations between lower weight status and higher DQI scores (135, 139). For the association between weight status and adherence to the MD, the results are more conflicting, some indicating no or weak inverse associations between high scores and BMI (19, 22), and others suggesting MD adherence to be protective against overweight and obesity (55, 87) and also other precursors for adiposity, such as waist circumference (67). The DQI is a healthy diet score based on several dietary guidelines, including all the available nutritional information and reflecting more aspects of the contributors of the diet to the quality of it. On the other hand, the MDS is a more "crude" score that does not extensively account for the different healthy and unhealthy contributors to diet quality within each food group. The MDS might therefore be too general to evaluate the true association between overweight and obesity for this population. These differences in the construction of the two diet quality scores might explain the differences we have observed in association with overweight.

The phenomenon of overweight and obesity for the child and adolescent population is complex. Although diet quality is a major determinant, other factors seems to play important singular and synergetic roles in this epidemic. Children with a better quality diet also seem to adopt other health promoting behaviours, such as having a higher physical activity level and spend more time outdoors. This correlation has also been found in previous studies, supporting the findings (19, 46, 104). An explanation might be that parents who promote a healthier diet, also promote a healthier lifestyle in general. As with other habits, being physically active is likely to track into adulthood (180) and might also be an important factor in battling overweight and obesity.

Parents whom themselves exhibit a healthier lifestyle are more likely to have offspring with the same patterns (30). From the current study, it is observed that mothers with a good quality diet are more likely to have children with high diet quality scores, regardless of the used score and the child's age. Some suggested mechanisms of the parent-child diet quality association, are shared meals and food environments, as well as parental modelling (117). Sotos-Prieto et al (30) found a statistically significant association between parental diet and the child's diet, meaning that the same dietary habits were observed especially for the consumption of healthy foods such as vegetables, fruits, fish and olive oil ($p<0.001$). Both energy intake and other metrics of diet quality are also found to be related (117). However, other studies has shown that the influence from parental diet on the child's diet will decrease with age, especially during adolescence (164), and some believe the parent-child dietary resemblance to be weak (113). During adolescence, their increased autonomy (181) and pubertal changes, as well as changes in energy and nutrient needs may play a role in their diverting food choices and behaviours (182). Bargiota et al (183) also found that body image for this age group can have a strong influence on food choices. From the growing evidence on adolescents and diet, an explanation for the association in the current study might be the age at which the diet quality is measured. Younger children seem to have a diet quality more closely linked to that of its parents. Seeing as diet quality is found to track into adulthood, one might argue that the diet of the adolescent age group is only a phase, and that the parental influence in early childhood serves as a foundation for food choices later in life.

Higher parental education, another important determinant for children's diet quality, and a proxy of high socioeconomic status (SES), was found to be associated with increased diet quality in this study. At 3 years both maternal and paternal higher education were positively associated with diet quality, and at 7 years paternal higher education was found to be statistically significant. Higher education, and hence more likely a better SES, is one of the most important determinants of good general health and also a better diet quality (184). Several studies in the literature support the correlation between having at least one parent with higher education and a good diet quality (33, 158, 184) and low maternal level of education has been linked to a decreased probability of the child having a good quality diet (158). Reasons for this associations might include lack of preferred foods, inadequate information or poorer ability to decide what is healthy and make healthy choices for their family.

The association of sleep and diet quality was inconsistent in this study, with shorter sleep duration up to 3 years being associated with a lower DQI score at 3 years, but shorter sleep duration at 7 years was associated with a high fMDS score at 7 years. The previous literature linking short sleep duration with poorer diet quality and increased risk of obesity, is supportive of the results from the DQI scores in this study (45, 64, 132). The positive association between lack of sleep at 7 years and high fMDS score is inconsistent with that from previous literature, where lack of sleep is associated with a lower quality diet. Nevertheless, the association with sleep and DQI is a prospective association, as sleep was assessed before 3 years and diet was assessed at 3 years. On the other hand, the association between sleep and fMDS is cross-sectional at 7 years. The interplay between increased body weight and its major risk factors, such as diet, sleep and physical activity is very difficult to assess in cross-sectional study designs. A potential explanation would be that a high fMDS represents high food intake, as it is not adjusted for energy intake, that might be related to increase risk of overweight, and overweight children tend to have worse sleeping habits, compared to normal weight children (45).

Our results indicate that children with food allergies at 3 years had worse DQI and better fMDS scores at 3 years. At 7 years, it was found again that having food allergies (at 7 years) was also associated with a better fMDS score, indicating a better diet quality. The research on diet quality and allergy in children seems to be scarce. Having a diet with higher levels of fruits, vegetables and home-prepared foods was found to be associated with less food allergy (185), and that having a food allergy might have a negative impact on the quality and quantity of food choices (186). This is in agreement with our results between food allergy and worse

DQI score. A reason for children in the current study scoring high on diet quality (with the fMDS), might be due to the need to be stricter about the diet to avoid allergens and therefore having to prepare meals from fresh groceries. As a paradox, Vassilopoulou et al (186) believe that having food allergy could be a disadvantage due to the possible lack of nutritional education on how to eliminate allergens from the diet and not having the tools to find alternative nutrient sources. This might well depend on the study population, as children from more educated and privileged homes will have more resources to meet their needs. However, the food allergy at 3 years was reported by the mother and was not confirmed by an immune-assay test. This might have been a factor causing an overestimation of children with allergies, were the elimination of foods has been less critical.

## 4.1 Strengths and limitations

### *Strengths*

The large study population and the possibility to investigate a large set of potential determinants are major strengths of the current study. Although women participating in MoBa are not fully representative of all pregnant women, participants were recruited from urban and rural regions in all parts of Norway and represent different age and socioeconomic groups. Furthermore, the prospective cohort as study design made it possible to investigating diet quality and the development of overweight and obesity over time, demonstrating possible causality (187). The use of two different dietary indices might also be considered a strength as the two indices had comparable determinants, while only the more complex index, the DQI was sufficiently nuanced to remain significantly associated with overweight at 7 years.

### *Selection bias*

A general limitation of MoBa is the low participation rate (41%). The people who normally tends to join and stay the course of a study, are those with higher education and better health (187). An unusual finding, was that the majority of fathers included in this study had a low level of education, detected from the descriptive statistics. A possible explanation for the low level of education amongst fathers in this study, might be that the fathers in this group are unemployed or work less than those who are more educated, thereby having time to accompany the mothers in the clinics and being available for participation. As a limitation of prospective cohort studies, the loss to follow up in our study is evident. For this study the participation rate was 39% and 21% of mother-child pairs at 3 and 7 years, respectively.

Participants whose parents exhibit socially stigmatized behaviors, might have been less likely to follow up (187), causing potential biased/faulty estimation of our results. Most likely, this would bias the estimates towards the null.

### *Information bias / misclassification*

All dietary data is self-reported. Similar to self-reported dietary intake, parental-reported intake of their children is based on memory and recall, and is prone to misreporting leading to under- and overestimation of foods intakes (187). Also, food frequency questionnaires are crude estimates, and might not be suited for precise estimation (188). The weight and length/height at 7 years was reported by the mother, and might be not be precise or accurate, contributing to further misclassification with regards to weight status in the population.

### *Confounding*

The large study population might be both a strength and a limitation of the study. As a strength, the detailed information on a large number of participant characteristics allowed us to check for a large set of variables. Socioeconomic status is closely related to a healthy lifestyle and the variables that reflect socioeconomic status the most are education, household income, smoking and parental BMI. However, the study is observational and residual or unmeasured cofounding cannot be excluded.

# 5. Conclusion

***Research question 1: Which a-priori diet quality indices can be applied in the Norwegian Mother and Child Cohort Study to describe diet quality of Norwegian children at 3 and 7 years?***

Conclusion: Based on desired criteria for index application, the fMDS by Tognon et al (87) and the DQI by Huybrechts et al (125) were chosen for this study. This was based on several factors including applicability in further planned research within the Catch-up project, the inclusion of desired food groups which was attainable from MoBa, previous use in the same age groups, the inclusion of a diversity component and the fact that the two different indices were based on dietary recommendations and the known Mediterranean diet, respectively.

***Research question 2: What is the diet quality in Norwegian children according to selected dietary quality indices identified in subtask 1?***

Conclusion: When using the fMDS score at 3 years to assess diet quality we found that 64% children had a low adherence to the MD, whilst 36% had a high adherence. At 7 years 66% had a low adherence and 34% a high adherence.

When using the DQI to assess dietary quality, the mean (SD) total score was 59.2 (SD 12.2) and 59 (SD 9.9) for the 3 and 7-year olds respectively. Of the three main components of the score, the dietary diversity was higher at 3 than at 7 years with a mean of 73.7 (SD 13.3) vs. 62.4 (SD 16.4), while dietary quality was higher at 7 years with a mean score of 56.6 (SD 43.4) and a mean of 47.9 (SD 20,6) at 3 years. Dietary diversity was similar for both ages (3 years: mean (SD)= 58,5 ( 8,5)and 7 years: mean (SD)= 58.4 (9.8).

The results show that Norwegian children had moderate to low quality diet.

***Research question 3: How does child characteristics and parental socio-demographic, lifestyle and pregnancy-related characteristics impact dietary quality of the children in MoBa?***

Conclusion: Of parental characteristics, high maternal diet quality was a significant determinant for better diet quality in children, regardless of the diet quality assessment method. At 3 years both maternal and paternal higher education level was positively associated with increased diet quality, with paternal education being statistically significant for high diet quality at 7 years.

Regarding the child characteristics, spending more time outdoors was positively associated with a better quality diet, whereas longer screen time was associated with low diet quality with both scores.

***Research question 4: Is child dietary quality associated with weight development in MoBa?***

Conclusion: Having a high adherence to the MD at 3 years was associated with lower odds of overweight/obesity at 7 years, when adjusting for confounders, but the results did not reach statistical significance. When exploring the association using the DQI, being in the middle or upper tertile, was associated with reduced risk for overweight, with the upper tertile also being significant (compared to children with total DQI in the lower tertile). From regression analysis of the three different components of the DQI (diversity, quality and equilibrium), only the quality component score was statistically significantly associated with a reduced risk for overweight 7 years, both in the middle and upper tertile.

### *Final conclusion*

The results indicate that Norwegian children have an overall low quality diet, especially when compared to our European counterparts. This and the findings regarding weight development and diet quality, makes this a concern for future generations. The majority of significant determinants of diet quality found in this study, such as level of education, time spent outdoors, routines of sleep and time spent in front of the TV, are all modifiable risk factors. Higher educational level and children having good role models in terms of other detected lifestyle factors might be protective.

## 6. Suggestions for further research

The global burden of disease project has shown that diet quality is a major determinant of health and longevity. This has inspired further nutrition research. A recent study argue that despite criticism and controversy, nutrition science can be relied on to improve our understanding of food and health (189). The authors write: "With each scientific shift—from a focus on single nutrient deficiencies to overall diets and chronic disease, from simple approaches to more rigorous methods, and from a few individual studies to diverse research designs with complementary findings—has come greater understanding."

The results of this thesis adds to the existing knowledge that determinants of child weight development originate early in life. At the same time, the existing knowledge also point to limited success related to lasting weight loss in children who are overweight. Therefore, an important area for future research is to identify cost-effective strategies to help parents achieve healthy pregnancies and healthy infant and toddler environments.

The extensive data in MoBa makes it possible to follow the children into the future and to study how dietary quality in childhood not only influence weight development in childhood, but also in later life. Prospective cohorts like MoBa is limited by the observational design. However, randomized controlled trials with food quality as the intervention is virtually impossible to perform.

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# Appendix

Search terms for literature review:
In MEDLINE: Child/, Adolescents/, ("child" [MeSH terms] or "adolescents" [MeSH terms]). (child* or adolescent*).tw.kw.. (("child" [MeSH terms] or "adolescents" [MeSH terms]) or ((child* or adolescent*).tw.kw.)). Diet* index*.tw.kw., Diet* score*.tw.kw., Diet*pattern*.tw.kw., Diet* indices.tw.kw., KIDMED.tw.kw. ("Diet*index*.tw.kw" or "Diet*score*.tw.kw" or "Diet*pattern*. Tw.kw." or "Diet*indices.tw.kw." or "KIDMED.mp" ). (("child" [MeSH terms] or "adolescents" [MeSH terms]) or ((child* or adolescent*).tw.kw.)) and ("Diet*index*.tw.kw" or "Diet*score*.tw.kw" or "Diet*pattern*. Tw.kw." or "Diet*indices.tw.kw." or "KIDMED.tw.kw")). Animals/[MeSH terms], Humans/[MeSH terms]. ((Animals/[MeSH terms]) not (Animals/[MeSH terms]) and (Humans/[MeSH terms])). (("child" [MeSH terms] or "adolescents" [MeSH terms]) or ((child* or adolescent*).tw.kw.)) and ("Diet*index*.tw.kw" or "Diet*score*.tw.kw" or "Diet*pattern*. Tw.kw." or "Diet*indices.tw.kw." or "KIDMED.tw.kw") not ((Animals/[MeSH terms]) not (Animals/[MeSH terms]) and (Humans/[MeSH terms])). limit last search to (danish or english or norwegian or swedish).

In Embase: Child/, Children/, Adolescents/, ("child" [MeSH terms] or "children/[MeSH terms]) or "adolescents" [MeSH terms]). (child* or adolescent*).tw.kw.. (("child" [MeSH terms] or "children" [MeSH terms] or "adolescents" [MeSH terms]) or ((child* or adolescent*).tw.kw.)). Diet* index*.tw.kw., Diet* score*.tw.kw., Diet*pattern*.tw.kw., Diet* indices.tw.kw., KIDMED.tw.kw. ("Diet*index*.tw.kw" or "Diet*score*.tw.kw" or "Diet*pattern*. Tw.kw." or "Diet*indices.tw.kw." or "KIDMED.mp" ). (("child" [MeSH terms] or"children" [MeSH terms] or "adolescents" [MeSH terms]) or ((child* or adolescent*).tw.kw.)) and ("Diet*index*.tw.kw" or "Diet*score*.tw.kw" or "Diet*pattern*. Tw.kw." or "Diet*indices.tw.kw." or "KIDMED.tw.kw")). Animals/[MeSH terms], Humans/[MeSH terms]. ((Animals/[MeSH terms]) not (Animals/[MeSH terms]) and (Humans/ [MeSH terms])). (("child" [MeSH terms] or "children" [MeSH terms] or "adolescents" [MeSH terms]) or ((child* or adolescent*).tw.kw.)) and ("Diet*index*.tw.kw" or "Diet*score*.tw.kw" or "Diet*pattern*. Tw.kw." or "Diet*indices.tw.kw." or "KIDMED.tw.kw") not ((Animals/[MeSH terms]) not (Animals/[MeSH terms]) and (Humans/[MeSH terms])). limit last search to (danish or english or norwegian or swedish).

# Healthy diet in Norwegian children: determinants and associations with body weight. Results from The Norwegian Mother and Child Cohort Study (MoBa).

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Abstract

**Background/objectives:** A healthy diet protects against malnutrition as well as other non-communicable diseases, and it is well known that dietary patterns track into adulthood. The increasing prevalence of overweight and obesity in children calls for immediate attention, and diet quality is of high importance. The many determinants of diet quality is well worth the attention, as this is a complex phenomenon, especially for this age group. The aim of this study was to explore the diet quality in Norwegian children and the potential determinants thereof. Further we explored the association of the diet quality and weight status in the population. **Subjects/method:** The present analysis was based on a sample of children from the prospective population-based Norwegian Mother and Child Cohort Study (MoBa). Diet quality was assessed as i) adherence to a Mediterranean-like diet, estimated using a food frequency-based Mediterranean Diet Score (fMDS) and ii) by the diet quality index (DQI), reflecting compliance to food-based dietary guidelines for 34,074 three-year-old (pre-school age) and 18,350 seven-year-old children (school age). Determinants of diet quality were explored by a stepwise backward selection procedure (p-value<0.001). Overweight and obesity at 7 years amongst the children in the cohort was determined by the International Obesity Task Force (IOTF) Body Mass Index (BMI) cut-offs  and the relationship with diet quality was assessed by logistic regression models. **Results:** We found that 36% and 34% of the children had high adherence to the Mediterranean diet (fMDS score range: 3-6) at pre-school and school age, respectively. When comparing the two age points, more than half of the children (63%) had the same adherence level, while 18% improved their adherence. The average DQI score was 59% at both age points, and half of our study population (49%) retained the same dietary quality level and 26% increased their DQI from 3 to 7 years. Regarding the determinants, high maternal diet quality during pregnancy was a determinant of better child diet quality at 3 and 7 years, regardless of the diet quality assessment method. In addition, high maternal energy intake during pregnancy and longer screen time in childhood were associated with lower diet quality at both ages, regardless of the diet quality assessment method. Dietary quality at 3 years was associated with a lower risk for overweight at 7 years. **Conclusion:** Children in Norway seem to have a moderate to low quality diet. According to this preliminary analysis, modifiable early-life and childhood factors may affect diet quality of Norwegian children. Diet quality also seem to have an effect on weight development in the population.

Keywords: MoBa, Diet quality, diet, nutrition, children, overweight, obesity.

## Introduction

In developed countries there is an increase in overweight and obesity in the child and adolescent population (1). Apart from genetic predisposition to weight gain, increasing adherence to unhealthy diets (low diet quality) and decreasing physical activity in these age groups have a major negative impact on this trend. There is growing evidence that childhood obesity and dietary patterns can track into adulthood (2), and for this reason the diet quality of this generation is an important public health issue (3). A healthy diet fosters growth and development and protects against malnutrition and NCD's such as diabetes, heart disease, stroke and cancer (4). These medical conditions causes a decrease in peoples' quality of life, in addition to being a serious financial and social burden (5).

The determinants of diet quality is complex, and for children even more so, as they are not completely in control of their own diet (6, 7). Personal, social, economic and emotional factors are all contributors to the food choices making up the quality of the diet. Children's eating patterns have shown to be heavily influenced by their physical as well as their social environment (8). Socio-economic status (SES) and sociocultural factors can be decisive when it comes to the type of foods children consume. Mealtime structure has also shown to be important when it comes to eating behavior for this age group. Maternal level of education, presence of father in the household and having lunch at the table is found to be associated with children's diet quality (9).

As a determinant in the development of an increasingly overweight and obese child population, diet quality in itself is of high importance (10). The relationship between diet and obesity has been established with regards to energy imbalance, but what part of the diet is most influential on weight status is not completely understood (11). The use of dietary indices might contribute to the understanding of this missing link, creating possibilities for assessing the quality of and the different components of the diet as a whole. Several a-priori dietary indices are developed for use in adults, and some are developed or modified for use in the child and adolescent population. Amongst these are the Diet Quality Index (DQI) (12) which was developed to reflect the adherence to the Flemish dietary guidelines amongst pre-school children and has been shown to be positively associated with a decreased risk of CVD (cardiovascular disease) risk in adolescents, as well as being predictive of potential determinants of diet quality in a group of European pre-schoolers and their parents/caregivers (the HELENA study) (13, 14). Another dietary index, the frequency-based Mediterranean

Diet Score (fMDS), was developed to assess the adherence to a Mediterranean dietary pattern in European children aged 2-9 years (the IDEFICS study) (15). The Mediterranean diet is considered a healthy dietary pattern and several epidemiological and experimental studies have shown associations between high adherence to the Mediterranean diet and better health, such as lower risk for developing CVDs, cancers and Alzheimer's disease in adults (7). Both indices include food items or food groups which are considered beneficial and/or detrimental to health, but focus on slightly different elements and their contribution to the quality of the diet.

There is limited research on diet quality in Norwegian children. However, current national dietary surveys conclude that although there is room for improvement, most children follow the dietary recommendations (16, 17). Today, approximately 15-20% of Norwegian children are overweight or obese according to reports from the Norwegian Institute of Public Health (18). Health promotion in young children is important, as both the diet quality and physical activity levels are found to decline when reaching adolescence (19, 20). Preventive strategies are dependent on complex pathways, and it is important to understand the complexity of the modifiable risk factors of this epidemic in early life (5). The aim of this study was to evaluate the diet quality of Norwegian Children in MoBa using the two previously mentioned indices, and identify potential determinants for their diet quality. Further, we assessed the prospective association between children's diet quality and weight status, with the hypothesis that children with a better diet quality will gain less weight over time.

## Methods

### *Study population*

The present analysis was based on a sample of women and children in the Norwegian Mother and Child (MoBa) Cohort Study, a prospective population-based pregnancy cohort study conducted by the Norwegian Institute of Public Health and designed to study various exposures and health outcomes (21). From 1999 to 2008, pregnant women across Norway were recruited into MoBa through postal invitation prior to their first prenatal visit, around 17–18 weeks of gestation. The women consented to participation in 41% of pregnancies. The cohort now includes 114,500 children, 95,200 mothers and 75,200 fathers. Informed consent was obtained upon recruitment. The current analysis is based on version 9 of the quality-assured data files released for research in 2015 with linkage to the Medical Birth Registry of Norway (MBRN). The data collection in MoBa was licensed by the Norwegian Data

Inspectorate and approval from The Regional Committee for Medical Research Ethics. The current study was approved by The Regional Committee for Medical Research Ethics (2017/1299).

To be eligible for inclusion in the current study, women had to have answered two questionnaires during pregnancy and be registered in MBRN. The first questionnaire (answered in gestational week 15) collected information on health, socio-demographic factors and lifestyles, and background factors. The second questionnaire (answered in gestational week 22) was a validated semi-quantitative food frequency questionnaire (FFQ) used in MoBa from March 2002 and designed to assess maternal diet during the first half of pregnancy (22, 23).

Out of the total MoBa population, 87,720 mother-child pairs were of singleton, live born pregnancies without congenital malformations and chromosomal anomalies and with available information from the two pregnancy questionnaires. Of these, 34,074 (39%) mother-child pairs were included for the assessment of dietary quality at 3 years and 18,350 (21%) mother-child pairs for the assessment of dietary quality at 7 years, with available information on child's diet at the two time points and other important characteristics collected in postnatal questionnaires. A flow chart demonstrating the selection process for inclusion, is presented in figure 1.

*Dietary assessment and diet quality in childhood*

The dietary intake was assessed with the mothers filling in semi-quantitative food frequency questionnaires (FFQs) in the diet section of the MoBa questionnaires. The two questionnaires used to calculate the child diet index scores were Q6 (at 3 years), which contained 36 food items grouped into categories to fit both indices, and Q8 (at 7 years) covering 50 food items which were grouped into categories in the same way. We evaluated diet quality in children using two different indices, namely the fMDS and the DQI. For calculating DQI scores, the information on consumption frequency was converted into grams per day using portion sizes standardized by the World Health Organization and the Norwegian Directory of Health. The portion sizes used for calculations are presented in Table 1 and 2.

*Dietary indices*

An *fMDS* (food frequency-based Mediterranean Diet Score) developed by Tognon et al (15) was used to assess the adherence to a Mediterranean like diet at 3 and 7 years. The score was calculated by using the frequency of consumption from the following 6 food groups: Vegetables, fruits and nuts, cereals, fish, dairy products and meat products. The daily frequencies were divided by the total daily frequency of all food items included in the questionnaire, to obtain relative frequencies of each food group. The latter values were categorized according to sex-specific medians to identify high and low intakes. Intakes higher than the median relative frequency were given a point of 1 in group 1 – 4 (vegetables, fruits and nuts, cereals and fish) and given a point of 1 if below the median relative frequency in groups 5 and 6 (dairy and meat products). The final score had a maximum of 6 points (score range 0-6), and a high adherence to the Mediterranean like diet was characterized by an fMDS score >3.

A modified version of the *DQI* (Diet Quality Index) developed by Huybrechts et al (12) was used to assess the adherence to dietary recommendations, and is the summary of three major components: Dietary diversity, dietary quality and dietary equilibrium.

Calculation for DQI: Diversity score + quality score + equilibrium score/3 = total DQI score (possible range:-25-100%).

To get a full score in the dietary *diversity* component, one would need to consume at least one serving of food per day from each of the recommended food groups (FGs).

Calculation for dietary diversity: Number of different FGs achieved with regards to recommendations/total number of FGs x 100% = dietary diversity score (possible range 0-100%).

For the dietary *quality* component, items within each FG were categorized into preference, moderation and low nutrient, energy dense groups. Scoring 1 point if intake of a food item from the preference group, 0 if intake of a food item from the moderation group and -1 if intake of food item from the low nutrient, energy dense food group.

Calculation for dietary quality: (Factor food item x food quantity food item)/Total quantity all FGs = Dietary quality score (possible range: -100-100%).

The *equilibrium* component is verifying if there is a balance in the intake of the different food items where an adequate and moderate intake of the recommendations are reassured. In order to calculate dietary equilibrium, dietary adequacy (Actual intake within FG/minimum recommendations for FG)/total number of FGs x 100 = Dietary adequacy score (possible range: 0-100%)) and dietary moderation (1-(Actual intake within FG-upper recommendations for FG)/ upper recommendations for FG)/ total number of FGs x 100= Dietary moderation score (possible range: 0-100%)) needs to be calculated.

Final calculation of the equilibrium component: (Dietary adequacy FG/Dietary excess FG)/ number of different FG x 100 = Dietary equilibrium score (possible range: 0-100%).

*Maternal diet and parental sociodemographic and lifestyle factors as potential determinants of child's diet quality*

We assessed maternal adherence to the Norwegian food based dietary guidelines was assessed using the HEI-NFG (24). The following components were included: Fresh fruit, vegetables, whole-grain, fish, fatty fish, red meat, salt and added sugar.

The following maternal characteristics were also assessed as potential determinants for child diet quality: Maternal age, energy intake during pregnancy, fiber intake during pregnancy, pre-pregnancy BMI, gestational weight gain (in relation to recommendations), parity, maternal education, marital status, mode of delivery, gestational diabetes, gestational hypertension, pre-eclampsia, maternal chronic disease, smoking during pregnancy, second hand smoking during pregnancy, folic acid supplements before and during early pregnancy. In addition paternal age, educational level and BMI were assessed.

*Child characteristics as potential determinants of child's diet quality*

Using information in all available postnatal questionnaires and MBRN we assessed numerous child characteristics of potential impact on diet quality. These included child gender obtained from MBRN, breastfeeding duration obtained from the 6 month questionnaire and daycare initiation obtained from the 18 month questionnaire. The following variables were obtained from the 3-year questionnaire; any dietary supplement before 3 years, sleep duration before 3 years, food allergy at 3 years, time spent in front of the TV (screentime) at age 3 years, and time spent outdoors at 3 years. Finally, the following variables were obtained from the 7-year questionnaire; sleep duration at 7 years, leisure physical activity at 7 years, food allergy at 7 years, and time spent watching TV (screentime) at 7 years.

*Weight status*

Anthropometric information of weight and length/height were reported by the mothers in questionnaires. Overweight and obesity at 7 years amongst the children in the cohort was determined by the International (International Obesity Task Force; IOTF) Body Mass Index (BMI) cut-offs (25). These are gender and age specific cut-offs. Boys and girls at 7 years with

BMI>20.59 kg/m$^2$ and BMI>20.39 kg/m$^2$ respectively, as well as boys and girls of 7.5 years old with BMI>21.06 kg/m$^2$ and BMI>20.89 kg/m$^2$ were defined as overweight and or obese.

*Statistical analysis*

For the statistical analysis Stata SE version 15 was used. For the categorical fMDS, t-tests and Chi-square tests were used to test differences between categories of potential determinants of diet quality. For the continuous DQI scores, t-tests and one-way ANOVA test were used to test differences between categories, while Pearson's correlation coefficient was used to examine linearity between continuous variables that were potential determinants of diet quality. Stepwise backward elimination procedure was performed on the full multivariable model to retain the strongest and statistically significant determinants for the different diet quality scores (with p-value <0.001 as cut-off). Multivariable logistic regression models and linear regression models were fitted for the categorical fMDS and continuous DQI at 3 and 7 years, respectively.

To check for associations between child's diet quality at 3 years and overweight at 7 years, logistic regression models were used. The DQI scores were categorized in tertiles, as low, medium or high diet quality. Three different models were defined, and adjusted for the following; Model 1: child BMI at 3 years, child gender and maternal education. Model 2: Adding time spent outdoors, sleep and TV time at 7 years. Model 3: Adding maternal HEI scores during pregnancy and pre-pregnancy BMI. The level of significance for all tests was 0.05 except for the stepwise backward selection procedure where we used a smaller value (0.001).

**Results**

*Characteristics of the study population*

The descriptive statistics of the study participants and the potential determinants of diet quality are presented in Table 3. Of the participants with complete information, 50.6% of the children were boys, and 49.4% were girls. The mean (SD) age of the included mothers was 30.4 (4.3) years of age, whilst 65% of the fathers were between 30 and 39 years. The mean (SD) pre-pregnancy BMI of the mothers was 24 (4.2) (normal BMI 18.5-25 kg/m$^2$) and 45% of the mothers gained more weight than recommended during their pregnancy. Their mean total daily energy intake was 2,280 kcal/day. The BMI of the fathers showed that 45.2% were normal weight (BMI (kg/m$^2$) 18.5-25), whilst 44.8% were overweight (BMI (kg/m$^2$) 25-30). The maternal diet quality scores showed a mean (SD) HEI score of 44.7 (7.6). Regarding the level of education, the majority of the mothers (45.8%) had an average level of education (13-16 years), whilst for the fathers, the level of education was lower, with a majority having a low level of education (42.3%) ($\leq$ 12 years).

*Description of diet quality in childhood*

Diet quality in childhood is presented in Table 4. At 3 years, 35.7% and at 7 years, 34.1% of the children had high adherence to the Mediterranean diet score (fMDS> 3). Regarding the change of adherence over time (tracking), 46.1% of the children with high adherence at 3 years remained in the high adherence group at 7 years, while 72.5% of the 3-year-olds with low adherence remained in the same adherence level at 7 years (p-value<0.001 from Chi-square test, data not shown). Overall, 63% of the children did not change their adherence to MD, 18% had better adherence and 19% had worst adherence from 3 to 7 years.

For the total DQI, the mean (SD) was 59.2% (12.2) and 59.0% (9.9) at 3 and 7 years. DQI at 3 and 7 years were positively correlated (Pearson's correlation: 0.48, p-value<0.001-data not shown). Regarding the components of the DQI, mean (SD) of dietary diversity was 73.7% (13.3) and 62.4% (16.4), dietary quality was 47.9% (20.6) and 56.6% (43.4) and dietary equilibrium was 58.5% (8.5) and 58.4% (9.8) at 3 and 7 years, respectively.

*Determinants of dietary quality in childhood*

The strongest determinants for the two diet quality scores from the stepwise backward elimination procedure (p<0.001) are presented in Table 5. For the *fMDS* we observed that high adherence was positively associated with high maternal fibre intake and high maternal HEI score at both age points. Another interesting finding was that having food allergy at both 3 and 7 years was associated with a better quality diet when measured with the fDMS. At 7 years, high adherence was also associated with spending more than 3 hours outdoors (at 3 years) and interestingly sleeping less than recommended. We observed that lower odds of high adherence to the MD (low fMDS scores) was associated with increased maternal total daily energy intake at both 3 and 7 years, watching TV for 1-2 hours or for more than 3 hours daily at 3 years, and for more than 1 hour daily at 7 years, compared to less screen time.

For the *DQI*, a higher number of associations were discovered (Table 5). At both age points higher DQI score was associated with high maternal fiber intake and high maternal diet quality (HEI score), average and high parental education level, being female, late introduction of solid foods and spending more time outdoors at 3 years. In addition, starting daycare after

16 months/age was associated with higher score at 3 years, as well as being physically active for 5-7 or for ≥8 hours/daily at 7 years. Lower DQI scores at both age points was associated with increased maternal total daily energy intake, having siblings, maternal second hand smoking during pregnancy, mother non-users of folic acid supplements during early pregnancy and low breastfeeding duration (less than 12 months). Regarding the child-related characteristics, lower DQI scores was associated with longer screen time (1-2 hours or more than 3 hours/day) and seldom being outdoors at 3 years at both age points. Other associations with lower DQI scores at 3 years only, was mothers non-users of folic acid supplements before pregnancy, not receiving dietary supplements up to age of 3, sleeping less than recommended and having food allergy. In addition, at 7 years only, lower DQI scores were associated with increased maternal age and longer screentime at 7 years (>1hour/day).

*Association of dietary quality and weight status in childhood*

At 7 years, 12% of the children in the cohort were considered overweight or obese. Having high adherence to the MD at 3 years was associated with lower odds of overweight/ obesity at 7 years when adjusted for child BMI at 3 years, maternal education and child gender; however, the association was not significant (Table 6). Similar results were observed with model 2 and 3, when adjusting additional confounders.

Having total DQI score at the middle and upper tertile at 3 years was associated with lower risk for overweight, compared to children with total DQI in the lower tertile, while the associations of the upper vs. lower tertile were more consistent and also significant (Table 7). More specifically, children with the highest diet quality (upper tertile for DQI) at 3 years had 19%, 15% and 13% lower risk for being overweight at 7 years, after adjustment for different confounders (Table 7). Further, from running regression analysis on the three main components of the DQI at 3 years, namely diversity, quality and equilibrium, only dietary quality was statistically significantly associated with reduced risk of overweight at 7 years (Table 7). Dietary quality at 3 years in the middle and upper tertile were both significantly associated with a decreased risk for overweight at 7 years.

## Discussion

In the present prospective study, we found that 36% and 34% of the children had a high adherence to the MD at 3 and 7 years. For the DQI, the mean (SD) was 59.2 (12.2), and 59 (9.9) at 3 and 7 years, respectively. Among the potential determinants of the child's diet quality, the mother's diet quality, higher parental education, less screen time, being active and spending more time outdoors was associated with a higher diet quality. A high maternal total daily energy intake, seldom being outdoors and having longer screen time was associated with low diet quality with both scores. We found conflicting results with having food allergy and sleep duration as determinants for high and low diet quality in the population. From exploring the association with weight status, a high DQI score at 3 years was associated with a lower risk for overweight at 7 years. We found that high diet quality was the component of the DQI that was related to lower risk for overweight.

*Diet quality in Norwegian children*

The diet quality of the population as measured by the fMDS show results of high fMDS scores (>3) that resembles previous findings in similar Italian (37.5%) and German (35.1%) populations (15). In the same study they found high fMDS scores (>3) in 56.7% of Swedish and 24.2% of Cypriot children. This indicates that adherence to the known healthy MD dietary pattern among the children in the Norwegian cohort, is closer to that of children in southern European countries, than our Scandinavian neighbours. The adherence among the Cypriot children, indicate that the MD no longer has a clear geographical pattern, and that the use of MD based diet scores might well be useful when exploring diet quality in different populations independent of their geographical location. Previous studies have shown that Mediterranean countries have abandoned the MD, and have adopted more westernized diets (6, 7). Although the MD contains healthy foods such as olive oil, fish and legumes which are not as readily found or easily available in all countries, a possible explanation for the distribution might be that the intake of such foods are more dependent on income and educational level, than the origin of the diet itself. This reflection does not, however, explain the findings in our study when comparing results on adherence with those found in the Swedish population.

We observed lower DQI scores than found in other studies. In a study done by Huybrechts et al (12), the mean(SD) DQI was found to be 71(10) amongst 2.5 – 6.5 year old Belgian children, that is 1 SD higher than in our study. Also, the mean scores for the components diversity, quality and equilibrium were different in our study than reported elsewhere. In another multi-country study including European pre-school children (aged 3.5-5.5 years) and their parents/caregivers, the mean scores were also higher compared to our findings in Norwegian children. Their total DQI score being 68.3, whilst for the components, 61.7 for diversity, 56.5 for quality and 65.4 for equilibrium. When looking at the different included countries separately, children in our cohort scored higher in the diversity component, but lower in the other components, including the total DQI score. Compared to results from other European countries, Norwegian children have a slightly lower quality diet when measured with both the fMDS and DQI scores and this finding calls for concern.

*Determinants of child's diet quality*

Among the potential determinants of the child's diet quality, several was found to be significant. Parental characteristics such as dietary habits and educational level seems to be important factors on child's diet quality. Mothers with high diet quality scores and high fibre intake in pregnancy were more likely to have children with high diet quality for both fMDS and DQI at 3 as well as at 7 years. Also, a high maternal total daily energy intake was associated with low diet quality, again regardless of score and age. It is previously found significant associations between parent-child diet with regards to consumption of healthy foods such as vegetables, fruits, fish and olive oil (26), and also other metrics including energy intake are found to be related (27). Although there is supporting evidence of the parent-child diet association, not all believe the association to be particularly strong (28). Some suggested mechanisms of the parent-child diet quality association, are shared meals and food environments, as well as parental modelling. Keeping in mind that children are not in control of what foods they presumably can consume before reaching adolescence (7), the likelihood of the diet resembling that of its parents is present, and the parental influence in early childhood might as well serve as a foundation for food choices later in life.

Another important parental characteristic which was found to be associated with a better diet quality in this study was higher parental education. At 3 years both maternal and paternal higher education were positively associated with diet quality, and at 7 years paternal higher education was found to be significantly associated to diet quality. Higher education, being a proxy of higher SES, is one of the most important determinants of good general health and also a better diet quality (29). Several studies found in the literature support these findings, showing that having at least one parent with a higher level of education is associated with a good quality diet (9, 10, 29), and that a low maternal level of education is associated with a decreased probability of the child having a good quality diet (9). Reasons for the detected associations between educational level and diet quality might include the lack of preferred foods or accessibility, inadequate information or poorer ability to decide what is healthy, and therefore having difficulties making healthy choices for their family.

Other determinants found to be associated with the diet quality in the population, include allergies, behaviours and other lifestyle child characteristics. In our study, we found conflicting results regarding allergy and sleep duration both within the study and with regards to previous literature. Our results show that children with food allergies at 3 years had a good diet quality with regards to the fMDS, and worse diet quality when measured with the DQI score. At 7 years, it was found again that having food allergies was associated with a good diet quality (at 7 years) when measured with the fMDS. The research on diet quality and allergy in children seems to be scarce, although mainly supportive of the results found using the DQI score (30, 31). However, the food allergy at 3 years was reported by the mother and was not confirmed by an immune-assay test. This might have been a factor causing an overestimation of children with allergies, were elimination of foods have been less critical.

Children with a better quality diet also seem to adopt other health promoting behaviours, such as adhering to sleep recommendations, having less screen time, being more physical active and spending more time outdoors than children with lower diet quality. These associations has also been found in previous studies, supporting the findings (32-35). An explanation could be that parents who promote a healthier diet, also promote a healthier lifestyle in general. As with other habits, being physically active is likely to track into adulthood (36) and might also be an important factor in battling overweight and obesity.

As with allergy, the association of sleep and diet quality was inconsistent in this study. Shorter sleep duration up to 3 years was associated with a lower DQI score at 3 years, but shorter sleep duration at 7 years was associated with a high fMDS score at 7 years. The previous literature linking short sleep duration with poorer diet quality and increased risk of obesity, is supportive of the results from the DQI scores in this study (37-39), but not with the positive association between lack of sleep at 7 years and the high fMDS, indicating a better diet quality in this group. Nevertheless, the association with sleep and DQI is a prospective association, while the association between sleep and fMDS is cross-sectional at 7 years. The interplay between increased body weight and its major risk factors, such as diet, sleep and physical activity is very difficult to assess in cross-sectional study designs (40). A potential explanation could be that a high fMDS represents high food intake, as it is not adjusted for energy intake, that might be related to increase risk of overweight, and overweight children tend to have worse sleeping habits, compared to normal weight children (38)**.**

*Diet quality and weight status*

Our results on diet quality and weight status for the different indices were coherent with that of Jennings et al (11), who found weight status to be inversely associated with high DQI and HDI (the Healthy Diet Indicator) scores, but not with MDS scores when exploring weight status and diet quality amongst 9-10 year old British children. Previous studies have shown similar results, with significant associations between lower weight status and higher DQI-I and RC-DQI scores (41, 42). For the association between weight status and adherence to the MD, the results are more conflicting, some indicating no or weak inverse associations between high scores and BMI (32, 43), and others suggesting MD adherence to be protective against overweight and obesity (15, 44) and also other adiposity indices, such as waist circumference (45). The DQI is a healthy diet score based on several dietary guidelines, including all the available nutritional information and reflecting more aspects of the contributors of the diet to the quality of it. On the other hand, the fMDS is a more “crude” score that does not extensively account for the different healthy and unhealthy contributors to diet quality within each food group. The fMDS might therefore be too general to evaluate the true association between overweight and obesity for this population. These differences in the construction of the two diet quality scores might explain the differences we observed in their associations with overweight.

*Strengths and limitations*

Strengths of this study are the inclusion of the large study population attainable from MoBa and the coverage of a large set of potential determinants of diet quality. The study design also made it possible to investigate both diet quality and the development of overweight and obesity in the population prospectively, demonstrating possible causality. Further, the use of 2 different diet quality scores might increase and produce different knowledge on the same topic as they cover slightly different aspect of diet quality. Also this can give some indication as to what index is preferable in future studies.

The dietary data used in this study was self-reported. All self-reported data is prone to misreporting and bias, and reported food frequencies are crude estimates not well suited for precise estimation (46). The self-reporting of food intake is also vulnerable to under- and overestimation of healthy and unhealthy foods. Another limitation might have been that the questions on diet were restricted and the numbers of food items differed at the different time points, this may have had an impact on the comparability of the scores at the different time points.

A general limitation of MoBa is the low participation rate (41%). Self-selection implies that participants are older, better educated, include fewer smokers etc. Still, determinants of exposures and associations between exposures and outcomes can be regarded as valid (47, 48).

## Conclusion

In general, children in Norway seem to have a moderate to low quality diet compared to our European counterparts when measured both with the fMDS and the DQI scores. This finding is of concern for future generations. Several determinants found in this study indicates that parental diet choices both for themselves and their child(ren) affects the diet quality, and our findings suggest that diet quality matters for child weight development. The many significant determinants of diet quality in this study also shows the complexity of this concern. Regarding a majority of the significant determinants found in this study, several can be addressed in the work against a further increase in low diet quality and overweight in the child and adolescent population. Higher education for future generations might help mediate the protective effect of a good quality diet. Parents setting good examples for their children in routines of sleep, physical activity and screen time or other sedentary activities might also be protective. The results also corroborate that the current dietary guidelines, reflected in dietary quality score, is sound, and inspire all public health and medical practitioners to pay more attention to dietary counselling.

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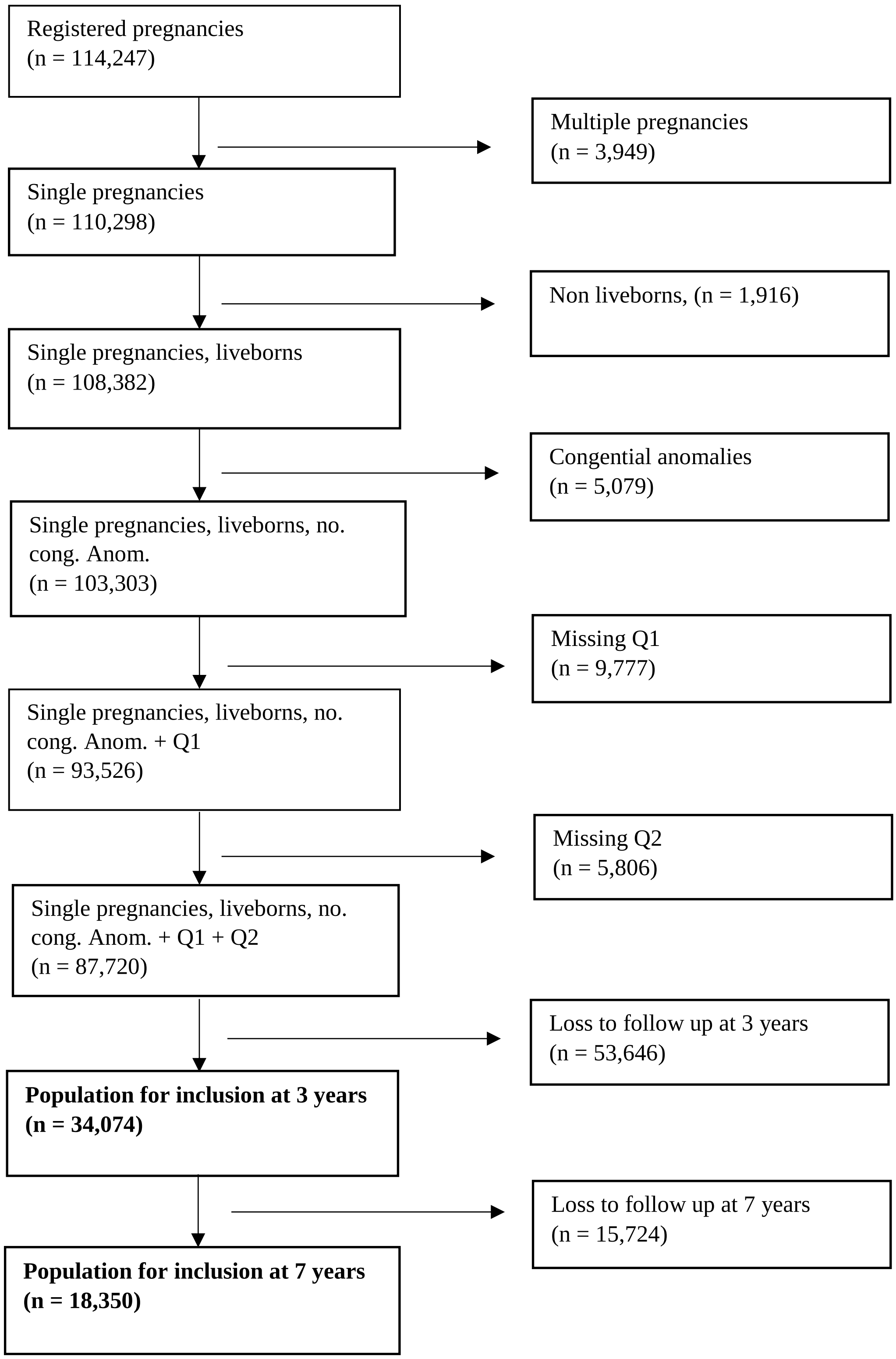


Figure 1. Flow chart of study population.

Table 1. Portions sizes assigned in food items included in the 3-years FFQ.

| **Food items (n=36)** | Portion sizes [a] | Source |
|---|---|---|
| **Vegetables & potatoes** | | |
| Cooked vegetables | 35-50g | b |
| Raw vegetables & salad | 40-50g | b |
| Potatoes | 80-120g | b |
| **Fruits** | | |
| Fruit | 50-100g | b |
| Raisins | 15-20g | b |
| Juice | 1/2 cup=100ml | b |
| **Cereals** | | |
| Bread | 1 slice=40-60g | b |
| Pasta, spaghetti, noodles | 75-95g | b |
| Rice | 65-80g | b |
| **Dairy products** | | |
| Full fat milk | 1/2 cup=100ml | b |
| Skimmed milk | 1/2 cup=100ml | b |
| Natural yoghurt | 1/2 cup=100ml | b |
| Fruit yoghurt | 1/2 cup=100ml | b |
| Probiotic yoghurt | 1/2 cup=100ml | b |
| Cheese | 20g | b |
| Brown cheese (whey cheese) | 16g | c |
| **Meat & products** | | |
| Meat and meat products | 40-65g | b |
| Meat spread (i.e. liver paste, ham) | 11-20g | c |
| **Eggs** | | |
| Eggs (boiled, fried, scrambled) | 1 egg=60g | b |
| **Fish & products** | | |
| Oily fish | 50-70g | b |
| White fish | 50-70g | b |
| Fish products (cakes, pudding, balls) | 50-70g | b |
| Fish spread (i.e. mackerel in tomato sauce, fish roe) | 15-40g | c |
| **Sweets** | | |
| Chocolate | 70g | c |
| Candy | 15g | c |
| Jam, honey, chocolate spread, other sweet spread | 15g | c |
| Ice cream | 40-50g | b |
| Fruit juice ice lolly | 85g | |
| Cookies | 11g | c |
| Buns, cakes, waffles | 50-85g | c |
| Pancakes | 65g | c |
| **Miscellaneous** | | |
| Cordial with sugar | 1/2 cup=100ml | b |
| Cordial with artificial sweetener | 1/2 cup=100ml | b |
| Pizza | 60-80g | b |
| Potato chips | 70-80g | b |
| Soup | 150-170ml | b |
| Water | 1 cup=250ml | b |

[a] If a range of portion sizes are available, the largest portion was selected for the calculations of intakes.

[b] WHO. Food and nutrition policy for schools. A tool for the development of school nutrition programmes in the European Region. Copenhagen: World Health Organization. Programme for Nutrition and Food Security, 2006.
[c] Norwegian Directorate of Health, University of Oslo, Norwegian Food Safety Authority. Weights, measures and portion sizes for foods, 2015.

Table 2. Portions sizes assigned in food items included in the 7-years FFQ.

| **Food items (n=50)** | Portion sizes [a] | Source |
|---|---|---|
| **Vegetables & potatoes** | | |
| Carrot | 56-70g | b |
| Cabbage, cauliflower, broccoli | 56-70g | b |
| Salad | 42-56g | b |
| Other vegetables | 56-70g | b |
| Vegetable-based dish | 56-70g | b |
| Potatoes | 84-170g | b |
| **Fruits** | | |
| Orange, clementine | 100-200g | b |
| Banana | 50-100g | b |
| Apple, pear, grapes | 50-100g | b |
| Orange juice & other juice | 1/2 cup=100ml | b |
| Apple nectar & other nectar | 1/2 cup=100ml | b |
| Other fruits | 50-100g | b |
| **Nuts** | | |
| Peanuts | 165g | c |
| Peanut-butter | 15g | c |
| Other nuts | 165g | c |
| **Cereals** | | |
| White bread | 1 slice=56-70g | b |
| Medium refined grain bread | 1 slice=56-70g | b |
| Whole grain bread | 1 slice=56-70g | b |
| Crispbread | 1 piece=14g | c |
| Breakfast cereals (i.e. Cornflakes, Honeycorn, Frosties) | 35g | c |
| Muesli, oatmeal | 100g | c |
| Rice, spaghetti, pasta | 80-180g | b |
| **Dairy products** | | |
| Cheese (yellow/white cheese, whey-cheese, cheese spread) | 45g | b |
| Full fat milk | 1 cup=200ml | b |
| Skimmed milk | 1 cup=200ml | b |
| Chocolate milk | 1 cup=200ml | b |
| Cultured milk | 1 cup=200ml | b |
| Yoghurt | 3/4 cup=175ml | b |
| **Meat & products** | | |
| Meat spread (i.e. liver paste, cold meat cuts) | 11-20g | c |
| Meat (i.e. chops, steak) | 42-56g | b |
| Meat products (i.e. sausages, meatballs, beef-patty) | 70-120g | b |
| **Eggs** | | |
| Egg | 1 egg=60g | b |
| **Fish & products** | | |
| Fish spread (i.e. fish roe) | 15-40g | c |
| Oily fish (salmon, mackerel, herring) | 90-160g | b |
| Other fish (cod, Pollack or similar) | 90-160g | b |
| Fish products (balls, pudding or similar) | 90-160g | b |
| Shellfish | 150g | c |
| **Sweets** | | |
| Chocolate & nut spread | 15g | c |

| | | |
|---|---|---|
| Pancakes | 65g | c |
| Buns, waffles, cakes | 50-85g | c |
| Ice cream and milk based desserts | 84-98g | b |
| Chocolate & candy | 15-70g | c |
| Jam | 15g | c |
| **Miscellaneous** | | |
| Pizza | 84-98g | b |
| Potato chips | 80-84g | b |
| Cordial with sugar | 1/2 cup=100ml | b |
| Cordial with artificial sweetener | 1/2 cup=100ml | b |
| Soda drink with sugar | 1/2 cup=100ml | b |
| Soda drink with artificial sweetener | 1/2 cup=100ml | b |
| Water | 1 cup=250ml | b |

[a] If a range of portion sizes are available, the largest portion was selected for the calculations of intakes.

[b] WHO. Food and nutrition policy for schools. A tool for the development of school nutrition programmes in the European Region. Copenhagen: World Health Organization. Programme for Nutrition and Food Security, 2006.

[c] Norwegian Directorate of Health, University of Oslo, Norwegian Food Safety Authority. Weights, measures and portion sizes for foods, 2015.

Table 3. Potential determinants of diet quality in children, from MoBa 2002–2008.

| | N | Mean (SD) |
|---|---|---|
| ***Maternal characteristics during pregnancy*** | | |
| Age (years) | 34,074 | 30.4 (4.3) |
| Maternal total daily energy intake (kcal/day) | 34,074 | 2280 (584) |
| Maternal fiber intake (g/day) | 34,074 | 31 (10) |
| Maternal HEI score | 34,074 | 44.7 (7.6) |
| Maternal pre-pregnancy BMI (Kg/m$^2$) | 34,074 | 24.0 (4.2) |
| | **N** | **%** |
| IOM Gestational weight gain | | |
| Less than recommended | 6,123 | 18.67 |
| As recommended | 11,907 | 36.31 |
| More than recommended | 14,762 | 45.02 |
| Parity | | |
| Nulliparous | 16,617 | 48.77 |
| Multiparous | 17,457 | 51.23 |
| Maternal education (years) | | |
| Low ($\leq$12) | 8,588 | 25.20 |
| Average (13-16) | 15,606 | 45.80 |
| High ($\geq$17) | 9,880 | 29,00 |
| Marital status | | |
| With partner | 33,167 | 97.43 |
| Other | 875 | 2.57 |
| Mode of delivery | | |
| Normal | 29,635 | 86.97 |
| Caesarean | 4,439 | 13.03 |
| Gestational diabetes | | |
| No | 33;796 | 99.18 |
| Yes | 278 | 0.82 |
| Gestational hypertension | | |
| No | 32,099 | 94.20 |
| Yes | 1,975 | 5.80 |
| Preeclampsia | | |
| No | 32,802 | 96.27 |
| Yes | 1,272 | 3.73 |
| Smoking in early pregnancy | | |
| No | 31,957 | 94.35 |
| Occasionally | 687 | 2.03 |
| Daily | 1,226 | 3.62 |
| Second hand smoking in early pregnancy | | |
| No | 31,075 | 91.60 |
| Yes | 2,850 | 8.40 |
| Folic acid supplements before pregnancy | | |
| No use | 16,797 | 49.30 |
| Use | 17,277 | 50.70 |
| Folic acid supplements in early pregnancy | | |
| No use | 6,385 | 18.74 |
| Use | 27,689 | 81.26 |

| | | |
|---|---|---|
| ***Paternal characteristics*** | | |
| Paternal age | | |
| < 30 years | 8,763 | 25.77 |
| 30-39 years | 21,962 | 64.58 |
| ≥40years | 3,281 | 9.65 |
| Paternal BMI (Kg/m$^{2}$) | | |
| Underweight (<18.5) | 58 | 0.17 |
| Normal (18.5-25) | 15,005 | 45.24 |
| Overweight (25-30) | 14,887 | 44.89 |
| Obese (>30) | 3,215 | 9.69 |
| Paternal education (years) | | |
| Low (≤12) | 13,741 | 42.28 |
| Average (13-16) | 9,958 | 30.64 |
| High (≥17) | 8,798 | 27.07 |
| ***Child characteristics*** | N | Mean (SD) |
| Gestational age (weeks) | 33,951 | 40.0 (1.7) |
| Birth weight (kg) | 34,074 | 3,606 (0.5) |
| Gender | N | % |
| Boys | 17,250 | 50.63 |
| Girls | 16,824 | 49.37 |
| Breastfeeding duration (months) | | |
| >12 | 13,626 | 39.99 |
| 9-12 | 9,003 | 26.42 |
| 5-8 | 7,770 | 22.80 |
| Never/0-4 | 3,675 | 10.79 |
| Timing of solid food introduction (months) | | |
| <6 | 27,615 | 81.04 |
| ≥6 | 6,459 | 18.96 |
| Starting daycare | | |
| Not going | 14,645 | 42.98 |
| <16 months | 168 | 0.49 |
| 16-18 months | 19,261 | 56.53 |
| Dietary supplements before 3 years | | |
| No | 1,967 | 5.79 |
| Yes | 31,999 | 94.21 |
| Food allergy before 3 years | | |
| No | 31,657 | 92.91 |
| Yes | 2,417 | 7.09 |
| Sleep duration before 3 years | | |
| As recommended | 32,215 | 96.01 |
| Less than recommended | 1,339 | 3.99 |
| ***At 3 years*** | | |
| Food allergy at 3 years | | |
| No | 31,872 | 93.54 |
| Yes | 2,202 | 6.46 |
| TV watching at 3 years (hours/day) | | |
| <1 | 19,936 | 58.72 |
| 1-2 | 13,115 | 38.63 |
| ≥3 | 898 | 2.65 |

| | | |
|---|---|---|
| Spending time outdoors at 3 years (hours/day) | | |
| Seldom/<1 | 1,057 | 3.12 |
| 1-3 | 21,394 | 63.14 |
| >3 | 11,431 | 33.74 |
| ***At 7 years*** | | |
| Sleep duration at 7 years | | |
| Less than recommended | 17,743 | 97.55 |
| As recommended | 327 | 1.80 |
| More than recommended | 119 | 0.65 |
| Physical activity at 7 years (hours/day) | | |
| 0-2 | 3,328 | 18.40 |
| 3-4 | 5,899 | 32.62 |
| 5-7 | 6,410 | 35.45 |
| ≥8 | 2,447 | 13.53 |
| Food allergy at 7 years | | |
| No | 16,481 | 89.81 |
| Yes | 1,869 | 10.19 |
| TV watching at 7 years (hour/day) | | |
| ≤1 | 9,271 | 50.86 |
| >1 | 8,957 | 49.14 |

Table 4. Description of dietary quality of Norwegian children at 3 and 7 years, as assessed by the food frequency-based Mediterranean Diet Score (fMDS) and the Diet Quality Index (DQI), from MoBa 2002-2008.

| | All children | |
|---|---|---|
| **Dietary quality indices** | N | % |
| **Adherence to the Mediterranean diet** | | |
| At 3 years | | |
| Low (fMDS≤3) | 21,924 | 64.3 |
| High (fMDS>3) | 12,150 | 35.7 |
| At 7 years | | |
| Low (fMDS≤3) | 12,093 | 65.9 |
| High (fMDS>3) | 6,257 | 34.1 |
| | N | Mean (SD) |
| **Diet Quality Index (DQI)** | | |
| At 3 years | 34,074 | 59.2 (12.2) |
| At 7 years | 18,350 | 59.0 (9.9) |
| ***DQI components*** | | |
| **Dietary diversity** | | |
| At 3 years | 34,074 | 73.7 (13.3) |
| At 7 years | 18,350 | 62.4 (16.4) |
| **Dietary quality** | | |
| At 3 years | 34,074 | 47.9 (20.6) |
| At 7 years | 18,350 | 56.6 (43.4) |
| **Dietary equilibrium** | | |
| At 3 years | 34,074 | 58.5 (8.5) |
| At 7 years | 18,350 | 58.4 (9.8) |

Table 5. Determinants of Diet Quality at 3 and 7 years from stepwise backward selection, from MoBa 2002-2008

| | DQI | | | | High adherence to MD (fMDS>3) | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 years (n=34,074) | | 7 years (n=18,350) | | 3 years (n=34074) | | 7 years (n=18,350) | |
| | **beta** | **95%CI** | **beta** | **95%CI** | **OR** | **95%CI** | **OR** | **95%CI** |
| **Maternal characteristics** | | | | | | | | |
| Age | | | -0.09 | -0.12, -0.05 | 0.98 | 0.98, 0.99 | | |
| Total energy intake | -1.46 | -1.65, -1.27 | -1.16 | -1.40, -0.92 | 0.84 | 0.81, 0.87 | 0.88 | 0.83, 0.93 |
| Fiber intake | 0.10 | 0.08, 0.12 | 0.09 | 0.07, 0.11 | 1.01 | 1.00, 1.01 | 1.01 | 1.01, 1.02 |
| HEI-NFG | 0.27 | 0.25, 0.29 | 0.25 | 0.22, 0.27 | 1.03 | 1.03, 1.04 | 1.03 | 1.03, 1.04 |
| Parity | | | | | | | | |
| Nulliparous | Ref. | | Ref. | | | | Ref. | |
| Multiparous | -2.05 | -2.28, -1.09 | -1.65 | -1.97, -1.33 | | | 0.88 | 0.82, 0.94 |
| Maternal education (years) | | | | | | | | |
| Low (≤ 12) | Ref. | | | | | | | |
| Average (13-16) | 1.18 | 0.87, 1.50 | | | | | | |
| High (≥ 17) | 1.33 | 0.95, 1.70 | | | | | | |
| Second hand smoking during pregnancy | | | | | | | | |
| No | Ref. | | Ref. | | | | | |
| Yes | -0.96 | -1.38, -0.54 | -0.96 | -1.51, -0.40 | | | | |
| Folic acid supplements before pregnancy | | | | | | | | |
| No | -0.68 | -0.92, -0.44 | | | | | | |
| Yes | Ref. | | | | | | | |
| Folic acid supplements during early pregnancy | | | | | | | | |
| No | -1.16 | -1.47, -0.85 | -1.11 | -1.49, -0.73 | | | | |
| Yes | Ref. | | Ref. | | | | | |
| ***Paternal characteristics*** | | | | | | | | |
| Paternal education (years) | | | | | | | | |
| Low (≤12) | Ref. | | Ref. | | | | | |
| Average (13-16) | 0.70 | 0.41, 0.98 | 0.68 | 0.33, 1.03 | | | | |
| High (≥17) | 1.26 | 0.93, 1.59 | 1.42 | 1.04, 1.80 | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***Child characteristics*** | | | | | | | | |
| Total breastfeeding duration (months) | | | | | | | | |
| >12 | Ref | | Ref | | | | | |
| 9-12 | -0.39 | -0.67,-0,11 | -0.86 | -1.22, -0.50 | | | | |
| 5-8 | -1.01 | -1.30, -0.73 | -1.13 | -1.53, -0.73 | | | | |
| Never/0-4 | -1.73 | -2.12, -1.34 | -1.17 | -1.71, -0.64 | | | | |
| Timing of solid food introduction | | | | | | | | |
| <6months | Ref | | Ref | | | | | |
| ≥6months | 0.77 | 0.47 , 1.07 | 1.08 | 0.69, 1.47 | | | | |
| Starting daycare | | | | | | | | |
| Not going | Ref | | Ref | | | | | |
| <16 months | 0.79 | -0.78,2.36 | 0.01 | -1.94,1.96 | | | | |
| 16-18 months | 1.30 | 1.06, 1.53 | 0.59 | 0.29, 0.88 | | | | |
| Any dietary supplements before 3 years | | | | | | | | |
| Yes | Ref | | | | | | | |
| No | -1.59 | -2.08, -1.09 | | | | | | |
| Sleep duration before 3 years | | | | | | | | |
| As recommended | Ref | | | | | | | |
| Less than recommended | -2.14 | -2.73, -1.55 | | | | | | |
| Food allergy at 3 years | | | | | | | | |
| No | Ref | | | | Ref | | | |
| Yes | -2.56 | -3.02, -2.10 | | | 1.69 | 1.54, 1.85 | | |
| TV watching at 3 years | | | | | | | | |
| Less than one hour or none | Ref | | Ref | | Ref | | | |
| 1-2 hours | -2.25 | -2.49, -2.01 | -0.92 | -1.23, -0.60 | 0.88 | 0.84, 0.93 | | |
| ≥3 hours | -4.96 | -5.68, -4.23 | -2.58 | -3.54, -1.63 | 0.72 | 0.61, 0.84 | | |
| Time spend outdoors at 3 years | | | | | | | | |
| 1-3 hours | Ref. | | Ref | | | | Ref. | |
| >3 hours | 0.46 | 0.22, 0.71 | 0.63 | 0.32, 0.94 | | | 1.16 | 1.08, 1.24 |
| Seldom/<1 hour | -3.60 | -4.26, -2.93 | -1.67 | -2.51, -0.83 | | | 0.90 | 0.74, 1.08 |

| | | | | |
|---|---|---|---|---|
| Sleep duration at 7 years | | | | |
| As recommended | | | Ref. | |
| Less than recommended | | | 1.72 | 1.35, 2.20 |
| More than recommended | | | 1.37 | 0.94,1.99 |
| Physical activity at 7 years | | | | |
| 0-2 hours/day | Ref | | | |
| 3-4 hours/day | 0.62 | 0.22,1,03 | | |
| 5-7 hours/day | 0.89 | 0.57, 1.21 | | |
| ≥8 hours/day | 1.71 | 1.26, 2.15 | | |
| Food allergy at 7 years | | | | |
| No | | | Ref. | |
| Yes | | | 1.24 | 1.11, 1.38 |
| TV-watching at 7 years | | | | |
| ≤1 hour/day | Ref. | | Ref. | |
| >1 hour/day | -2.19 | -2.50, -1.88 | 0.80 | 0.75, 0.85 |

Table 6. Association between fMDS score at 3 years and overweight at 7 years.

| High vs. Low fMDS at 3 years | Risk for overweight at 7 years | | | |
|---|---|---|---|---|
| | n | OR | 95%CI | |
| Model 1 [a] | 17,630 | 0.97 | 0.87 | 1.08 |
| Model 2 [b] | 16,441 | 0.99 | 0.88 | 1.10 |
| Model 3 [c] | 16,015 | 0.98 | 0.88 | 1.10 |

[a] Model 1 is adjusted for child BMI at 3 years, maternal education and child gender.

[b] Model 2 is adjusted for variables of Model 1 and physical activity, screen time and sleep duration at 3 years.

[c] Model 3 is adjusted for the variables in Model 2 and maternal dietary quality (HEI-NFG score) in pregnancy and maternal pre-pregnancy BMI.

Table 7. Association between DQI and its components at 3 years and overweight at 7 years.

| | Risk for overweight at 7 years | | |
|---|---|---|---|
| | OR | 95% CI | |
| ***DQI at 3 years*** | | | |
| Model 1 (n=16,337) [a] | | | |
| Lower tertile | Reference | | |
| Middle tertile | 0.95 | 0.84 | 1.08 |
| Upper tertile | **0.81** | **0.71** | **0.92** |
| Model 2 (n=15,988) [b] | | | |
| Lower tertile | Reference | | |
| Middle tertile | 0.99 | 0.87 | 1.13 |
| Upper tertile | **0.85** | **0.74** | **0.97** |
| Model 3 (n=15,988) [c] | | | |
| Lower tertile | Reference | | |
| Middle tertile | 1.02 | 0.89 | 1.16 |
| Upper tertile | **0.87** | **0.75** | **0.99** |
| *DQI components* | | | |
| ***DQI Diversity*** | | | |
| Model 1 (n=16,337) [a] | | | |
| Lower tertile | Reference | | |
| Middle tertile | 1.01 | 0.83 | 1.24 |
| Upper tertile | 0.93 | 0.77 | 1.11 |
| Model 2 (n=15,988) [b] | | | |
| Lower tertile | Reference | | |
| Middle tertile | 1.05 | 0.85 | 1.29 |
| Upper tertile | 0.96 | 0.79 | 1.16 |
| Model 3 (n=15,988) [c] | | | |
| Lower tertile | Reference | | |
| Middle tertile | 1.07 | 0.86 | 1.32 |
| Upper tertile | 0.99 | 0.81 | 1.20 |
| **DQI quality** | | | |
| Model 1 (n=16,337) [a] | | | |
| Lower tertile | Reference | | |
| Middle tertile | **0.82** | **0.73** | **0.93** |
| Upper tertile | **0.78** | **0.68** | **0.89** |
| Model 2 (n=15,988) [b] | | | |
| Lower tertile | Reference | | |
| Middle tertile | **0.85** | **0.75** | **0.97** |
| Upper tertile | **0.81** | **0.71** | **0.93** |
| Model 3 (n=15,988) [c] | | | |
| Lower tertile | Reference | | |
| Middle tertile | **0.87** | **0.76** | **0.99** |
| Upper tertile | **0.82** | **0.71** | **0.93** |

| | | | |
|---|---|---|---|
| **DQI equilibrium** | | | |
| Model 1 (n=16,337) [a] | | | |
| Lower tertile | Reference | | |
| Middle tertile | 1.01 | 0.88 | 1.14 |
| Upper tertile | 0.87 | 0.77 | 1.00 |
| Model 2 (n=15,988) [b] | | | |
| Lower tertile | Reference | | |
| Middle tertile | 1.03 | 0.90 | 1.17 |
| Upper tertile | 0.90 | 0.79 | 1.17 |
| Model 3 (n=15,988) [c] | | | |
| Lower tertile | Reference | | |
| Middle tertile | 1.05 | 0.92 | 1.19 |
| Upper tertile | 0.92 | 0.81 | 1.06 |

[a] Model 1 is adjusted for child BMI at 3 years, maternal education and child gender.
[b] Model 2 is adjusted for variables of Model 1 and physical activity, screen time and sleep duration at 3 years.
[c] Model 3 is adjusted for the variables in Model 2 and maternal dietary quality (HEI-NFG score) in pregnancy and maternal pre-pregnancy BMI.

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