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Diet, Body Adiposity and Cardiometabolic Risk in a Population Sample of Primary School Children

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ABSTRACT

Overweight and cardiometabolic diseases are major health concerns worldwide. They often start to develop in early childhood. Early identification of risk factors for overweight and cardiometabolic diseases is crucial in order to develop prevention programmes targeted for risk groups. The aims of this doctoral thesis were to investigate dietary factors and to identify dietary determinants of excess body adiposity and cardiometabolic risk in a population sample of 512 Finnish girls and boys 6–8 years of age participating in the Physical Activity and Nutrition in Children (PANIC) Study.

The number of meals per day, the consumption of food and the intakes of nutrients were assessed by 4-day food records. Five previously published dietary quality indices and a new index developed in the PANIC Study were calculated. Eating behaviour was assessed using the Children's Eating Behaviour Questionnaire. Overweight was defined using cutoffs for body mass index proposed by the International Obesity Task Force. Body fat percentage was measured by the dual-energy X-ray absorptiometry. Cardiometabolic risk was assessed by a continuous metabolic risk score computed using Z-scores of waist circumference, fasting serum insulin, fasting plasma glucose, triglycerides and high-density lipoprotein cholesterol and the mean of systolic and diastolic blood pressure.

Less than half of children ate all three main meals (breakfast, lunch and dinner) every day. Instead, snacks were a major source of energy and sucrose. A minority of children consumed vegetables, fruit and berries as recommended. As many as a quarter of children consumed sugar-sweetened beverages daily. The intakes of saturated fat, sucrose and salt were higher and the intakes of dietary fibre, vitamin D and iron were lower than recommended among children. Children with a lower socioeconomic position were less likely to eat as recommended than children with a higher socioeconomic position. Skipping main meals and a higher intake of protein were associated with an increased body adiposity in children. Of eating behaviour dimensions, a faster eating rate, a higher enjoyment of food, food responsiveness and emotional overeating and a lower satiety responsiveness were associated with a higher body adiposity. Skipping main meals was also associated with an increased cardiometabolic risk among children. Moreover, a higher consumption of sugar-sweetened beverages, red meat and low-fat vegetable oil-based margarine and a lower consumption of vegetable oil were related to a higher cardiometabolic risk. Particularly, a dietary quality index developed in the PANIC Study and based on the above-mentioned dietary factors combined with skipping main meals seemed to increase cardiometabolic risk in children. However, previously published dietary quality indices were not associated with cardiometabolic risk in children.

In conclusion, the results of this doctoral thesis indicate that many components of diet are not at recommended levels among children. Dietary factors may be associated with an increased body adiposity and cardiometabolic risk already in childhood.

National Library of Medicine Classification: QT 235, QU 145, WS 130, WD 200, WD 210
Medical Subject Headings: Meals; Eating; Food and Beverages; Diet; Food Habits; Feeding Behavior; Adiposity; Overweight; Risk Factors; Metabolic Diseases; Socioeconomic Factors; Child; Finland

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TIIVISTELMÄ

Ylipaino sekä aineenvaihdunta- ja verenkiertoelinsairaudet ovat merkittäviä terveysongelmia maailmanlaajuisesti. Niiden kehittyminen alkaa usein jo varhain lapsuudessa. Näiden terveysongelmien riskitekijöiden varhainen selvittäminen auttaa kehittämään sairauksien ennaltaehkäisyä ja intervention suuntaamista siitä eniten hyötyville. Tämän väitöskirjatyön tavoitteina oli tutkia ruokavaliota ja sen yhteyttä kehon rasvapitoisuuteen sekä aineenvaihdunta- ja verenkiertoelinsairauksien vaaratekijöihin 512 6–8-vuotiaan suomalaislapsen väestöotoksessa osana Lasten liikunta ja ravitsemus –tutkimusta.

Päivittäisten aterioiden määrä, ruoankäyttö ja ravintoaineiden saanti määritettiin neljän päivän ruokapäiväkirjalla. Viisi aiemmin julkaistua mittaria ja Lasten liikunta ja ravitsemus -tutkimuksessa kehitetty uusi mittari laskettiin kuvaamaan kokonaisruokavalion terveellisyyttä. Syömiskäyttäytymistä mitattiin Lasten syömiskäyttäytymiskyselyllä. Ylipaino määritettiin Lihavuustutkijoiden kansainvälisen työryhmän kehittämien painoindeksin raja-arvoja käyttäen. Kehon rasvapitoisuus mitattiin kaksisuuntaisella röntgensädeabsorptiometrilla. Aineenvaihdunta- ja verenkiertoelinsairauksien vaara laskettiin vyötärönympäryksestä, seerumin insuliinin sekä plasman glukoosin, triglyseridien ja HDL-kolesterolin paastopitoisuuksista sekä systolisen ja diastolisen verenpaineen keskiarvosta.

Alle puolet lapsista söi kolme pääateriaa (aaminen, lounas ja päivällinen) päivittäin. Suuri osa energian ja sokerin saannista kertyi välipaloista. Vain pieni osa lapsista söi kasviksia, hedelmiä ja marjoja suosituksen mukaisesti. Neljännes lapsista käytti sokeroituja juomia päivittäin. Tyydyttyneen rasvan, sokerin ja suolan saannit olivat suositusta korkeammat ja ravintokuidun, D-vitamiinin ja raudan saannit olivat suositusta matalammat. Lapset, joiden perheiden sosioekonominen asema oli alhainen, söivät epätodennäköisimmin suositusten mukaisesti. Pääaterioiden väliin jättäminen ja liiallinen proteiinin saanti sekä nopea syöminen, ruoasta nauttiminen, syömisen halu, mielialaan liittyvä runsas syöminen ja kylläisyyden heikko tunteminen olivat yhteydessä suurempaan kehon rasvapitoisuuteen. Pääaterioiden väliin jättäminen, kasviöljyn vähäinen käyttö ja punaisen lihan, vähärasvaisten margariinien ja sokeroitujen juomien liiallinen käyttö olivat yhteydessä suurempaan aineenvaihdunta- ja verenkiertosairauksien vaaratekijöiden kasautumaan. Näistä ruoankäyttötekijöistä Lasten liikunta ja ravitsemus –tutkimuksessa kehitetty ruokavaliomittari yhdistettynä epäsäännölliseen ateriarytmiin suurensi aineenvaihdunta- ja verenkiertoelinsairauksien vaaratekijöiden kasautumaa. Aiemmin kehitetyt kokonaisruokavaliomittarit eivät olleet yhteydessä vaaratekijöiden kasautumaan.

Tämän väitöskirjatyön tulosten mukaan monet ruokavaliotekijät eivät ole suositusten mukaisia lapsilla. Ruokavaliotekijät voivat olla yhteydessä suurempaan kehon rasvapitoisuuteen ja aineenvaihdunta- ja verenkiertoelinsairauksien vaaratekijöiden kasautumaan jo lapsilla.

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Aino-Maija Eloranta

List of the original publications

This dissertation is based on the following original publications:

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II Eloranta A-M, Lindi V, Schwab U, Tompuri T, Kiiskinen S, Lakka H-M, Laitinen T and Lakka T A. Dietary factors associating with overweight and body adiposity in Finnish children aged 6–8 years: the PANIC Study. *Int J Obes 36: 950-955, 2012.*

III Eloranta A-M, Lindi V, Schwab U, Kiiskinen S, Venäläinen T, Lakka H-M Laaksonen D E and Lakka T A. Dietary factors associated with metabolic risk score in Finnish children aged 6–8 years: the PANIC study. *Eur J Nutr 53: 1431-1439, 2014.*

IV Eloranta A-M, Schwab U, Venäläinen T, Kiiskinen S, Lakka H-M, Laaksonen D E, Lakka T A and Lindi V. Dietary quality indices in assessment of cardiometabolic risk among Finnish children 6–8 years of age – the PANIC Study. *Submitted.*

The publications were adapted with the permission of the copyright owners. In addition, some previously unpublished data are presented.

Contents

Abbreviations

BMI	body mass index
BMI-SDS	body mass index standard deviation score
BMR	basal metabolic rate
BSDS	Baltic Sea Diet Score
CDC	Centers for Disease Control and Prevention
CEBQ	Children's Eating Behaviour Questionnaire
CI	confidence interval
DASH	Dietary Approach to Stop Hypertension
DIMERIC	Diet to Assess Metabolic Risk in Children
DXA	dual-energy X-ray absorptiometry
E%	percentage of total energy intake
EMT	electronic media time
FCHEI	Finnish Children Healthy Eating Index
FTO	fat mass and obesity associated
GLM	general linear model
HDI	Healthy Diet Indicator
HDL	high density lipoprotein
IGF-1	insulin-like growth factor 1
IOTF	International Obesity Task Force
IQR	interquartile range
KIDMED	Mediterranean Diet Quality Index for Children and Adolescents
LDL	low density lipoprotein
MDS	Mediterranean Diet Score
MUFA	monounsaturated fat
OR	odds ratio
PA	physical activity
PANIC	Physical Activity and Nutrition in Children
PUFA	polyunsaturated fat
SFA	saturated fat
SD	standard deviation
WHO	World Health Organization

1 Introduction

The prevalence of overweight has increased among children during the last decades (1-4). Overweight in childhood is associated with an increased risk of obesity, metabolic syndrome, type 2 diabetes, atherosclerosis, hypertension and premature death in adulthood (5-10). Moreover, the cluster of several cardiometabolic risk factors, such as insulin resistance, dyslipidaemia and elevated blood pressure, starts to develop already in childhood and often tracks into adulthood.

Dietary habits have changed remarkably among children during the last decades, parallell to the increased prevalence of overweight. For example, the frequency of warm meals has decreased and the consumption of snacks, fast foods and sugar-sweetened beverages has increased (11). These changes are similar to those observed among adults (12).

Thus far, only a few dietary factors have consistently been associated wih the risk of childhood overweight (13). One explanation for the difficulty in identifying independent dietary risk factors is that diet is result of a combination of behavioural, environmental and genetic factors. Therefore, studies that take into account different dimensions of diet, including the overall quality of diet, eating frequency and eating behaviour, are needed. Moreover, studies on the associations of dietary factors with the clustering of cardiometabolic risk factors in children are scarce. Because overweight and cardiometabolic risk factors are partly genetically determined (14,15), modifiable risk factors for overweight and cardiometabolic risk, most importantly dietary factors, physical activity and sedentary behaviour, are important in preventing these conditions. Knowledge on dietary factors associated with excess body adiposity and cardiometabolic risk in children would provide a useful basis for planning interventions for the early prevention of metabolic syndrome, type 2 diabetes and cardiovascular diseases later in life.

The objectives of this doctoral thesis were to investigate dietary factors and their associations with excess body adiposity and cardiometabolic risk among Finnish primary school children.

2 Review of the literature

This review of literature provides an overview of the recent literature on dietary habits, body adiposity and cardiometabolic risk in primary school children. In addition, some data on other age groups are presented for comparison with the population of interest.

2.1 METHODOLOGY OF STUDYING DIETARY HABITS

The variety of methods used to collect nutrition data is wide. The appropriate method for dietary assessment always depends on the purpose for which it is needed as well as the size and characteristics of the study sample. Each method has its strengths but also limitations and practical issues to be considered. In this chapter, the common methods of studying dietary habits are reviewed with an emphasis on the methods used in this doctoral thesis.

2.1.1 Food records

Food records are commonly used in the collection of detailed dietary data and are often regarded as the gold standard method of assessing dietary intake (16). The respondents report subjectively all eating and drinking with weighted or estimated portion sizes in the records during the predefined days. Because the records measure the current diet directly and are optimally filled during or soon after the eating occasion, this method does not rely on memory.

However, some limitations need to be addressed when using the food record method. Because the record requires literacy, specific groups, including children, may not be able to administer the record themselves (16). Moreover, intraindividual variation in the food consumption is generally large, and a short period of recoded time may not capture the long-term or habitual consumption of foods and intake of nutrients. While increasing the number of recorded days may give more accurate dietary intake data, it may also cause a higher respondent burden, a lower commitment and a poorer data quality. Moreover, it has been reported that recording may modify the food consumption of the respondent and therefore increase the chance of misreporting. Particularly, underreporting is common among overweight individuals. The method is also relatively expensive and time-consuming for both respondents and investigators.

When the respondent has recorded food consumption, investigators can convert the food consumption data into nutrient intakes using nutritional databases. The databases include the nutrient composition of foods based on laboratory analyses, food composition tables and calculations according to ingredients of foods (17). The accuracy and completeness of these databases as well as the culture-specific information of foods and receipes are of great importance in assessing nutrient intake.

Besides quality and portion sizes of foods consumed, other information, such as timing or place of eating, may also be recorded in the food records. Therefore, food records can also be used for assessing eating frequency. At the moment, there are no standard criteria for definitions of different meals or eating frequency. Meals and snacks have been defined according to varying criteria, including the time of eating, the place of eating and composition of eating occasion (18). The culture-specifity of eating frequency, in addition to the lack of uniform criteria of it, hampers the comparison of findings from different studies.

2.1.2 Food frequency questionnaires

Food frequency questionnaires generally consist of a list of food items and a selection of options of the frequency of use relating to each food item (16). The questionnaires can be self-administered, but interviewing is recommended when feasible (19). The strengths of the method include the feasibility for large study samples, low respondent burden and relatively low costs. Moreover, the questionnaire provides data on the habitual consumption of foods. However, the retrospective nature of the method can lead to misreporting due dependence on memory, particularly in children (16). Moreover, calculating estimated nutrient intake requires the use of a semi-quantitative food frequency questionnaire that collects information on habitual portion sizes in addition to frequencies of use.

2.1.3 Dietary quality indices

Diet always consists of combinations of foods with complex compositions of nutrients that may have synergistic effects and interactions. The health-related effects of single foods or nutrients may be hard to detect. Therefore, approaches combining several dietary components have increasingly been developed and used for assessing a healthy diet (20). Dietary quality indices, created calculating a sum score using the consumption of selected foods or the intakes of selected nutrients, are a widely used approach (21).

Dietary quality indices are typically based on previous dietary knowledge and general dietary recommendations and high scoring of an index reflects a good adherence to the recommended diet. However, there are no standard guidelines for the development of dietary quality indices (21). To date, several approaches have been used related to variables included in the index, the cut-off values and the scorings. Moreover, dietary quality indices can be based on the detailed food consumption data derived from different methods, commonly food records, food frequency questionnaires or specific questionnaires developed for calculating the particular index.

The Dietary Approach to Stop Hypertension (DASH) Score is one of the dietary quality indices that can use food records as the basic method for data collection. It is characterised by increased consumption of vegetables, fruit, nuts, whole grain and legumes, low-fat dairy products, fish and lean meats, decreased consumption of sugar-sweetened products and decreased intake of sodium. It was originally developed for treatment of hypertension in adults (22). However, the adherence to the DASH-style diet has been used as an indicator of a healthy diet in children, as well (23).

One of the most traditional indices is the Mediterranean Diet Score (MDS) which describes a collection of healthy dietary habits traditionally followed in the Mediterranean region (24,25). Multiple forms of Mediterranean diet indices have been developed to fit the studied populations due to culture-specific differencies in dietary habits. All forms of MDS are characterised by high consumptions of vegetables, fruit, legumes, cereals and fish and low consumptions of meat and dairy products. Moreover, a specific Mediterranean Diet Quality Index for Children and Adolescents (KIDMED) Questionnaire has been developed for calculating the adherence to the Mediterranean diet among children (26).

The Baltic Sea Diet Score (BSDS) is another region-specific dietary quality index that was recently introduced to indicate a healthy diet traditionally consumed in Nordic countries. BSDS consists of a higher consumption of Nordic fruit and berries, vegetables, whole grains, fish and low-fat milk and a lower consumption of red and processed meat (27).

The Healthy Diet Indicator (HDI) is developed to measure the adherence to the dietary guidelines for the prevention of chronic diseases defined by the World Health Organization (WHO) (28). The scoring therefore uses the cutoff points of guidelines, contrary to the DASH Score, MDS and BSDS. The scoring of the DASH Score, MDS and BSDS are population-specific and the components are scored according to the cutoff points in medians, quartiles or quintiles of their distribution.

Recently, the Finnish Children Healthy Eating Index (FCHEI) was introduced to measure the adherence to a healthy diet of Finnish children in particular. The index was developed to take into account the main indicators for a healthy diet of Finnish children including a high consumption of vegetables, fruit, skimmed milk, fish and vegetable-based fats and a low consumption of products containing high amounts of sugar (29).

2.1.4 Eating behaviour

In small study samples, observation can be regarded as the best method for studying eating behaviours (30). However, for large study samples, observation may be impractical to organise. Moreover, there is always a chance that the participant changes the eating behaviour as a result of being observed (30). Therefore, questionnaires have been developed to assess dimensions of eating behaviour in large study samples (31).

So far, only a few questionnaires have been developed to take into account the specific dimensions of eating behaviour in children. One of them is the Children's Eating Behaviour Questionnaire (CEBQ), developed to measure eating behaviour among preschool- and school-aged children (32). CEBQ measures four food approach dimensions, including food responsiveness, emotional overeating, enjoyment of food and desire to drink, and four food avoidance dimensions, including satiety responsiveness, slowness in eating, emotional undereating and food fussiness. Good internal reliability and repeatability of the questionnaire has been reported (33). Moreover, three eating behaviour dimensions of the questionnaire, satiety responsiveness, food responsiveness and enjoyment of food, have been validated against behavioural measures of eating among children 4–5 years of age (34).

2.2 DIETARY RECOMMENDATIONS FOR CHILDREN

The Finnish Nutrition Recommendations are based on existing scientific knowledge. The latest Nordic Nutiriton Recommendations were published in 2012 (35) and the Finnish recommendation based on them in 2014 (36). The recommendations are intended to general population, not for individuals or groups with diseases or conditions that may affect their nutrient requirements. For example, growing children are recommended to adapt the recommended quality of diet after the first year of life and to gradually increase the intake of foods and nutrients with age to meet the recommended amounts. More detailed recommendations are given for children in only some components.

A regular meal pattern, comprising for example of breakfast, lunch and dinner and 1–2 snacks, is recommended (36). In children, the intake of energy should be more evenly divided between main meals and snacks than in adults. Children cannot eat large amounts at one sitting and snacks provide a possibility to obtain enough energy and nutrients thoughout the day. According to the previous Nordic Nutrition Recommendations published in 2004, children should optimally receive approximately 20% of daily energy from breakfast, 25% from lunch, 25% from dinner and 30% from snacks (37).

The Finnish Nutrition Recommendations give general guidelines for the consumption of most important food groups (36). The consumption of vegetables, fruit and berries is recommended to be 5–6 portions daily, corresponding 500 g of vegetables, fruit and berries daily for adults. A half of the total amount should be fruit and berries and a combination of cooked and uncooked vegetables is recommended. Grain products are recommended to be chosen high in fibre and low in salt and at least half of the grains should be wholemeal products. A recommended amount of grain products is 9 portions for men and 6 portions for women, one portion corresponding for example to one slice of bread or one decilitre of cooked pasta. However, no specific recommendation of the amount of grain products for children is given. A daily amount of 5–6 decilitres of milk, sourmilk, yoghurts and other liquid dairy products and 2–3 slices of cheese are recommended. Liquid dairy products shold contain at most 1% of fat. Cheese is recommended to be low in salt and containing at most 17% of fat. Fish is recommended to be used 2–3 times weekly with varying species. The consumption of red meat and processed meat products, instead, is recommended to be limited to 500 g per week. Two to three eggs per week can be consumed. Vegetable oil-based margarines containing at least 60% of fat are the recommended choices for spreads on bread. Vegetable oils or vegetable oil-based products are also recommended to be used for cooking and for salad dessings. Approximately 30 g of unflavoured seeds and nuts can be eaten daily. For daily drinks, tap water, mineral water, skimmed milk and skimmed sourmilk are recommended. In addition, one glass of fruit juice daily can be used as a part of a meal. However, sugar-sweetened beverages are not recommended for a regular use.

The recommended intakes of energy and nutrients are mainly the same for adults and children from 2 years of age on (36). Because optimal energy intake depends on sex, age, body composition and the level of physical activity, no actual recommendations for energy intake can be given. However, a theoretical frame for energy requirements for different age groups is introduced. For example, for children 6–9 years of age, an estimated energy requirement of 6.9 MJ per day is given. The recommended proportions of energy nutrients vary less with age. The intake of total fat is recommended to be 25–40 percent of total energy intake (E%) for adults and children from 2 years of age on. The intake of saturated fat (SFA) is recommended to be limited to less than 10 E%. The intake of monounsaturated fat (MUFA) is recommended to be 10–20 E% and the intake of polyunsaturated fat (PUFA) 5–10 E%. The intake of total carbohydrates should be in the range 45–60 E%. The intake of added sugars should be less than 10 E%. The intake of dietary fibre is recommended to be 2–3 g/MJ in children 2 years of age or older. As children mature, the intake should gradually increase to reach the recommended level for adults, 25–35 g per day corresponding approximately 3 g/MJ, during adolescence. The recommendation for protein intake is 10–20 E%. In addition, the recommended daily intakes for vitamins and minerals are given in detail for different age groups in the recommendations (36).

The current recommendations emphasise the importance of the quality of the whole diet for health (36). Diets high in vegetables, fruit and berries, nuts and seeds, whole grains, fish and seafood, vegetable oils and vegetable oil-based fat spreads and low-fat dairy products are recommended. A traditional Mediterranean-like dietary pattern and a healthy Nordic dietary pattern, both rich in unrefined plant food and dense in micronutrients, are given as examples of healthy diet patterns.

2.3 DIETARY HABITS AND THEIR TRENDS IN FINNISH CHILDREN

Dietary habits start to develop from early childhood as a result of both genetics and environmental influences. A balanced diet is essential for children to ensure the optimal development at time of rapid growth. However, the quality of diet declines after the first year of life at the time the children adapt to the regular family diet (38). Thereafter, dietary habits become established rapidly and they often track into adulthood (39). Therefore, early childhood is a crucial period for the development of healthy dietary habits.

In Finland, no systematic, nationwide collection of data on diet in children has been conducted. However, several local studies have reported dietary habits among Finnish children starting in the 1970s. In this chapter, the literature on dietary habits and their changes during past decades among Finnish children and adolescents is reviewed.

2.3.1 Eating frequency

A regular eating frequency is considered the basis of a healthy diet. However, recent studies show that the frequency of main meals, including breakfast, lunch and dinner, has decreased worldwide. Particularly, skipping breakfast has become common among adolescents (40). Meanwhile, the frequency of snacking has increased (41).

According to Finnish studies, eating frequency seems to be rather regular among preschool and primary school children. The majority of Finnish primary school children eat breakfast (84–99%), school lunch (87–96%) and dinner (80–89%) daily (42-44). However, eating frequency becomes less regular in adolescence. Among secondary school children, breakfast is eaten daily by 60–80% (45), school lunch by 70–80% and dinner by 70–80% of children (42,45). Moreover, only half of school children and adolescents have dinner with their family daily or nearly so (45,46). Altogether, only 30% of adolescent girls and 40% of adolescent boys have all three main meals daily (47).

The majority of Finnish school children have one to two snacks daily (46). During school days, snacks provide 41% of the total daily energy in Finnish secondary school children, while breakfast provides 16–17%, school lunch 19–20% and dinner 28–29% of the total daily energy (45). However, the proportion of meals and snacks from the total energy intake in younger children is not known.

2.3.2 Food consumption

Food consumption has changed markedly in Finland during the past decades (48). For example, the consumption of products high in total and SFA has decreased. While one quarter of children usually consumed skimmed milk in the 1990s (44), half of children consumed it in the late 2000s (42). In line, the quality of spread on bread has changed. In the late 1990s, half of children used soft margarine on bread (44), while in the late 2000s, soft margarine was used by 71% of children (42).

Although the consumption of vegetables, fruit and berries has increased among adults (12), an opposite trend has been seen among children. In late 1980s, children consumed approximately 100 g of vegetables and 400 g of fruit and berries daily (27), whereas the corresponding values in 2000s were approximately 50 g of vegetables and 100 g of fruit and berries daily (38). In line, less than a quarter of Finnish school children reported eating vegetables daily (46).

The consumption of grain products has decreased among Finnish adults (12), but they still provide the majority of daily energy intake in children (49). Rye bread is consumed by approximately 80% of Finnish 6-year-old children, while white bread is consumed by half of children (38). Moreover, half of children consume breakfast cereals regularly. Moreover, a majority of preschoolers regularly eat porridge (38), but the consumption of porridge slightly decreases at school age (46).

Among Finnish adults, the consumption of meat has increased during the last decades, while the consumption of fish has not changed during this period (12). Virtually all Finnish preschool children regularly eat meat, but less than half of children regularly eat fish (38). While meat is consumed approximately 170 g per day among 6-year-olds, fish is consumed slightly over 20 g per day (38).

A high consumption of products high in sucrose has been reported among preschool children. An average of one glass of sugar-sweetened beverages is consumed daily by 6-year-old Finnish children (38). A fifth of schoolstarters consume sugar-sweetened juice at afternoon snack daily (42). Approximately a fifth of schoolchildren also consume sugar-sweetened beverages daily (46). These beverages are the most common source of sucrose, providing a third of the total intake of sucrose (45). Furthermore, sweetened yoghurts, dairy-based desserts, sweets and chocolate are commonly eaten by most of the Finnish children (38,46).

2.3.3 Intakes of energy and nutrients

The intake of energy has been reported to be lower than recommended in children and adolescents in Finland (45) and in other European countries (50). This is suggested to be the result of the decreased levels of physical activity among children. The trend is alarming, because the adequate intake of essential nutrients for optimal growth may be challenging with a very low intake of energy.

The proportion of energy derived from fat has decreased constantly among Finnish children, starting from 40 E% in the early 1970s (51). A recent Finnish study reported the proportion of energy derived from fat to be in the recommended level, approximately 30 E%, among children (38). Parallel to the decrease in the intake of total fat, the intake of SFA has decreased and the intake of unsaturated fat has increased among children. However, the intake of SFA is still approximately 13–14 E% (38) which is higher than recommended (36). Meanwhile, the proportion of energy derived from protein and sucrose has slightly increased. In addition to the intake of SFA, the intake of sucrose is higher than recommended (38,45,52), and the intakes of PUFA and dietary fibre are lower than recommended in children (38). A comparison across European countries shows that most European children share the excessive intake of saturated fat and sucrose and the inadequate intake of unsaturated fat and dietary fibre (50). However, some differences in the intakes of energy nutrients across European countries have been observed. For example, children from Southern Europe obtain a higher proportion of energy from fat and a lower proportion of energy from carbohydrates compared to Finnish children (50).

The intake of most vitamins and minerals is adequate among Finnish children (38) and adolescents (45). However, the intakes of vitamin D and iron have consistently been reported to be lower than recommended throughout childhood and adolescence (38,53). Moreover, inadequate intakes of vitamin E, vitamin A and folate have been found in some studies (38,45,53,54). An excessive intake of sodium in children has been reported across Europe (50). However, the intake of some other micronutrients differs slightly across Europe. While Finnish children have a rather high intake of vitamin D compared to children from other European countries, the intake of vitamin E is rather low in Finnish children (50).

2.3.4 Dietary quality assessed by indices

In one of the few studies that have used dietary quality indices as a measure of a healthy diet among Finnish children, a higher scoring in FCHEI was associated with lower intakes of SFA and sugars and higher intakes of PUFA, dietary fibre, vitamin D and vitamin E among preschool children. Being cared for at home, a low maternal education level and residence in a semi-urban area were associated with a lower dietary quality according to the FCHEI among preschool children. However, whether FCHEI is feasible among primary school children, is not yet known.

Mediterranean diet describes a collection of dietary habits traditionally followed in the Mediterranean region (24). However, in a European context, there is some evidence that children from Northern countries currently have a higher adherence to the Mediterranean diet than children from Southern Europe (55). However, there are no studies on adherence to the Mediaterranean diet among Finnish children.

2.3.5 Eating behaviour

Eating behaviour patterns are highly herited and start developing already in infancy. Starting at a very young age, eating behaviour is influenced by numerous environmental signals in addition to genetic predisposition (56). The most important environmental factors affecting eating behaviour are those related to parents. Attitudes and model behaviour of parents play a significant role in the development of healthy eating behaviour in children (57). Moreover, some maternal feeding practices, such as pressure to eat and controlling feeding, have been associated with food avoidance behaviour in children (57,58). Moreover, there is a strong evidence that exposure to new foods increases the acceptance of them (59).

Adverse eating behaviour traits are associated with a low quality of diet (60). However, a limited number of studies have analysed eating behaviour traits at the population level in children. According to the reporting of the parents, 10% of Finnish schoolstarters were fussy about eating (42). Moreover, 30% of Finnish 5-year-old children were considered poor eaters by the parents (61). One Finnish study reported that primary school children living with only one biological parent had a higher likelihood of emotional overeating than those living with both biological parents, regardless of body weight of the child (62). Moreover, enjoyment of food and emotional undereating were found to decrease and food fussiness was observed to increase with age among preschool children in Sweden (63).

2.4 DETERMINANTS OF DIET IN CHILDREN

2.4.1 Age

A very regular eating frequency has been reported in preschool and young primary school children (42,44). In adolescence, the frequency of main meals is reported to decrease. Particularly, skipping breakfast and school lunch becomes more common in adolescence (11,42,45). Moreover, the frequency of family meals decreases with the age of child (42).

The diet of children changes markedly as the child adapts to the regular family diet after the first year of life (38). Particularly, the consumption of sugary products, such as dairy desserts and sweet pastries, increases at preschool age. Moreover, the consumption of sugar-sweetened beverages, especially fruit drinks, increases rapidly. In adolescence, the consumption of sugar-sweetened beverages remains high and is characterised by the consumption outside home in addition to the consumption at home (11). Moreover, the consumption of snack foods is common in adolescence (45). However, the consumption of vegetables, fruit and fish is reported to be low throughout childhood and adolescence (38,42).

The energy intake relative to body weight is at the highest in infancy and decreases thereafter during childhood (64). However, the absolute intake of energy shows an opposite trend with age. In the preschool age, the proportion of energy derived from saturated fat and sucrose increase and the energy derived from PUFA decrease (38). Due to the increased energy intake, the absolute intakes of most vitamins and minerals increase with age (64), with an exception of the decrease in the intake of vitamin D after infancy (38).

Eating behaviour traits also change with age. Neofobia and food fussiness are characteristic in the preschool age (63), and the prevalence of food fussiness decreases in the primary school age (65). In line, satiety responsiveness and slowness in eating have been reported to diminish from preschool age to primary school age, while enjoyment of food and food responsiveness increase with age (32).

2.4.2 Sex

Differences in diet between sexes are well acknowledged among adults. For example, women obtain a lower proportion of their energy from main meals than men (66). Moreover, women have been reported to eat more vegetables, fruit, sour milk products, cheese and sweets but less potatoes, meat and sausages than men (66). Some of these differences seem to start developing in early childhood.

The tendency towards obtaining a lower proportion of energy from main meals in women than in men has also been observed in adolescents. Among 13-year-old Finnish children, 81% of boys reported eating breakfast daily, while only 69% of girls did so (45). Boys were also more likely to have dinner daily than girls. Similar findings have been reported internationally (67).

Differences in food consumption between sexes have not been found among the youngest age groups (38). However, the differences start to develop before school age (38), girls consuming more vegetables, fruit and berries than boys from 6 years of age on (38,45). Similar results have been found among British school children (68). Moreover, boys were reported to eat more breakfast cereals and meat and less fish and cheese than girls (68).

Boys have a higher energy intake than girls throughout childhood, beginning from the first year of life (38). Accordingly, boys have higher absolute intakes of protein, fat and carbohydrates, but the percentages of energy derived from energy nutrients do not differ between sexes (45). Boys have higher absolute intakes of several vitamins and minerals, including vitamin E, vitamin D, folate, magnesium, iron, calcium, potassium and zinc, but girls have higher densities of vitamin E, folate, vitamin C, magnesium and iron in relation to energy intake (45).

Despite the differences in the consumption of foods and intake of nutrients, no difference in the overall quality of diet addressed by FCHEI was found between girls and boys (29). Moreover, there are few differences in eating behaviour dimensions between boys and girls. Only eating rate was reported to be higher among boys than among girls in a Finnish study (62).

2.4.3 Socioeconomic background

Socioeconomic background has repeatedly been associated with several dietary factors among children. Generally, a higher socioeconomic position has been related to a better health consciousness in eating frequency. A cross-sectional study among Welsh primary school children showed that children from families with socioeconomic deprivation were more likely to skip breakfast or to have an unhealthy breakfast, including sweet snacks or crisps, than children from other families (69). Furthermore, British children from families with a lower socioeconomic position received a higher proportion of energy from snacks than children from families with a higher socioeconomic position (70). In line, a low maternal education level has been associated with a more frequent consumption of low-quality snacks, such as sweets and crisps, between meals among Dutch preschool children (71). In adolescents, a low socioeconomic status of the family has been associated with having family meals less frequently (67). However, also the opposite associations have been reported. A Scottish study reported that children from lower socioeconomic groups tended to eat more meals and fewer snacks than children from higher groups (72).

A lower consumption of healthy foods, such as vegetables, fruit and wholemeal bread, and a higher consumption of unhealthy foods, such as sugar-sweetened beverages, desserts, butter and high-fat milk, have consistently been associated with a lower socioeconomic position in children (44,49,73,74). The exclusive use of whole-fat milk was the highest in American children whose parents had the lowest education while the use of low-fat milk was the highest among American children whose parents had the highest education (75).

Differences in food consumption across socioeconomic levels have also been seen in the levels of nutrient intakes. Children who have lower educated parents tend to obtain a higher proportion of energy from added sugar and a lower proportion from PUFA and protein. Moreover, the intakes of some micronutrients, such as vitamin C, vitamin D and calcium, are reported to be lower among children with a lower socioeconomic position (76,77).

There are many possible explanations for the associations of a low socioeconomic position with a lower quality of diet in children due to varying methods used for assessing socioeconomic background. Most commonly, socioeconomic background in children has been assessed using parental education level or household income. However, also the number of children in the family, parental occupational status and the place of residence, have been used. The different aspects of socioeconomic background may contribute to diet in different ways. The associations of socioeconomic background with dietary habits may not only be due to financial constrains or the lack of nutritional knowledge, but also a result of peer group behaviour, lack of time or availability of environmental possibilities, such as accessibility to grocery shops.

2.4.4 Physical activity

Higher levels of physical activity have been related to a more regular eating frequency, particularly related to breakfast, among children and adolescents (78-80). Little is known about the associations of physical activity with the consumption of foods among children.

However, physical activity has been found to predict a better adherence to a Mediterranean diet among children (81), suggesting that physical activity is associated with the consumption of several healthy foods.

Lower levels of physical activity have been associated with a lower energy intake among adolescents (82). It has also been suggested that physically inactive children and adolescents are at risk of inadequate intakes of several nutrients that are essential for optimal growth and development due to their lower energy intake.

2.4.5 Sedentary behaviour

Higher levels of sedentary behaviour have been associated with less healthy dietary choices among children and adolescents (83). For example, a lower consumption of vegetables and fruit and a higher consumption of sugar-sweetened beverages, energy-dense snacks and fast foods have consistently been related to a higher television time in children (83).

Part of the association between electronic media use and an unhealthy diet has been suggested to be due to exposure to television advertisements (84). Another explanation may be the distraction caused by electronic media use, which may lead to the reduction of internal satiety signals (85). Most of the available data deal with the associations of television watching with dietary habits. Whether similar relationships of other sedentary behaviour, such as playing computer games, with dietary factors exist, is not well known.

2.4.6 Genetic factors

Genetic influences explain a moderate to high proportion of the variation in several dietary factors. According to the results of twin studies, the frequency of breakfast eating is highly herited among adults (86), while the number of meals and snacks has been shown to be slighty less herited (87).

Among adults, genetic predisposition has been suggested to explain 20–50% of the variation in food consumption (87,88). Food preferences have also been reported to be partly herited among children (89). In a study among British preschoolers, genetic factors explained 20–50% of the variation in the consumption of vegetables, fruit and desserts and almost 80% of the variation in the consumption of meat (89). However, heritability for the intakes of energy and energy nutrients have been reported to be lower in children (90).

The dimensions of eating behaviour have also been shown to be highly herited. Among children, more than 60% of the variation in eating rate (91,92), satiety responsiveness and enjoyment of food (93) has been explained by genetic predisposition. Heritability seems to explain a higher proportion of eating behaviour traits among preschool children compared to school-age children (92). Among adults, several other eating behaviour dimensions, such as taste preferences (94) and food neophobia (95) have also been observed to be moderately herited.

2.5 OVERWEIGHT AND OBESITY IN CHILDREN

2.5.1 Epidemiology of overweight and obesity in children

The prevalence of overweight and obesity in children and adolescents has increased during the past decades in most developed countries (2,3), including Finland (1,4). In 2006, 10% of boys and 18% of girls were overweight or obese at the age of 5 years. At the age of 12 years, 24% of the boys and 19% of the girls were overweight or obese (4). Between the years 1986 and 2006, the prevalence of overweight in 12-year-old children had increased 1.8-fold in boys and 1.5-fold in girls. However, the prevalence of overweight remained nearly unchanged in children in younger age groups. Recent studies have reported that the increase in the prevalence of overweight and obesity in children seems to be leveling off internationally (96). However, it has been suggested that this trend may partly be explained by a selection bias (97). Because of the increased awareness and also stigmatisation of childhood overweight during the past years, non-participation of overweight children in studies may have become more common. It is also possible that the stabilisation of the increase is due to different trends in subgroups of children. For example, the prevalence of overweight may have decreased in higher socioeconomic groups, while the prevalence has still increased among other groups. Despite the possible plateau, the prevalence of childhood overweight remains high.

Overweight children have a high risk of becoming overweight adults (6). Moreover, overweight in childhood is associated with an increased risk of metabolic syndrome, type 2 diabetes, atherosclerosis, hypertension and premature death in adulthood (5-7,10). Therefore, preventing overweight in children is a major public health challenge. In this review of literature, the term overweight refers to overweight including obesity.

2.5.2 Definition of overweight and obesity in children

The WHO defines overweight and obesity as "abnormal or excessive fat accumulation that may impair health" (98). Because the direct assessment of the amount of fat mass requires expensive and laborious equipment, several surrogate measures of body adiposity have been widely accepted and used. The most commonly used surrogate marker for body adiposity is body mass index (BMI), determined by weight in kilograms divided by height in meters squared. For adults, BMI cutoff points 25–29.9 for overweight and ≥30 for obesity are internationally agreed (98). For children and adolescents, however, the impacts of age, sex, puberty and ethnicity on growth make the classification of body adiposity difficult. So far, there are no worldwide consensus for defining overweight and obesity by BMI cutoff points in children. In Europe, the most commonly used classification of overweight and obesity is that proposed by the International Obesity Task Force (IOTF). The definitions are based on international reference data and provide cutoff points for overweight, corresponding to an adult BMI of 25, and for obesity, corresponding to an adult BMI of 30, taking age and sex into account (99). National growth charts have also been developed and used as national reference data for defining overweight and obesity in children (100).

Particularly excess visceral adiposity increases the risk of cardiometabolic diseases not only in adults, but also in children (101). Waist circumference can be used as a surrogate marker for visceral adiposity. However, the lack of national reference values for waist circumference hinders its use in public health practice.

In research settings, also more accurate and direct measures of body adiposity can be used. Although these techniques are too laborious and expensive for public health practice, they can provide standards for the validation of less direct measures of body adiposity. One of these techniques is dual-energy X-ray absorptiometry (DXA), which utilises the varying absorption of X-ray in different tissues. DXA is shown to be a reliable measure of body adiposity in all age groups, including children (102).

2.5.3 Dietary factors associated with overweight and obesity in children

Overweight is a result of a long-term imbalance between energy intake and total energy expenditure (103). Energy imbalance, however, can be caused by several different habits related to eating, physical activity or sedentary behaviour. Moreover, many genetic, environmental and behavioural factors and their interactions affect energy balance, and in most cases, the cause of overweight is a combination of various factors. Therefore, the identification of individual risk factors for overweight is difficult. Only a few dietary factors have consistently been shown to increase the risk of overweight in children.

Diet in infancy

A longer duration of breastfeeding has convincingly been related to a decreased risk of overweight in children in several systematic reviews and meta-analyses (104-107). In addition to the beneficial effects of exclusive breastfeeding, also a longer duration of breastfeeding after introducing complementary foods is associated with a lower risk of overweight. One meta-analysis observed a dose-response association between breastfeeding and the risk of overweight later in life, every additional month of breastfeeding resulting in a 4% decrease in the risk of overweight (106). However, the most crucial period of breastfeeding showing the most reduction in the risk of overweight seems to be the first six months of life (108).

One explanation for the association of breastfeeding with a lower risk of overweight is that breastfeeding supports self-regulation of food intake in children (109). Even more importantly, a breastfeeding mother must also rely on the self-regulation of the infant instead of regulating the food intake of the infant according to the visual assessment of the amount of food consumed, which may affect the total food intake of the infant. The explanation may also be in the composition of breast milk compared to formula (109). Breast milk contains less protein and more bioactive compounds than formula that may also have favourable long-term effects on the metabolism of the child. The association between breastfeeding and the risk of overweight may, however, be partly confounded by sociodemographic and lifestyle factors, such as lower parental education level and maternal smoking, that have been associated with a shorter duration of breastfeeding (110).

Despite the duration of breastfeeding, early introduction to complementary foods may increase the risk of overweight in later childhood. In a recent review, some studies reported that a delayed introduction to complementary foods in infancy was associated with a lower BMI in later childhood (111). Particularly, an introduction to complementary foods very early, at the age of less than 3–4 months, seemed to associate with a higher BMI. However, some confounding factors, such as the duration of breastfeeding and maternal socioeconomic status, partly explained this relationship in some studies, and no conclusion on the association of the timing of complementary feeding with childhood BMI could be drawn. Moreover, results on the association of the introduction to certain food groups in the infancy with higher BMI in later life are controversial.

Eating frequency

In the past years, irregular eating frequency has gained interest as a risk factor for childhood overweight. Systematic reviews and meta-analyses have shown an association of a higher number of daily eating occasions with a lower risk of overweight in children (112,113). Finnish children (43) and American girls (114) having a regular meal pattern consisting of at least three meals daily have been observed to have a lower body adiposity than children with a less regular meal pattern.

Of daily meals, breakfast has been of particular interest in relation to childhood overweight. Systematic reviews have shown that although the regular eating of breakfast is associated with an increased energy intake, it is also related to a reduced risk of overweight (115,116). However, most of the available data are from observational studies, and therefore no conclusions on the causality of the relationship cannot be drawn.

Recently, meals other than breakfast have also gained interest in relation to overweight. For example, a higher frequency of having dinner together with the family has been associated with a lower risk of overweight (117,118). In another study, however, having lunch or dinner in front of the television was related to an increased risk of overweight among children (119). Snacks have been reported to have a relatively low nutritional value, but the frequency of snacks has not been independently associated with the risk of overweight in children (120,121). However, the role of meals and meal patterns in relation to overweight in young children is challenging to confirm in intervention studies. The causality and the magnitude of the association are still to be established.

The mechanisms explaining the association of a more regular eating with a lower risk of overweight are not yet clearly understood. A more efficient thermogenesis (122) and a better insulin sensitivity (123) due to a more regular eating have been suggested as possible biological mechanisms. However, there is no strong evidence for these favourable metabolic effects of regular eating (124). Moreover, regular eating in children has also been related to other healthy lifestyle factors, such as a lower energy intake from between-meal snacks (125), a higher level of physical activity (126) and a more frequent participation in sports (127), that may partly explain the association.

Food consumption

There is a wide public health concern about the high proportion of energy derived from sugar-sweetened beverages in the diet of children (128). A recent meta-analysis showed that a higher consumption of sugar-sweetened beverages is associated with a higher weight gain among children (129). The pooled estimate of seven prospective studies indicated that each additional daily serving of sugar-sweetened beverages increased the BMI by 0.06 over a period of one year. One of the most plausible explanations for the association of a higher consumption of sugar-sweetened beverages with overweight is the lower satiety responses after energy taken from fluid compared to a solid meal, resulting in no compensatory decrease in energy intake in later meals. Another explanation may be that a higher consumption of sugar-sweetened beverages is related to other eating habits, such as a higher consumption of candies and sweet snacks (130) that underlie the association.

Furthermore, a lower consumption of breakfast cereals was associated with a higher risk of overweight in a recent review (131). Children and adolescents who consumed breakfast cereals regularly had a 10–50% lower risk of being overweight than children who consumed cereals irregularly or not at all (131). Whether the protective effect was due to the consumption of breakfast cereals or the breakfast as such could not be clarified. However, two of the studies included in the review found that children who ate other foods for breakfast than cereals tended to have their BMI values between children who ate cereals for breakfast and children who skipped breakfast (132,133). This finding suggests that eating cereals for breakfast may be the specific eating habit that is associated with a lower risk of overweight in children.

Findings on the associations of consumption of other foods with the risk of overweight in children have varied more. Some studies have reported the association of a lower consumption of vegetables and fruit with a higher body adiposity in children and adolescents (134,135), whereas some other studies have reported an opposite relationship (136) and most studies have not found any association (137). Moreover, lower consumptions of whole grain products (135,138) and low-fat dairy products (135) and higher consumptions of meat (139) and fast foods (134) have been associated with a higher body adiposity among children, but the findings have not been confirmed in other studies.

Intakes of energy and energy nutrients

Although many studies have investigated the role of the intake of energy and nutrients in the development of childhood overweight, conflicting findings have been reported, and a clear concensus on the topic is lacking (13). It has been suggested that energy imbalance causing the development of excess body fat is relatively small but lasts a long period of time. Therefore, the association of energy intake with overweight in children is difficult to observe in short-term studies. The strong interrelationships between energy nutrient intakes hamper studies attempted to observe the independent associations of single energy nutrients with overweight.

One of the most consistent findings concerning the associations of energy nutrients with the risk of overweight in children is the relationship between a higher protein intake in infancy and during the transition to the family diet and a higher risk of overweight in later childhood (140). One explanation for this observation is that a high protein intake stimulates the secretion of insulin-like growth factor 1 (IGF-1) in circulating plasma (141). The increased plasma IGF-1 levels may then accelerate growth and increase skeletal muscle mass and adipose tissue by increasing protein synthesis and cell proliferation. For example, the higher composition of protein in formula compared to breast milk is suggested to be one of the explanations for the association of the lack of breastfeeding in infancy with the increased risk of overweight in later childhood. However, these mechanisms have been suggested to begin to operate only in populations with high intakes of protein. Agostoni et al. suggested that a safe intake of protein during the first years of life would be 8–12 E% (142). They also suggested that the positive correlation between protein intake and body adiposity in later childhood would be seen only if protein intake exceeds 15–16 E% (142). Some studies have also reported that an increased protein intake at preschool age is associated with an increased risk of childhood overweight (143,144). However, few studies have confirmed these findings (13).

A high fat intake has been suggested as one of the reasons for the development of overweight among children, because the energy density of fat is much higher than that of other sources of energy. However, the findings of the association between fat intake and the risk of overweight in children are inconclusive (13). A lower intake of dietary fibre (145) and a higher intake of sugar (146) have been associated with a higher risk of overweight in some studies. However, these observations have not been confirmed in other studies, and therefore no conclusions can be drawn.

Dietary quality assessed by indices

Despite the increasing use of dietary quality indices in studies, reports on their associations with childhood overweight are scarce (Table 1). The adherence to the DASH-style diet has been used as an indicator of a healthy diet in some studies in children. In a Canadian cross-sectional study, a higher adherence to the DASH eating pattern was associated with a lower BMI, waist circumference and hip circumference and a lower risk of being overweight in both boys and girls aged 12 years (147). In line, an American study on almost 2400 girls aged of 9–10 years in the beginning of the study found that the girls who had the highest DASH Score had the smallest gain in BMI over a 10-year follow-up and the lowest BMI in the end of the study (135).

A recent study in a sample of 16220 children aged 2–9 years from eight European countries found that a higher MDS was associated with a lower risk of being overweight (55). The results on the association of MDS with overweight or other adiposity indicators in studies using national samples, however, have not been consistent: one reported an inverse association (148), whereas one did not find any relationship between MDS and adiposity indicators (149).

Among British children 9–10 years of age, higher scoring in the HDI was associated with a lower waist circumference and body fat percentage (149). However, the association of HDI with body adiposity in children has not been assessed in any other studies. Moreover, while a higher BSDS has been associated with a lower waist circumference among Finnish adults (150), no studies have investigated the association of BSDS and body adiposity in children so far. In line, the relationship of FCHEI with body adiposity in children has not been studied so far.

Table 1. Studies on selected dietary quality indices and body adiposity measures in children and adolescents

Reference	**Subjects**	**Measure of body adiposity**	**Dietary quality index**	**Results**
Kontogianni et al. 2008 (151)	1305 children and adolescents 3–18 years of age	BMI	MDS (KIDMED)	In sub-group of adolescents (13–18 y) only, a lower KIDMED score was associated with a higher BMI.
Lazarou et al. 2010 (152)	1140 children and adolescents 9–13 years of age	Overweight by IOTF	MDS (KIDMED)	A lower KIDMED score was associated with a higher risk of being overweight. The association was no longer statistically significant when adjusted for physical activity.
Schröder et al. 2010 (148)	2513 adolescents and young adults 10–24 years of age	Waist	MDS (KIDMED)	A lower KIDMED score was associated with a higher waist.
Berz et al. 2011 (135)	2327 children 9 years of age	BMI-SDS	DASH Score	A lower DASH Score was associated with a higher gain in BMI during the 10-year follow-up.
Jennings et al. 2011 (149)	1700 children 9–10 years of age	BMI-SDS Waist Body fat percentage	HDI MDS	Waist and body fat percentage were higher in the first quintile of the HDI than in the fifth quintile. The MDS was not associated with any adiposity measure.
Hajna et al. 2012 (147)	1570 adolescents with mean age of 12.4 years	BMI Waist Hip Overweight by IOTF	DASH Score	A lower DASH Score was associated with a higher BMI, waist and hip circumference and risk of being overweight.
Tognon et al. 2013 (55)	16220 children 2–9 years of age	Waist Body fat percentage Overweight by IOTF	MDS	A lower MDS was associated with a higher body fat percentage and a higher risk of being overweight.

BMI, body mass index; IOTF, International Obesity Task Force (99); DASH, Dietary Approach to Stop Hypertension; BMI-SDS, body mass index standard deviation score; MDS, Mediterranean Diet Score; KIDMED, Mediterranean Diet Quality Index in children and adolescents; HDI, Healthy Diet Indicator. Reference numbers are given in brackets.

Eating behaviour

Several behavioural aspects play an important role in the development of overweight in children (31). According to the findings based on the CEBQ, behavioural factors measuring food approach, such as food responsiveness, emotional overeating and enjoyment of food, have been directly associated with body adiposity measures, while factors measuring food avoidance, such as satiety responsiveness, slowness in eating, emotional undereating and food fussiness, have been inversely associated with body adiposity measures (Table 2) (62,153-157). Furthermore, desire to drink has been associated with the weight status in some studies (62,155). Higher scores in desire to drink have also been related to a higher consumption of sugar-sweetened and artificially-sweetened sodas but have not been associated with the consumption of water (158), suggesting that the desire to drink is rather an indicator of desire for sweet taste than of a greater thrist or hunger. In contrast to other studies, a Swedish study on children 1–6 years of age did not find association of any of the eating behaviour traits with BMI-SDS in children (63). The finding suggests that the association of eating behaviour with overweight may not be observable at an early age.

Table 2. Studies on the Children's Eating Behaviour Questionnaire (QEBQ) and body adiposity measures in children

Reference	Subjects	Adiposity measure	Association of measures from Children's Eating Behaviour Questionnaire (CEBQ) with body adiposity measures							
			Enjoyment of food	**Food respon-siveness**	**Emotional overeating**	**Desire to drink**	**Satiety respon-siveness**	**Slowness in eating**	**Emotional undereating**	**Food fussiness**
Carnell & Wardle 2008 (159)*	572 children 3–5 years of age	BMI-SDS		+			-			
	10364 children 8–11 years of age	BMI-SDS		+			-			
		Waist-SDS		+			-			
Sleddens et al. 2008 (154)	135 children 6–7 years of age	BMI-SDS	+	+			-	-		
Viana et al. 2008 (153)	240 children 3–13 years of age	BMI-SDS	+	+	+		-	-	-	-
Webber et al. 2009 (155)	406 children 7–12 years of age	BMI-SDS	+	+	+	+	-	-		- (in girls)
		Overweight by IOTF	+	+	+	+	-	-		-
Santos et al. 2011 (156)	250 children 6–12 years of age	Overweight by IOTF	+	+	+		-	-		
Spence et al. 2011 (160)	1730 children 4–5 years of age	Overweight by CDC								
Svensson et al. 2011 (63)	174 children 1–6 years of age	BMI-SDS								
Rodenburg et al. 2012 (157)	1275 children 8–11 years of age	BMI-SDS	+	+	+	+	-	-	-	-

BMI-SDS, body mass index standard deviation score; Waist-SDS, waist circumference standard deviation score; IOTF, International Obesity Task Force (99); CDC, Centers for Disease Control and Prevention (161).

*Only the traits food responsiveness and satiety responsiveness of the questionnaire were used in the study.

+, direct association; -, inverse association.

Reference numbers are given in brackets.

2.5.4 Other factors associated with overweight and obesity in children

According to twin studies, genetic factors play a significant role in the development of overweight from early childhood (15,162). The genetic influence increases according to age, explaining approximately 50% of the variation in BMI at the age of four but almost 80% of the variation in BMI at the age of 11 (163). The role of each single gene polymorphism is small. However, the association of the common polymorphism (rs9939609) of the fat mass and obesity associated (FTO) gene with the risk of overweight has consistently been replicated in both adult and child populations (164).

A high birth weight, an indicator of intrauterine overnutrition, is strongly associated with a higher BMI in later childhood (165). Moreover, some studies have found that a low birth weight is also related to childhood overweight, particularly when accompanied by a high catch-up growth during the first year of life (165). However, the results on the association of a low birth weight with later overweight are not as consistent as those on the association of a high birth weight (166). A lower birth weight seems to be rather associated with a higher accumulation of visceral fat and a higher risk of related cardiometabolic diseases than with BMI or overweight (167).

Another critical period for the development of overweight seems to be the adiposity rebound that corresponds to the increase in BMI that occurs usually between ages 5 and 7 years following a decrease in BMI after the first year of life. An early timing of adiposity rebound has been associated with a higher BMI in later childhood (168). It has been suggested that both the number and the size of adipocytes increase rapidly at the age of adiposity rebound. However, it has been speculated whether the timing of the adiposity rebound provides any further confirmation in the prediction of later overweight than single measurements of BMI in childhood (169).

Parental overweight is a well-established risk factor for overweight throughout childhood. A study in a Finnish birth cohort showed that children whose both parents were overweight before pregnancy and throughout the childhood had a 10–15-fold risk of being overweight at the age of 16 years, compared to children whose parents were normal weight (170).

A higher maternal weight gain during pregnancy may also be associated with a higher risk of overweight in offspring. In an American sample, the risk of being overweight at the age of 7 years increased by 3% for every 1 kg of maternal weight gain during pregnancy (171).

Moreover, children born to mothers with gestational diabetes have a higher risk of overweight and obesity later in childhood. In a recent Swedish study, also siblings who were born after a non-diabetic pregnancy of mothers who had had prior gestational diabetes had an increased risk of overweight and obesity (172). This finding suggests that the association of maternal gestational diabetes with the overweight of offspring may be due to lifestyle habits of the family in addition to intrauterine factors associated with gestational diabetes.

Recent studies have suggested that gut microbiota could be associated with the development of overweight by influencing energy regulation among adults (173). Recently, differences in concentrations of bacterial species in gut microbiota also between normal weight and obese children have been reported (174,175). At the moment, the causality of the association of gut microbiota and childhood overweight as well as the magnitude of the contribution of gut microbiota to childhood overweight are yet to be established.

In addition, behavioural and sociodemographic heredity seems to play a significant role in the transmission of overweight from parents to offspring. A lower socioeconomic position increases the risk of being overweight in children (176) and adolescents (177). Moreover, maternal smoking during pregnancy has been reported to increase the risk of childhood overweight 1.5-fold in a meta-analysis (178). Other sociodemographic and behavioral factors did not explain this association.

Low levels of physical activity (179), high levels of sedentary behaviour, such as electronic media use (180), and a shorter sleep duration (181) of the child have also been associated with a higher risk of overweight in children.

2.6 CARDIOMETABOLIC RISK IN CHILDREN

2.6.1 Definition of cardiometabolic risk in children

Excess body fat, particularly in the visceral depots, has been associated with cardiometabolic risk factors, such as impaired insulin sensitivity, impaired glucose metabolism, dyslipidaemia, and elevated blood pressure in adults (182). The cluster of these factors is called the metabolic syndrome (183), and it predicts cardiovascular diseases (184), type 2 diabetes (185) and premature mortality in adults (184).

The cluster of cardiometabolic risk factors starts developing already in childhood and often tracks into adulthood (7). A higher cardiometabolic risk in childhood has been related to a higher risk of metabolic syndrome (7), type 2 diabetes (9) and premature death (8) in adulthood. Therefore, the identification of children with an elevated cardiometabolic risk is critical for initiating early interventions to prevent future complications.

Among adults, diagnostic criteria for the metabolic syndrome are internationally agreed (186). Despite the attempts to define the diagnostic criteria for metabolic syndrome in children and adolescents, thus far, no generalised cutoff points for metabolic risk factors or for metabolic syndrome have been established for children (187). In research, paediatric metabolic syndrome has been defined using several different criteria modified from definitions originally developed for adults (188,189). Currently, the only diagnostic tool for defining metabolic syndrome is the definition published by International Diabetes Federation (Table 3) (190). However, according to this definition, metabolic syndrome cannot be diagnosed in children younger than 10 years of age.

The cardiometabolic risk factors seem to be linearly associated with the risk of cardiovascular diseases in later life and, therefore, the cutoff points for risk factors for children are somewhat arbitrary (187). Recent studies have described continuous metabolic risk scores representing composite cardiometabolic risk factor profiles (191). These scores are commonly calculated as a sum of standardised risk factors. The use of a continuous score enables studying the development of cardiometabolic diseases starting at an early age when the risk factors are still at a relatively normal level. Moreover, the use of metabolic risk score can partly compensate the within-person fluctuation in single risk factors and therefore more precisely indicate subjects at high metabolic risk. Furthermore, because the prevalence of metabolic syndrome in children and adolescents is low according to any existing definition (192), the use of a continuous score describing the cardiometabolic risk instead of a dichotomous definition increases the statistical power in analyses. The metabolic risk score has been suggested to be a better predictor for the development of adult metabolic syndrome than the dichotomous definition of metabolic syndrome in childhood (193).

Table 3. The International Diabetes Federation definition for metabolic syndrome in children and adolescents (190)

Age	Abdominal obesity	Glucose metabolism	Fasting triglycerides	Fasting HDL cholesterol	Blood pressure
6 to <10 years[a]	Waist circumference ≥90th percentile				
10 to <16 years	Waist circumference ≥90th percentile or adult cutoff if lower	Fasting glucose concentration ≥5.6 mmol/l or known type 2 diabetes	≥1.7 mmol/l	<1.03 mmol/l	Systolic ≥130 mmHg or diastolic ≥85 mmHg
≥16 years[b]	Waist circumference ≥94 cm in men, ≥80 cm in women[c]	Fasting glucose concentration ≥5.6 mmol/l or known type 2 diabetes	≥1.7 mmol/l or treatment for this dyslipidaemia	<1.03 mmol/l in men, <1.29 mmol/l in women or treatment for this dyslipidaemia	Systolic ≥130 mmHg or diastolic ≥85 mmHg or treatment for hypertension

[a] Metabolic syndrome cannot be diagnosed, but further measurements should be made if the child has abdominal obesity and a family history of cardiometabolic diseases.
[b] International Diabetes Federation criteria for adults. Metabolic syndrome is diagnosed with abdominal obesity and any two other factors.
[c] Cutoffs for white people with European origin. Different cutoffs for other enthicities exist.

2.6.2 Dietary factors associated with cardiometabolic risk in children

Thus far, dietary factors associated with the cluster of cardiometabolic risk factors have not been well characterised in children. The current evidence is mostly based on findings on single risk factors. Moreover, current findings on the topic in Finnish primary school children are scarce.

Diet in the infancy

In an Australian birth cohort, children who were breastfed less than 4 months had an increased risk of having a clustered metabolic risk at the age of 8 years compared to children who were breastfed longer (194). Of single risk factors, the levels of systolic and diastolic blood pressure were observed to be higher at the age of 7 years among British children who had never been breastfed compared to children who had been breastfed (195). Adjustment for childhood BMI did not alter these associations. Other studies have found an association of being breastfed with lower concentrations of total cholesterol and LDL cholesterol in adulthood but not in childhood or adolescence (196).

The explanations for the beneficial effects of breastfeeding on cardiometabolic health in children are still to be established. It has been suggested that the composition of breast milk could explain the findings (197). For example, the lower sodium content and the optimally varying fatty acid composition of breast milk compared to formula or complementary foods could have beneficial effects on the metabolism of the infant.

Eating frequency

Although eating frequency seems to play an important role in the development of overweight in children, as described in chapter 2.3.2, only few studies have assessed the association of eating frequency with the features of metabolic syndrome in youth, particularly in young children (Table 4). Among adults, a more frequent eating frequency has been associated with reduced concentrations of total cholesterol, LDL cholesterol and triglycerides and lower levels of blood pressure (198). In line, studies on children and adolescents have reported that a more frequent eating frequency is associated with blood lipids, particularly with a lower concentration of total and LDL cholesterol (199,200) and a lower ratio of total-to-HDL cholesterol (199). Moreover, a recent study among Finnish adolescents found that a regular five-meal-a-day pattern including breakfast was associated with reduced risks of hypertriglyceridaemia in boys even after adjustment for several confounding factors, including maternal BMI (200). Moreover, a lower risk of hypertension was found in girls who had an irregular eating frequency but had breakfast compared to those who had an irregular eating frequency and skipped breakfast. The association of a higher frequency of breakfast with a better insulin sensitivity has also been reported among boys (201), while an other study found no association between the frequency of breakfast and insulin dynamics (202).

The reported metabolic effects of eating frequency could be a result of a lower concentration of circulating insulin released from pancreas as a result of eating several small meals during the day compared to infrequent large meals that release a sudden surge of insulin. Lower concentrations of insulin would result in less cholesterol synthesis in the liver and hence, lower concentrations of circulating cholesterol (198).

Table 4. Studies on eating frequency and cardiometabolic risk in children

Reference	**Subjects**	**Measures of cardio-metabolic risk**	**Eating frequency measures**	**Results**
Alexander et al. 2009 (202)	93 children and adolescents 10–17 years of age	Glucose tolerance test	Frequency of breakfast	Frequency of breakfast was not associated with insulin dynamics.
Sesé et al. 2012 (201)	895 children and adolescents 12–17 years of age	Metabolic risk score, homeostasis model assessment index	Frequency of breakfast and snacks	Snacking during school day was associated with a higher metabolic risk score among girls. Skipping breakfast was associated with a higher insulin resistance, measured by homeostasis model assessment index, among boys.
Jääskeläinen et al. 2013 (203)	6247 adolescents 16 years of age	Prevalence of metabolic syndrome, metabolic syndrome components	Frequency of daily meals	A regular five-meal-a-day was associated with a lower risk of hypertriglyceridaemia in boys. Adjusting for childhood factors, such as BMI, diminished the relationship.
Moschonis et al. 2013 (199)	2043 children and adolescents 9–13 years of age	Total, LDL and HDL cholesterol	Number of eating occasions	A higher number of eating occasions combined with higher levels of physical activity was associated with lower concentrations of total and LDL cholesterol and a lower total-to-HDL cholesterol ratio.
Murakami et al. 2014 (200)	818 children 4–10 years of age	Total, HDL and LDL cholesterol, blood pressure	Number of eating occasions	A more frequent eating frequency was associated with lower concentrations of total and LDL cholesterol.

BMI, body mass index; LDL, low density lipoprotein; HDL, high density lipoprotein.
Reference numbers are given in brackets.

Food consumption
Although the complete role of food consumption in the development of cardiometabolic risk is not yet comprehensively studied, the association of a higher consumption of sugar-sweetened beverages with impaired cardiometabolic health in children has been consistently detected. A higher consumption of sugar-sweetened beverages has been related to higher concentrations of plasma glucose (204), lower concentrations of HDL cholesterol (199,205,206), higher levels of systolic blood pressure (206,207) and diastolic blood pressure (204) and a higher clustering of several cardiometabolic risk factors (208) among children and adolescents in cross-sectional studies. Moreover, a prospective study among Australian adolescents showed that girls who moved into the highest tertile of the consumption of sugar-sweetened beverages between the ages of 14 and 17 years had a three times higher risk of being classified at a high metabolic risk at the age of 17 years than did girls who remained in the lowest tertile of the consumption of sugar-sweetened beverages (209).

Moreover, a lower consumption of breakfast cereals, chocolate- and nut-based spreads, jam and honey has also been associated with a higher metabolic risk score among a large sample of children 2–9 years of age from eight European countries (208). The authors discussed that these foods are commonly consumed at breakfast and a low consumption of them may therefore indicate omitting breakfast. In line, a lower consumption of breakfast cereals has also been associated with higher concentrations of total cholesterol and LDL cholesterol among American boys (210) and adolescent girls (211).

Other findings of the associations of food consumption with cardiometabolic risk among children have been mostly from single studies and have not been confirmed so far. For example, a higher consumptions of white bread, solid cooking fats and fast foods, such as hamburgers and pizza, have been associated with a higher cardiometabolic risk or higher levels of risk factors in children and adolescents (201,204,212). Some studies have also reported an association of lower consumption of fruit and vegetables with a higher risk of having metabolic syndrome in children (212) and adolescents (213). Findings concerning the relationship of the consumption of dairy products with cardiometabolic risk have been inconsistent (212,214,215).

Intakes of energy and energy nutrients
Although most of the studies that have investigated the association of diet with cardiometabolic risk factors in children have focused on the intakes of single nutrients, the findings are mostly inconclusive. A higher intake of total fat and SFA has been related to a higher concentration of fasting insulin and a higher insulin resistance among children (216,217). Moreover, a higher intake of total fat, SFA and MUFA has been associated with a higher systolic blood pressure among children (216). These findings were partly independent of BMI-SDS (216). In addition, an infancy-onset dietary counceling for a low SFA intake has been shown to result in an improved insulin sensitivity and lower concentrations of serum total and LDL cholesterol among Finnish children (218,219). It has been suggested that the quality of dietary fat could affect the fatty acid composition in cell membranes, and membranes high in saturated fat could impair insulin sensitivity by reducing insulin receptor binding and glucose transporter translocation (220,221).

Studies on the association of the intake of protein with cardiometabolic risk factors in children are scarce (140). Some studies have reported that a higher intake of protein is associated with lower levels of diastolic and systolic blood pressure in children (222,223). However, one study showed that the association of a higher protein intake with lower blood pressure diminished when calcium intake was taken into account, suggesting that a higher intake of calcium could have the independent effect on blood pressure rather than that of protein (222). In line, the findings on the association of protein intake with insulin resistance are inconclusive. A high intake of dairy protein, particularly whey, has been suggested to increase the concentration of fasting insulin among children (224), but the relationship is yet to be eshtablished.

The intake of total carbohydrates has shown inconsistent associations with cardiometabolic risk factors (13), however, the quality of carbohydrates has shown a more consistent effect. A higher intake of dietary fibre has been associated with lower insulin resistance (225) and a lower concentration of total cholesterol (226). A higher intake of soluble fibre has also been associated with having a lower number of metabolic risk features among children (227). Soluble fibre is reported to modulate insulin response to carbohydrates and to cause a blunted postprandial insulin secretion (228). Moreover, soluble fibre has the ability to bind bile acids in small intestine, resulting an increase in the excretion of bile acids in faeces and thus, a decrease in the circulating total and LDL cholesterol (229).

Moreover, a higher intake of sugar has been associated with a higher insulin resistance (225), a higher concentration of triglycerides and a higher diastolic blood pressure (230) among children. A high amount of rapidly absorbable carbohydrates, such as sucrose, may cause a high glycemic load, which can result in glucose intolerance and insulin resistance. Moreover, some adverse health effects may also be partly due to fructose, most commonly consumed as part of sucrose. Fructose is known to stimulate hepatic de novo lipogenesis which may result in increased concentration of plasma triglycerides (231). Moreover, a high intake of fructose, at least in some people, may increase the levels of uric acid, which may be associated with elevated blood pressure (207).

Dietary quality assessed by indices

The DASH eating pattern was originally developed to prevent hypertension in adults and the association of this diet with blood pressure levels has been studied extensively among adults (232). The association of the adherence to the DASH-style diet with blood pressure among children and adolescents has been studied to a lesser extent. In line with the results among adults, the adherence to the DASH-style dietary pattern, defined as high intakes of vegetables, fruit and dairy products in the study, was associated with a smaller yearly increase in blood pressure over 8 years in American children of the Framingham Children's Study (23). Moreover, the adherence to the DASH-style dietary pattern was related to a decreased risk of having elevated blood pressure among adolescent girls, also independently from BMI (233). To date, only one study has assessed the effect of DASH eating pattern on the metabolic syndrome among adolescents (234). In this cross-over clinical trial, 60 post-pubertal girls 9–17 years of age with metabolic syndrome were randomized to receive either the recommendation to follow the DASH diet or usual dietary advice for six weeks. The recommendations to follow the DASH diet, compared with the usual dietary advice, reduced the prevalence of high blood pressure and metabolic syndrome. However, no effects on glucose or lipid profiles were found. Whether the DASH-style diet is associated with cardiometabolic risk factors and the combination of them in prepubertal children is not known.

Studies on the association of Mediterranean diet with cardiometabolic health in children are scarce. Among Cypriot children 10–13 years of age, children who had an average or a high adherence to the Mediterranean-like eating pattern had a 75% lower risk of having elevated diastolic blood pressure, compared with those with a low adherence to that diet (235). The associations of the BSDS, HDI and FCHEI with cardiometabolic risk among children have not been studied thus far.

Eating behaviour

Studies on the associations of eating behaviour with cardiometabolic risk in children are rare. Among adults, a higher eating competence, indicating more relaxed eating attitudes, a higher food acceptance, a higher internal regulation of food intake and better skills in planning eating, has been associated with lower levels of systolic and diastolic blood pressure, higher concentrations of HDL cholesterol and a lower risk of having high concentrations of LDL cholesterol and triglycerides (236). Among children, having binge eating episodes was associated with a higher risk of metabolic syndrome in children with overweight or with a high risk of becoming overweight (237). However, other studies on the topic among children and adolescents are lacking.

2.4.3 Other factors associated with cardiometabolic risk in children

A high familial aggregation in cardiometabolic risk factors has been documented among adults (238). In a recent study among Mexican American children and adolescents from families with an increased risk of type 2 diabetes, metabolic syndrome exhibited 68% heritability (239).

Early growth is suggested to contribute to the development of cardiometabolic risk factors, also independently from body adiposity. As proposed by Barker (240), a small birth weight for gestational age, an indicator of inappropriate intrauterine nutrition and growth, is associated with an increased cardiometabolic risk later in life. It is known that a deficient nutrient intake may lead to structural and metabolic adaptation in organs less prior in fetal development, as fetus favours the nutrient adequacy in most crucial organs, such as the brain. The consequences of these adaptations are seen already at young age. Children who are born small for gestational age are reported to have higher insulin resistance (241,242) and a higher concentration of plasma triglycerides (243) already in childhood. An accelerated catch-up growth during the first months of life seems to play a role in the association of size at birth with cardiometabolic risk. Among children born small for gestational age, an increased insulin resistance was detected among those children who had had a high catch-up growth but not among those children who did not have that. Moreover, an accelerated growth velocity during the first months of life seem to increase the insulin resistance in later childhood only among children born small for gestational age, not among children born appropriate for gestational age (243,244). These findings suggest that a combination of a low birth weight and an accelerated growth velocity during infancy is particularly detrimental for cardiometabolic health in later childhood. In line with accelerated growth, also body height is associated with a higher cardiometabolic risk, independently of body adiposity, among children (245).

Early timing of adiposity rebound has been associated, not only with adiposity as described in chapter 2.3.3, but also with an adverse cardiometabolic profile in adulthood (246). This relation is independent of growth in infancy or BMI at the time of adiposity rebound.

In addition to the development of overweight in offspring, as described in chapter 2.3.3, parental background seems to affect the development of cardiometabolic dysfunctions in offspring, also independently of body adiposity. For example, a low family income was one of the strongest predictors of insulin resistance among Greek children 9–13 years of age, also after controlling for BMI of the children (241). Moreover, maternal current smoking status has been associated with a high cluster of metabolic risk factors among children even after controlling for child BMI (247). Maternal smoking status may be an indicator of smoking during pregnancy, which has also been associated with a higher risk of having a cluster of metabolic risk factors at the age of 8 years (194).

Lifestyle habits contribute to cardiometabolic health throughout childhood. In a recent review, a majority of the included studies reported an association of lower levels of physical activity with a higher insulin resistance independently from body adiposity (248). Moreover, lower levels of physical activity have been associated with a higher clustering of several metabolic risk factors among European children 9–15 years of age (249). In a recent study, particularly a low amount of vigorous physical activity was associated with a higher metabolic risk score (250). Furthermore, high levels of sedentary behaviour, particularly high levels of electronic media time, have been associated with a higher cardiometabolic risk in children (251).

3 *Aims of the study*

The aim of this doctoral thesis was to investigate dietary factors and their associations with overweight, body adiposity and cardiometabolic risk in a population sample of Finnish girls and boys 6–8 years of age.

The specific aims of the doctoral thesis were

1. to investigate eating frequency, food consumption and nutrient intake and the associations of socioeconomic background with eating frequency and food consumption in children (*Study I*),

2. to study the associations of eating frequency, nutrient intake and eating behaviour with overweight, body adiposity and waist and hip circumferences in children (*Study II*),

3. to examine the associations of eating frequency and food consumption with the clustering of cardiometabolic risk factors in children (*Study III*),

4. to compare the relationships of previously developed dietary quality indices to body adiposity and the clustering of cardiometabolic risk factors and to develop a new dietary quality index specifically to measure cardiometabolic risk in children (*Study IV*).

4 Study design and study population

4.1 DESIGN OF THE PHYSICAL ACTIVITY AND NUTRITION IN CHILDREN (PANIC) STUDY

This doctoral thesis was conducted as part of the Physical Activity and Nutrition in Children (PANIC) Study. The PANIC Study is a long-term controlled exercise and diet intervention study in a population sample of primary school children from the city of Kuopio, Finland (Figure 1). The baseline examinations were performed in 2007–2009. The participants were allocated into the exercise and diet intervention group (n=309) and into the control group (n=203), according to schools. Children and their parents in the intervention group received intensive, family-based physical activity and diet counselling for two years. Control children did not receive any intervention during the two-year period. A two-year follow-up study was carried out for all children in 2009–2012 with the same assessments as in the baseline study. Thereafter, a less intensive intervention will continue until adulthood for the intervention group. The participants will be re-examined in adolescence and in early adulthood.

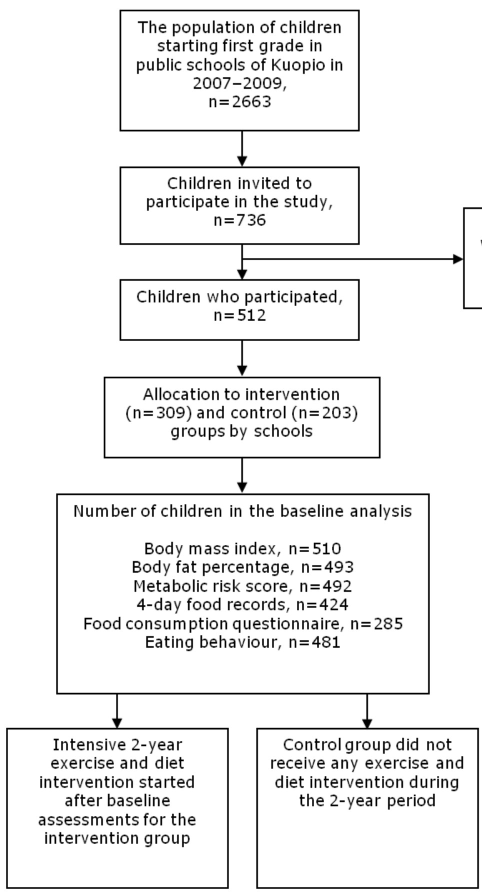

Figure 1. Flow chart of the Physical Activity and Nutrition in Children (PANIC) Study population

The aim of the PANIC Study is to identify risk factors and risk groups for chronic diseases already in early childhood and to study the effects of physical activity, sedentary behaviour, diet and genetic factors on health and wellbeing among children and adolescents.

The study protocol of the PANIC Study was approved by the Research Ethics Committee of the Hospital District of Northern Savo. All participating children and their parents gave their informed written consent.

This doctoral thesis follows a cross-sectional study design using the baseline measurements of the PANIC Study. The children in the intervention group had not received any exercise or diet intervention at the time of the baseline measurements, and the intervention and control children were treated similarly during the measurements. Therefore, this doctoral thesis treats the baseline data as a cohort.

4.2 PARTICIPANTS

Invitation letters were sent to the principal custodian of children by mail according to the registration for first class of 16 public schools of the city of Kuopio. Private schools and classes providing preparing education for immigrant children and classes for children with severe special needs were excluded. The parents were asked to contact the study for participation. If the parents did not make contact, they were contacted by telephone. Of 736 invited children, 512 (70%) participated in the baseline study. In the 16 public schools of Kuopio, the participation rate differed from 55 to 87%. Of the participants, 248 (48.4%) were girls and 264 (51.6%) were boys. The participants did not differ in sex distribution, age or BMI-SDS from other children of the same age from primary schools of Kuopio based on available school health examination data (data not shown).

Table 5 summarises the number of subjects and inclusion criteria in *Studies I–IV*.

Table 5. Number of children and inclusion criteria in *Studies I–IV*

Study	**Number of children (girls, boys)**	**Inclusion criteria**
Study I	424 (211, 213)	Reliably filled food record available
	285 (147, 138)	Filled PANIC Food Consumption Questionnaire available
Study II	510 (247, 263)	Reliable body weight measurement available
	493 (242, 251)	Reliable body fat percentage measurement available
	481 (235, 246)	Filled Eating Behaviour Questionnaire available
	422 (210, 212)	Reliably filled food record available
Study III	408 (199, 209)	Reliable measures of all components needed for the calculation of the metabolic risk score available Reliably filled food record available
Study IV	413 (200, 213)	Reliable measures of all components needed for the calculation of the metabolic risk score available Reliably filled food record available

5 Methods

5.1 ASSESSMENTS

5.1.1 Dietary intake

Eating frequency, food consumption and nutrient intake were measured by food records administered by the parents on four predefined consecutive days, including either two weekdays and two weekend days (99.5 % of subjects) or three weekdays and one weekend day (0.5 % of subjects). Parents were instructed to record all food and drink consumption of their children by household measures and to ask their children about the food and drink consumption outside home. Schools and afternoon day care centres were asked for the details of the food served to the children, e.g. cooking fat and spread on the bread. Food records were reviewed by a clinical nutritionist of the study at return. Meals were defined by the nutritionists according to the recorded time and the type of food individually for each child taking into account the whole meal pattern of the child. Breakfast, lunch and dinner were classified as main meals and all smaller meals and eating and drinking occasions between main meals, including afternoon and evening snacks, as snacks. Food records were analysed using the Micro-Nutrica® dietary analysis software (version 2.5, the Social Insurance Institution of Finland). Data on nutrient intake obtained are based on Finnish laboratory analyses and international food composition tables (252). The Micro-Nutrica® software is a flexible database permitting continuous updates of existing food composition data and additions of new foods and recipes. Periodic updates were made to the database and new food items and products were added with their precise nutrient composition details received from the producers.

Food consumption was also assessed by the structured 17-item PANIC Food Consumption Questionnaire developed for the present study to complete the food record data. The type of usually chosen foods and the frequency of consumption of selected food items were recorded. Parents filled out the questionnaire on behalf of their child.

5.1.2 Dietary quality indices

Five previously published dietary quality indices, the DASH Score, BSDS, MDS, HDI and FCHEI were calculated as presented in Table 6.

The Diet to Assess Metabolic Risk in Children (DIMERIC) Score (Table 6) was designed as a food-based tool for the prediction of cardiometabolic risk in primary school children based on the findings of *Study III* (253). The consumptions of vegetable oils, low-fat (<60 %) vegetable oil-based margarines, sugar-sweetened beverages and red meat were included in the score, because they were independently associated with the metabolic risk score in children (253). The four components of the score were coded according to tertiles of their distribution. The consumption of vegetable oils was coded as 0 for the lowest tertile, as 1 for the middle tertile and as 2 for the highest tertile. Scoring was reversed for low-fat (<60 %) vegetable oil-based margarines, sugar-sweetened beverages and red meat. The components of the score were summed up to calculate the DIMERIC Score.

Table 6. Construction of dietary quality indices

	Components	**Scoring**
Dietary Approach to Stop Hypertension (DASH) Score[a] (254)	Fruit and fruit juice, g/d	Quintile 1=1, Quintile 2=2, Quintile 3=3, Quintile 4=4, Quintile 5=5
	Vegetables, excl.potatoes, g/d	Quintile 1=1, Quintile 2=2, Quintile 3=3, Quintile 4=4, Quintile 5=5
	High-fibre (≥5%) grain products, g/d	Quintile 1=1, Quintile 2=2, Quintile 3=3, Quintile 4=4, Quintile 5=5
	Low-fat (<1%) milk and sour milk products, g/d	Quintile 1=1, Quintile 2=2, Quintile 3=3, Quintile 4=4, Quintile 5=5
	Red meat and sausage, g/d	Quintile 1=5, Quintile 2=4, Quintile 3=3, Quintile 4=2, Quintile 5=1
	Sugar-sweetened beverages, g/d	Quintile 1=5, Quintile 2=4, Quintile 3=3, Quintile 4=2, Quintile 5=1
	Sodium intake, mg/d	Quintile 1=5, Quintile 2=4, Quintile 3=3, Quintile 4=2, Quintile 5=1
Baltic Sea Diet Score (BSDS)[b] (150)	Fruit and berries, g/d	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
	Vegetables incl. legumes, excl. potatoes, g/d	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
	High-fibre (≥5%) grain products, g/d	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
	Low-fat (<1%) milk, g/d	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
	Fish, g/d	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
	Red meat and sausage, g/d	Quartile 1=3, Quartile 2=2, Quartile 3=1, Quartile 4=0
	PUFA-to-SFA ratio	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
	Total fat intake, E%	Quartile 1=3, Quartile 2=2, Quartile 3=1, Quartile 4=0
Mediterranean Diet Score (MDS)[c] (255)	Vegetables, g/d	>sex-specific median=1, else=0
	Fruit, nuts and legumes, g/d	>sex-specific median=1, else=0
	Grain products, g/d	>sex-specific median=1, else=0
	Fish, g/d	>sex-specific median=1, else=0
	Red meat and sausage, g/d	<sex-specific median=1, else=0
	Poultry, g/d	<sex-specific median=1, else=0
	Dairy products, g/d	<sex-specific median=1, else=0
	MUFA-to-SFA ratio	>sex-specific median=1, else=0

Table 6 to be continued

Table 6 continues

	Components	Scoring
Healthy Diet Indicator (HDI) (28)	SFA, E%	0–10=1, else=0
	PUFA, E%	3–7=1, else=0
	Protein, E%	10–15=1, else=0
	Complex carbohydrates, E%	50–70=1, else=0
	Mono- and disaccharides, E%	0–10=1, else=0
	Dietary fibre, g/d	27–40=1, else=0
	Cholesterol, mg/d	0–300=1, else=0
	Fruit and vegetables, g/d	>400=1, else=0
	Pulses and nuts, g/d	>30=1, else=0
Finnish Children Healthy Eating Index (FCHEI) (29)	Vegetables, fruit and berries, g/d	Decile 1=1, Decile 2=2, Decile 3=3, Decile 4=4, Decile 5=5, Decile 6=6, Decile 7=7, Decile 8=8, Decile 9=9, Decile 10=10
	Vegetable oils and vegetable oil-based margarine (fat ≥60%), g/d	Non-consumers=0, Decile 1=1, Decile 2=2, Decile 3=3, Decile 4=4, Decile 5=5, Decile 6=6, Decile 7=7, Decile 8=8, Decile 9=9, Decile 10=10
	Foods containing high amounts of sugar, g/d[d]	Decile 1=10, Decile 2=9, Decile 3=8, Decile 4=7, Decile 5=6, Decile 6=5, Decile 7=4, Decile 8=3, Decile 9=2, Decile 10=1
	Fish, g/d[e]	Non-consumers=0, Decile 5=1, Decile 6=2, Decile 7=3, Decile 8=4, Decile 9=5, Decile 10=6
	Low-fat (<1%) milk, g/d[e]	Non-consumers=0, Decile 2=1, Decile 3=2, Decile 4=3, Decile 5=4, Decile 6=5, Decile 7=6, Decile 8=7, Decile 9=8, Decile 10=9
Diet to Assess Metabolic Risk in Children (DIMERIC) Score	Vegetable oils, g/d	Tertile 1=0, Tertile 2=1, Tertile 3=2
	Low-fat (<60%) vegetable oil-based margarine, g/d	Tertile 1=2, Tertile 2=1, Tertile 3=0
	Sugar-sweetened beverages, g/d	Tertile 1=2, Tertile 2=1, Tertile 3=0
	Red meat, g/d	Tertile 1=2, Tertile 2=1, Tertile 3=0

PUFA, polyunsaturated fat; SFA, saturated fat; E%, percentage of total energy intake; MUFA, monounsaturated fat.

[a] The consumption of nuts, legumes and soy was excluded from the DASH Score because of a very low consumption of these foods in this study sample.

[b] The consumption of alcohol was excluded from the BSDS, because children in this study sample did not drink alcohol.

[c] The consumption of alcohol was excluded from the MDS, and the consumption of legumes was included in the fruit and nut group because of a very low consumption of legumes in this study sample.

[d] Including sugar-sweetened beverages, fruit juices, added sugar, chocolate, sweets, pastries, biscuits, ice cream and puddings.

[e] As all non-consumers of food groups received a score of 0 points and there were considerable proportions of non-consumers, the maximum score is less than 10 points.

Reference numbers are given in brackets.

5.1.3 Eating behaviour

Eating behaviour was measured by the CEBQ administered by the parents (32). An official version back translated from English to Finnish was used. The 35 questions of the questionnaire represented eight categories of eating behavior: enjoyment of food, food responsiveness, emotional overeating, desire to drink, satiety responsiveness, slowness in eating, emotional under-eating and food fussiness. Each question offered response options from never to always on a 1 to 5 Likert scale, and the mean of responses of each category was calculated and used in the analyses.

Principal component analysis with a Varimax rotation was performed for the Finnish translation including all 35 questions of the questionnaire in the present study sample. Similar to the original version (32), a structure of eight eating behaviour sub-scales was revealed and used in the analyses. Furthermore, the Finnish translation showed good internal consistency within seven of the eight sub-scales (Cronbach's alphas 0.77–0.90). Only the sub-scale Emotional under-eating did not show internal consistency (Cronbach's alpha 0.18).

5.1.4 Body composition

All measurements were performed by trained research staff using same calibrated equipment and a standard protocol. Body height was measured three times to an accuracy of 0.1 cm by a wall-mounted stadiometer in the Frankfurt plane without shoes. Waist and hip circumferences were measured three times to an accuracy of 0.1 cm standing and with an unstretchable measuring tape adjusted horizontally. Waist circumference was measured after expiration at mid-distance between the bottom of the rib cage and the top of the iliac crest. Hip circumference was measured at the level of the great trochanters. The mean of the nearest two values of height as well as waist and hip circumferences was used for the analyses. Body weight was measured twice with the accuracy of 0.1 kg using a calibrated InBody® 720 bioelectrical impedance device (Biospace, Seoul, Korea), after overnight fasting, empty-bladdered and standing in light underwear. The mean of the two values was used for the analyses. BMI was calculated as body weight (kg) divided by body height (m) squared. BMI-SDS were calculated using Finnish (100) and British (256) growth references. The prevalences of overweight and obesity were assessed using the age- and sex-specific BMI cutoffs by the IOTF (99). Body fat percentage was measured by the DXA method with the Lunar® DXA device (Lunar Prodigy Advance; GE Medical Systems, Madison, Wisconsin, USA) empty-bladdered and lying in light clothing.

5.1.5 Blood pressure

Blood pressure was measured manually by a calibrated aneroid sphygmomanometer (Heine Gamma G7, Germany) prior to the blood sampling. The measurement protocol included, after a 5-minute rest, three measurements from the right arm in the sitting position at 2-minute intervals. The mean of all three measurements was used as the systolic and diastolic blood pressures.

5.1.6 Biochemical measurements

Venous blood samples were drawn after a 12-hour fast. Biochemical analyses were done using Cobas 6000 analysers (Hitachi High Technology Co, Tokyo, Japan) in the Eastern Finland Laboratory Centre Joint Authority Enterprise. A hexokinase method was used to analyse the plasma concentration of glucose (Roche Diagnostics Co, Mannheim, Germany). Serum concentration of insulin was analysed using electrochemiluminescence immunoassay (ECLIA) with sandwich principle (Roche Diagnostics Co). A colorimetric enzymatic assay was used to analyse plasma concentrations of total cholesterol and plasma triglycerides (Roche Diagnostics Co). Homogeneous enzymatic colorimetric assays were used to analyse plasma concentrations of HDL and LDL cholesterol (Roche Diagnostics Co).

5.1.7 Metabolic risk score

A continuous variable was created to assess the clustering of cardiometabolic risk factors of the children. The metabolic risk score was calculated as a sum of standardised variables (Z-scores) of waist circumference, fasting serum concentration of insulin, fasting plasma concentrations of glucose, triglycerides and HDL cholesterol and the mean of diastolic and systolic blood pressures. The Z-score of HDL cholesterol was multiplied by -1, because it is inversely associated with the metabolic risk. A higher metabolic risk score indicates a less favorable cardiometabolic profile.

5.1.8 Physical activity and electronic media time

Time spent in physical activity and electronic media time was assessed by the PANIC Physical Activity Questionnaire filled out by the parents with their child at home. Physical activity included organised sports, supervised exercise other than sports, unsupervised physical activity, physically active school transportation, physical activity during recess and physical education. Electronic media time included watching television and videos, using computer, playing video games, using mobile phone and playing mobile games.

5.1.9 Socioeconomic background

Socioeconomic background was assessed by the annual household income and the level of education of the parents. The annual household income was asked by a structured questionnaire from both parents and coded into three categories (≤30 000€, 30 001–60 000€ and >60 000€). The level of education was asked by a structured questionnaire from both parents and coded into three categories (vocational school or less, vocational high school, university) based on the highest completed or ongoing degree. If the parents reported different categories, the higher category was used in the analyses. Parents also reported years of birth of the siblings of the child. The number of siblings and the order of birth were calculated.

5.1.10 Other assessments

Pubertal stage was assessed by a physician using Tanner staging (257). Puberty was defined as breast development at Tanner stage ≥2 for girls and testicular volume ≥4 ml assessed using an orchidometer for boys.

5.2 STATISTICAL METHODS

Statistical analyses were performed using the SPSS Statistics for Windows software versions 14.0 (SPSS Inc., Chicago, IL, USA), 17.0 and 19.0 (IBM Corp., Armonk, NY, USA). All associations and differences in averages were considered statistically significant if the *P*-value was <0.05.

Differences in dietary factors between girls and boys were compared by the Mann-Whitney's U-test and Pearson's χ^2 test (*Study I*). Logistic regression analysis was used to model the association of socioeconomic background with reaching the recommended dietary guidelines (*Study I*). Moreover, logistic regression analysis was used to model the associations of dietary factors with the risk of being overweight (*Study II*) and associations of dietary quality indices with the risk of being in the highest fifth of the metabolic risk score (*Study IV*). Linear regression analysis was used to model the association of dietary factors with body fat percentage, waist and hip circumferences (*Study II*), metabolic risk score and individual cardiometabolic risk factors (*Study III*). Moreover, the independent associations of dietary factors with metabolic risk score and cardiometabolic risk factors were studied by entering all dietary factors into the same models by a stepwise forward method using a *P*-value of <0.05 as the entry criterion (*Study III*). The differences in the means of the metabolic risk score, cardiometabolic risk factors and the intake of nutrients across the quartiles of the dietary quality indices were analysed using general linear models (*Study IV*).

To adjust for potential confounding effects in logistic and linear regression models and general linear models, covariates were entered in the models.

6 Results

6.1 BASIC CHARACTERISTICS

The total study sample comprised 512 children. The basic characteristics are presented in Table 7. According to the IOTF criteria (99), 10.9% of girls and 6.5% of boys were overweight and 4.5% of girls and 4.6% of boys were obese. Almost all children, 96.3%, were prepubertal at Tanner stage M1 or G1. Of all children, 12.8% were the only child in the family, 38.1% had one sibling, 33.0% had two siblings and 16.3% had three or more siblings. Of children who had siblings, 35.4% were firstborn and 39.6% were lastborn.

Defined by the highest degree in the family, 17.4% of the families had vocational school degree or less, 45.2% had vocational high school degree and 37.4% had university degree. Annual household income was ≤30 000€ in 19.3% of families, 30 001–60 000€ in 42.9% of families and >60 000€ in 37.8% of the families.

Table 7. Characteristics of 512 children

	All (n=512) Median (IQR)	**Girls (n=248) Median (IQR)**	**Boys (n=264) Median (IQR)**	***P* value[a]**
Age, y	7.6 (7.4–7.9)	7.6 (7.3–7.9)	7.6 (7.4–7.9)	0.313
Weight, kg[b]	25.9 (23.4–29.3)	25.5 (23.3–29.0)	26.6 (23.8–29.5)	**0.039**
Height, cm	129.0 (125.1–132.1)	128.0 (123.7–131.1)	130.2 (126.5–132.6)	**<0.001**
BMI[b]	15.7 (14.7–17.0)	15.7 (14.6–16.9)	15.6 (14.7–17.0)	0.844
BMI-SDS, Finnish reference values[b]	-0.2 (-1.0–0.5)	-0.2 (-1.0–0.5)	-0.2 (-1.0–0.6)	0.942
BMI-SDS, international reference values[c]	0.0 (-0.8–0.7)	-0.1 (-0.8–0.6)	0.0 (-0.8–0.8)	0.336
Waist circumference, cm[d]	55.6 (53.0–59.0)	54.8 (52.3–58.1)	56.5 (53.6–59.5)	**0.001**
Hip circumference, cm[f]	65.3 (62.5–69.3)	65.4 (62.6–69.4)	65.2 (62.2–69.2)	0.680
Body fat percentage, %[f]	18.7 (13.4–24.2)	20.6 (17.4–27.0)	15.0 (11.3–21.6)	**<0.001**
Metabolic risk score[g]	-0.2 (-2.4–2.2)	0.0 (-2.2–2.2)	-0.4 (-2.6–2.1)	0.603
Fasting serum insulin, mU/l[h]	4.1 (2.8–5.7)	4.5 (3.3–6.1)	3.9 (2.5–5.5)	**0.002**
Fasting plasma glucose, mmol/l[i]	4.8 (4.6–5.0)	4.8 (4.5–4.9)	4.9 (4.6–5.1)	**<0.001**
Fasting plasma total cholesterol, mmol/l[j]	4.20 (3.90–4.70)	4.30 (3.90–4.70)	4.20 (3.80–4.63)	0.092
Fasting plasma LDL cholesterol, mmol/l[j]	2.30 (2.00–2.70)	2.40 (2.00–2.80)	2.30 (1.98–2.60)	**0.034**
Fasting plasma HDL cholesterol, mmol/l[j]	1.58 (1.40–1.77)	1.56 (1.37–1.73)	1.60 (1.42–1.79)	**0.023**

Table 7 to be continued

Table 7 continues

	All (n=512) Median (IQR)	**Girls (n=248) Median (IQR)**	**Boys (n=264) Median (IQR)**	***P* value[a]**
Fasting plasma triglycerides, mmol/l[j]	0.55 (0.43–0.70)	0.56 (0.45–0.72)	0.53 (0.41–0.66)	**0.013**
Systolic blood pressure, mmHg[e]	100 (95–105)	100 (95–105)	100 (96–105)	0.311
Diastolic blood pressure, mmHg[e]	61 (57–67)	61 (57–66)	61 (57–67)	0.601
Total physical activity, min/d[k]	107 (77–141)	101 (72–131)	115 (82–152)	**0.001**
Electronic media time, min/d[l]	98 (66–129)	90 (60–116)	101 (77–138)	**<0.001**

IQR, interquartile range; BMI, body mass index; BMI-SDS, body mass index standard deviation score; LDL, low density lipoprotein; HDL, high density lipoprotein.

[a] Difference between girls and boys tested using Mann-Whitney's U-test
[b] n=510 (247 girls, 263 boys). Calculated based on Finnish reference values (100).
[c] n=510 (247 girls, 263 boys). Calculated based on British reference values (256).
[d] n=511 (247 girls, 264 boys).
[e] n=510 (246 girls, 264 boys)
[f] n=493 (242 girls, 251 boys)
[g] n=492 (233 girls, 259 boys)
[h] n=493 (234 girls, 259 boys)
[i] n=504 (242 girls, 262 boys)
[j] n=505 (243 girls, 262 boys)
[k] n=502 (244 girls, 258 boys)
[l] n=492 (234 girls, 258 boys)

6.2 EATING FREQUENCY (*STUDIES I, II* AND *III*)

6.2.1 Eating frequency in children

Altogether, girls and boys had on average 5.5 eating occasions daily. Girls had 2.7 and boys had 2.8 main meals, and both girls and boys had 2.7 snacks daily. Almost all children had breakfast daily, in both weekdays and weekend days (Table 8). However, children had lunch and dinner more frequently on weekdays than on weekend days. Altogether, 34% of girls and 45% of boys had all three main meals daily.

Table 8. Proportion of children eating meals daily calculated from 4-day food records

	All four recorded days		**Weekdays**		**Weekend days**	
	Girls, n=211 % (n)	**Boys, n=213 % (n)**	**Girls, n=211 % (n)**	**Boys, n=213 % (n)**	**Girls, n=211 % (n)**	**Boys, n=213 % (n)**
Breakfast	95 (201)	96 (205)	98 (206)	98 (208)	97 (204)	98 (209)
Lunch	75 (159)	79 (169)	96 (203)	94 (200)	77 (162)	82 (174)
Dinner	48 (102)	55 (119)	81 (171)	90 (192)	54 (114)	60 (128)
Snacks[a]						
<2/d	13 (28)	12 (26)	11 (23)	8 (16)	20 (43)	15 (32)
2–3/d	57 (120)	62 (132)	70 (148)	70 (148)	49 (103)	60 (127)
>3/d	30 (63)	26 (55)	19 (40)	23 (49)	31 (65)	25 (54)

[a] Snakcs include all eating and drinking occasions between main meals, incuding afternoon and evening snacks.

Of the total energy intake, 17% and 16% was obtained from breakfast, 21% and 21% from lunch, 20% and 21% from dinner, and 42% and 41% from snacks, in girls and boys, respectively. The proportions of total fat, SFA, MUFA, PUFA and sucrose of total energy intake and dietary fibre density in main meals and snacks are presented in Figure 2. Snacks contributed 68% of the daily sucrose intake in girls and 67 % in boys. There were no differences in the proportion of nutrients in main meals and snacks between girls and boys.

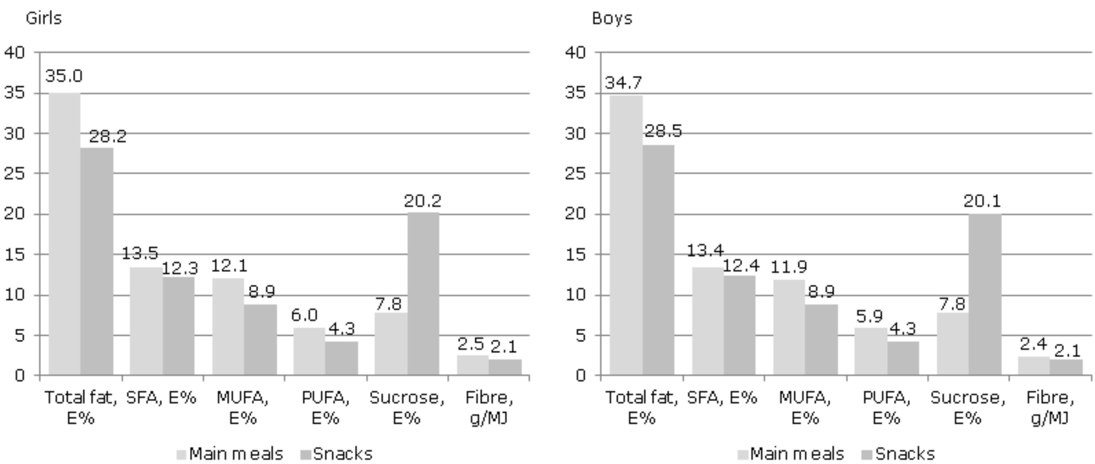

Figure 2. Proportion of selected nutrients of total energy intake and fiber density in main meals and snacks in girls and boys. SFA, saturated fat; MUFA, monounsaturated fat; PUFA, polyunsaturated fat.

Association of socioeconomic background with eating frequency
Children from families with a vocational high school degree (odds ratio (OR) 3.02, 95% confidence interval (CI) 1.61–5.68) and from families with a university degree (OR 2.54, 95% CI 1.34–4.83) more likely consumed all three main meals daily than children from families with a vocational school degree or less.

6.2.2 Associations of eating frequency with body adiposity and cardiometabolic risk

Children who did not eat all main meals daily had a 63% higher risk of being overweight compared to children who ate all main meals daily, adjusted for physical activity, electronic media time and household income (Table 9). Skipping main meals was also associated with higher body fat percentage and waist and hip circumferences after adjustment for age, sex, physical activity, electronic media time and household income. The number of daily snacks, however, was not related to the measures of body adiposity.

Skipping main meals was also associated with a higher metabolic risk score (standardised regression coefficient β -0.18, *P* value <0.001). Adjustments for age, sex, body height, physical activity, electronic media time, total energy intake or food consumption variables did not alter the association (data not shown). Of individual metabolic risk factors, skipping main meals was statistically significantly associated with a higher fasting serum concentration of insulin (β -0.15, *P* value <0.01) and plasma concentration of glucose (β -0.10, *P* value <0.05) after adjustment for age, sex, physical activity, electronic media time and total energy intake. The association of skipping main meals with a higher serum concentration of insulin remained statistically significant when the model was further adjusted for food consumption variables (β -0.15, *P* value <0.01), but was no longer statistically significant after further adjustment for BMI-SDS (data not shown). Instead, after further adjustment for household income, skipping main meals was associated with a higher plasma concentration of glucose (β -0.11, *P* value <0.05) and a lower plasma concentration of HDL cholesterol (β 0.10, *P* value <0.05). The number of daily snacks was not related to the metabolic risk score or individual cardiometabolic risk factors.

Table 9. Eating frequency and the risk of being overweight and standardised regression coefficients for the associations with body fat percentage and waist and hip circumferences

	Risk of being overweight	**Body fat percentage**	**Waist circumference**	**Hip circumference**
	OR (95 % CI)	**β (*P* value)**	**β (*P* value)**	**β (*P* value)**
Number of main meals[a]		**-0.12 (0.012)**	**-0.16 (0.002)**	**-0.15 (0.002)**
<3/d	1.00 (reference)			
3/d	**0.37 (0.18–0.75)**			
Number of snacks[b]		0.01 (0.866)	0.02 (0.675)	0.03 (0.575)
<2/d	1.00 (reference)			
2–3/d	2.88 (0.83–9.94)			
>3/d	3.12 (0.86–11.39)			

Odds ratios (ORs) and 95% confidence intervals (CIs) are from logistic regression models adjusted for physical activity, electronic media time and household income.

Standardised regression coefficients (βs) are from linear regression models adjusted for age, sex, physical activity, electronic media time and household income.

[a] Number of main meals coded as 0=less than three main meals daily, 1=three main meals daily.

[b] Number of snacks coded as 0=less than two snacks daily, 1=2–3 snacks daily, 2=greater than 3 snacks daily.

Statistically significant associations are presented in bold.

6.3 FOOD CONSUMPTION (*STUDIES I* AND *III*)

6.3.1 Food consumption in children

Food consumption was assessed by the PANIC Food Consumption Questionnaire (Table 10) in addition to the 4-day food records (Table 11). Majority of the children commonly ate high-fibre bread instead of low-fibre bread. However, low-fibre pasta, rice and other cooked grain products were consumed in higher amounts than high-fibre products. Only 4.1% of girls and 3.6% of boys consumed vegetables, fruit and berries the recommended five portions daily, and almost a fifth of children consumed them one portion or less per day. Skimmed milk was used by two thirds of the childen, while less than a third of children used fat-containing milk. However, most children used fat-containing yoghurts instead of fat-free yoghurts. Low-fat products were commonly used in cheese and cold cuts, as recommended. More than half of the children consumed fish less often than the recommended twice a week. Three quarters of girls and two thirds of boys used vegetable oil-based margarine on bread. Half of the children used sugar-sweetened beverages several times per week and a quarter consumed them daily. No differences between girls and boys were found based on the Food Consumption Questionnaire. However, the food record data showed that boys consumed more red meat, sausages and sweets and chocolate than girls.

Table 10. Food consumption in children. Proportion of users (number of subjects).

	All, n=285 % (n) of users	Girls, n=147 % (n) of users	Boys, n=138 % (n) of users	*P* value[a]
Bread				
High-fibre bread, ≥5% of fibre	88 (252)	88 (130)	88 (122)	
Low-fibre bread, <5% of fibre	12 (33)	12 (17)	12 (16)	0.994
Vegetables, fruit and berries[b]				
≥ 5 portions / day	4 (11)	4 (6)	4 (5)	
4 portions / day	11 (30)	9 (13)	12 (17)	
3 portions / day	31 (89)	35 (51)	28 (38)	
2 portions / day	36 (102)	35 (51)	37 (51)	
≤1 portion / day	19 (53)	18 (26)	20 (27)	0.688
Milk and sour milk				
Skimmed milk or sour milk, <1% of fat	65 (185)	63 (93)	67 (92)	
Milk or sour milk, ≥1% of fat	30 (84)	31(45)	28 (39)	
Does not drink milk	6 (16)	6 (9)	5 (7)	0.819
Yoghurts				
Fat-free	19 (54)	20 (30)	17 (24)	
≥2% of fat	68 (193)	65 (95)	71 (98)	
Does not eat yoghurts	13 (38)	15 (22)	12 (16)	0.502
Cheese				
≤17% of fat	55 (157)	61 (90)	49 (67)	
>17% of fat	29 (83)	25 (36)	34 (47)	
Does not eat cheese	16 (45)	14 (21)	17 (24)	0.093
Cold cuts and sausages on bread				
Whole meat cuts, <4% of fat	66 (188)	68 (100)	64 (88)	
Sausages, ≤12% of fat	8 (22)	5 (8)	10 (14)	
Sausages, >12% of fat	14 (41)	12 (18)	17 (23)	
Does not eat cold cuts or sausages	12 (34)	14 (21)	9 (13)	0.202
Fish				
≥ 2 times / week	43 (122)	42 (62)	44 (60)	
< 2 times / week	57 (163)	58 (85)	57 (78)	0.824
Spread on bread				
Vegetable oil-based margarine, 60–80% of fat	37 (105)	42 (61)	32 (44)	
Vegetable oil-based margarine, <60% of fat	33 (95)	32 (47)	35 (48)	
Butter or butter-oil-mixture or does not use	30 (85)	27 (39)	33 (46)	0.217
Sugar-sweetened beverages[c]				
once / week or less	17 (48)	16 (24)	17 (24)	
2–6 times / week	55 (158)	57 (84)	54 (74)	
daily	28 (79)	27 (39)	29 (40)	0.835
Puddings and ice cream				
once / week or less	63 (180)	61 (89)	66 (91)	
2–5 times / week	32 (91)	35 (52)	28 (39)	
≥ 6 times / week	5 (14)	4 (6)	6 (8)	0.390

[a] Difference between girls and boys tested with Pearson's χ^2 test.

[b] One portion is, for example, 1 dl of salad, 1 dl of berries or one small fruit.

[c] Including carbonated and non-carbonated sugar-sweetened juices and sodas and cocoa drinks.

Table 11. Food consumption in children. Median (interquartile range).

Food consumption, g/day	**All, n=408 Median (IQR)**	**Girls, n=199 Median (IQR)**	**Boys, n=209 Median (IQR)**	**P value[a]**
High-fibre bread, ≥5% of fibre	38 (23–59)	36 (23–58)	38 (23–59)	0.750
Low-fibre bread, <5% of fibre	22 (8–39)	21 (8–38)	23 (8–45)	0.249
High-fibre pasta and rice, ≥5% of fibre	10 (0–26)	10 (0–26)	11 (0–25)	0.877
Low-fibre pasta and rice, <5% of fibre	71 (46–106)	71 (47–100)	72 (43–112)	0.409
Breakfast cereals	4 (0–13)	4 (0–13)	4 (0–13)	0.946
Potatoes	70 (44–101)	66 (43–99)	73 (47–102)	0.130
Root vegetables	15 (4–31)	17 (5–32)	13 (2–29)	0.131
Non-root vegetables[b]	68 (39–104)	68 (43–102)	68 (39–105)	0.747
Fruit	75 (35–123)	77 (42–131)	70 (28–117)	0.060
Berries	10 (0–26)	11 (0–29)	8 (0–23)	0.155
Skimmed milk, <1% of fat	372 (90–604)	355 (94–588)	421 (88–634)	0.142
Milk, ≥1% of fat	94 (33–262)	86 (31–261)	100 (37–283)	0.472
Low-fat sour milk products, <1% of fat	0 (0–11)	0 (0–13)	0 (0–9)	0.677
High-fat sour milk products, ≥1% of fat	75 (25–131)	75 (25–125)	63 (25–143)	0.548
Cheese	11 (4–23)	12 (4–20)	11 (4–25)	0.946
Red meat[c]	52 (35–73)	48 (32–63)	56 (36–86)	**0.004**
Sausages[d]	15 (4–32)	12 (0–25)	18 (8–38)	**<0.001**
Poultry	10 (0–24)	10 (0–23)	10 (0–27)	0.858
Fish[e]	7 (0–25)	5 (0–22)	8 (0–28)	0.225
Egg	10 (6–19)	10 (6–18)	11 (6–20)	0.509
Vegetable oils	2 (1–4)	2 (1–4)	3 (1–5)	0.083
Vegetable oil-based margarine, 60–80 % of fat	5 (1–10)	5 (1–10)	5 (1–10)	0.433
Vegetable oil-based margarine, <60% of fat	0 (0–7)	0 (0–6)	0 (0–7)	0.339
Butter or butter-oil-mixture	3 (1–8)	3 (1–7)	3 (1–10)	0.727
Sugar-sweetened beverages[f]	113 (45–200)	93 (43–188)	125 (50–225)	0.068
Artificially sweetened beverages	0 (0–50)	0 (0–50)	0 (0–50)	0.791
Fruit juices	2 (0–50)	2 (0–50)	1 (0–50)	0.520
Sweets and chocolate	25 (10–44)	21 (10–38)	28 (11–50)	**0.012**

IQR, interquartile range.

[a] Difference between girls and boys tested with Mann-Whitney's U-Test.

[b] Includes all vegetables except root, e.g. leaf, stem, fruit and flower vegetables.

[c] Includes pork, beef, lamb, reindeer and game meat, but not sausages.

[d] Includes sausages, frankfurter and sausage cold cuts.

[e] Includes fish and shellfish.

[f] Includes carbonated and non-carbonated juices and sodas.

Statistically significant values are presented in bold.

Association of socioeconomic background with food consumption

Skimmed milk was about 2.4 times more commonly used in children whose parents were in the highest income group than in children whose parents were in the lowest income group (Table 12). Recommended fish consumption was 2.2 times more common in children whose parents were in the highest income group compared to children whose parents were in the lowest income group. Moreover, recommended fish consumption was 2.7 times more common in children whose parents had a vocational high school degree and 2.2 times more common in children whose parents had university degree than in children whose parents had vocational school education or less. Recommended high-fibre bread was 5.1 times more commonly used in children whose parents had a university degree and 2.6 times more commonly used in children whose parents had a vocational high school education, compared to the lowest education group. However, the odds of using the recommended vegetable oil-based margarine on bread decreased across ascending categories of parental education. There were no differences in the household income or parental education groups in the consumption of cheese (≤17% of fat vs. >17% of fat), cold cuts (≤4% of fat vs. >4% of fat), yoghurts (fat-free vs. ≥2% of fat), vegetables, fruit and berries (≥3 portions per day vs. <3 portions per day), sugar-sweetened beverages (once a week or less vs. twice a week or more) and puddings and ice cream (once a week or less vs. twice a week or more) among children.

Table 12. Annual household income, parental education and the odds using food items as recommended

	Skimmed milk[a]	**Vegetable oil-based margarine on bread**[b]	**Fish ≥2 times per week**[c]	**Bread ≥5% of fibre**[d]
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Annual household income				
≤30 000 € (n=58)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
30 001–60 000 € (n=110)	1.94 (0.97–3.86)	0.62 (0.30–1.27)	1.94 (0.98–3.82)	0.59 (0.22–1.58)
>60 000 € (n=111)	**2.43 (1.21–4.88)**	0.82 (0.39–1.70)	**2.21 (1.12–4.36)**	1.49 (0.49–4.55)
P for trend	**0.017**	0.956	**0.032**	0.314
Parental education				
Vocational school or less (n=54)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Vocational high school (n=128)	1.32 (0.66–2.67)	0.69 (0.32–1.49)	**2.69 (1.34–5.43)**	**2.57 (1.11–5.92)**
University (n=101)	1.30 (0.63 – 2.69)	**0.43 (0.20–0.94)**	**2.20 (1.06–4.54)**	**5.06 (1.80–14.29)**
P for trend	0.536	**0.023**	0.094	**0.002**

Odds ratios (ORs) and 95% confidence intervals (CIs) are from logistic regression models adjusted for sex.

[a] Milk consumption coded as 0=other than skimmed milk, 1=skimmed milk. Children who did not drink milk were excluded.

[b] The spread used on bread was coded as 0=butter or butter-oil-mixture, 1=vegetable oil-based margarine, 23–80% of fat. Children who did not use spread on bread were excluded.

[c] The frequency of fish consumption was coded as 0=<two times per week, 1=≥2 times per week.

[d] Bread consumption coded as 0=low-fibre bread, <5% of fibre, 1=high-fibre bread, ≥5% of fibre.

Statistically significant associations are presented in bold.

6.3.2 Associations of food consumption with cardiometabolic risk

A higher consumption of non-root vegetables, red meat, low-fat vegetable oil-based margarine and sugar-sweetened beverages, and a lower consumption of vegetable oils were associated with a higher metabolic risk score in children when adjusted for age and sex (Table 13, Model 1). Further adjustment for physical activity or electronic media time did not alter these relationships (Table 13, Model 2). After additional adjustment for energy intake, the association of the consumption of red meat with the metabolic risk score was no longer statistically significant (Table 13, Model 3). A higher consumption of non-root vegetables, low-fat vegetable oil-based margarine and sugar-sweetened beverages, and a lower consumption of vegetable oils were related to a higher metabolic risk score even after adjustment for the frequency of main meals and the consumption of all other foods that were independently related to the metabolic risk score (Table 13, Model 4). Further adjustment for household income had no impact on the associations of food consumption with the metabolic risk score (data not shown). However, after further adjustment for body height, the consumption of low-fat vegetable oil-based margarine was not longer associated with the metabolic risk score (data not shown).

The association of food consumption with metabolic risk factors adjusted for age, sex, physical activity, electronic media time and total energy intake are presented in Table 14, Model 3. A higher consumption of low-fat vegetable oil-based margarine was associated with a higher waist circumference after adjustment for age, sex, physical activity, electronic media time, energy intake, frequency of main meals and the consumption of all other foods that were independently related to the metabolic risk score (Table 14, Model 4). Higher consumptions of non-root vegetables, low-fat vegetable oil-based margarine and sugar-sweetened beverages were related to a higher fasting serum insulin concentration after these adjustments (Table 14, Model 4). A lower consumption of vegetable oils and higher consumptions of non-root vegetables and sugar-sweetened beverages were independently associated with higher fasting plasma glucose concentrations (Table 14, Model 4). Higher consumptions of non-root vegetables and low-fat vegetable oil-based margarine were related to lower HDL cholesterol concentrations (Table 14, Model 4). Higher consumptions of non-root vegetables and red meat were associated with higher levels of systolic blood pressure (Table 14, Model 4). A higher consumption of red meat and a lower consumption of vegetable oils were associated with higher levels of diastolic blood pressure (Table 14, Model 4).

After further adjustment for BMI-SDS, the consumption of low-fat vegetable oil-based margarine was no longer associated with fasting serum insulin concentrations, the consumption of red meat was no longer associated with the levels of systolic and diastolic blood pressure and the consumption of vegetable oils was no longer associated with the levels of diastolic blood pressure (Table 14, Model 5). Further adjustment for household income did not alter the associations (data not shown).

Table 13. The associations (standardised regression coefficient β and level of significance) of food consumption with metabolic risk score using linear regression models

Food consumption, g/day	**Model 1** Adjusted for age and sex	**Model 2** Adjusted for age, sex, PA and EMT	**Model 3** Adjusted for age, sex, PA, EMT and energy intake	**Model 4[a]** Adjusted for age, sex, PA, EMT, energy intake, frequency of main meals and other food consumption factors
High-fibre bread, ≥5% of fibre	-0.01	0.01	<0.01	
Low-fibre bread, <5% of fibre	0.05	0.05	0.05	
High-fibre pasta and rice, ≥5% of fibre	-0.05	-0.02	-0.03	
Low-fibre pasta and rice, <5% of fibre	-0.07	-0.07	-0.09	
Breakfast cereals	-0.01	0.01	<0.01	
Potatoes	0.05	0.04	0.03	
Root vegetables	-0.05	-0.04	-0.04	
Non-root vegetables	**0.12***	**0.16****	**0.16****	**0.18****
Fruit	0.05	0.09	0.08	
Berries	-0.06	-0.05	-0.06	
Skimmed milk, <1% of fat	0.09	0.09	0.08	
Milk, ≥1% of fat	-0.08	-0.06	-0.08	
Low-fat sour milk products, <1% of fat	-0.02	-0.02	-0.03	
High-fat sour milk products, ≥1% of fat	0.03	0.06	0.04	
Cheese	0.04	0.06	0.05	
Red meat	**0.12***	**0.10***	0.09	
Sausages	0.09	0.10	0.09	
Poultry	0.01	0.01	0.01	
Fish	0.02	0.04	0.04	
Egg	-0.06	-0.06	-0.08	
Vegetable oils	**-0.11***	**-0.11***	**-0.12***	**-0.10***
Vegetable oil-based margarine, ≥60% of fat	-0.09	-0.07	-0.08	
Vegetable oil-based margarine, <60% of fat	**0.14****	**0.13****	**0.13****	**0.13***
Butter or butter-oil mixture	-0.07	-0.06	-0.07	
Sugar-sweetened beverages	**0.14****	**0.14****	**0.13***	**0.11***
Artificially sweetened beverages	0.06	0.06	0.06	
Fruit juices	0.05	0.07	0.07	
Sweets and chocolate	<0.01	<0.01	-0.03	

PA, physical activity; EMT, electronic media time.
[a] Model 4 is created using stepwise forward method.
The metabloic risk score was calculated as a sum of Z-scores of of waist circumference, fasting serum concentration of insulin, fasting plasma concentrations of glucose, triglycerides and HDL cholesterol and the mean of diastolic and systolic blood pressure. The Z-score of HDL cholesterol was multiplied by -1.
* *P* < 0.05, ** *P* < 0.01, *** *P* < 0.001. Statistically significant values are presented in bold.

Table 14. The associations (standardised regression coefficient β and level of significance) of food consumption variables associated with the metabolic risk score with waist circumference, fasting insulin, glucose, triglycerides and HDL cholesterol concentrations and the levels of systolic and diastolic blood pressure

Food consumption, g/day	**Waist**	**fS-Insulin**	**fP-Glucose**	**fP-Trigly-cerides**	**fP-HDL cholesterol**	**Systolic blood pressure**	**Diastolic blood pressure**
Model 3							
Adjusted for age, sex, PA, EMT and energy intake							
Non-root vegetables	0.03	**0.12***	**0.13***	0.05	**-0.14****	**0.12***	-0.02
Red meat	0.08	**0.10***	-0.01	0.01	0.03	**0.12***	**0.12***
Vegetable oils	-0.07	-0.08	**-0.11***	-0.07	0.08	0.08	-0.10
Vegetable oil-based margarine, <60% of fat	**0.10***	0.10	0.02	0.08	**-0.15****	0.02	0.03
Sugar-sweetened beverages	0.01	**0.15****	**0.13***	0.10	-0.04	0.08	<0.01
Model 4[a]							
Adjusted for age, sex, PA, EMT, energy intake, frequency of main meals and other food consumption factors							
Non-root vegetables		**0.14****	**0.13***		**-0.15****	**0.12***	
Red meat						**0.12***	**0.13***
Vegetable oils			**-0.11***				**-0.10***
Vegetable oil-based margarine, <60% of fat	**0.11***	**0.11***			**-0.15****		
Sugar-sweetened beverages		**0.13***	**0.13***				
Model 5[a]							
Adjusted for age, sex, PA, EMT, energy intake, frequency of main meals, other food consumption factors, and BMI-SDS							
Non-root vegetables		**0.11***	**0.13***		**-0.14****	**0.11***	
Red meat							
Vegetable oils			**-0.11***				
Vegetable oil-based margarine, <60% of fat					**-0.14****		
Sugar-sweetened beverages		**0.14****	**0.13***				

HDL, high density lipoprotein; PA, physical activity; EMT, electronic media time; BMI-SDS, body mass index standard deviation score.
[a] Models 4 and 5 are created using stepwise forward method.
* P < 0.05, ** P < 0.01, *** P < 0.001. Statistically significant values are presented in bold.

6.4 INTAKES OF ENERGY AND NUTRIENTS (*STUDIES I*, *II* AND *IV*)

6.4.1 Intakes of energy and nutrients in children

The intakes of energy, energy nutrients, fibre and selected vitamins and minerals in girls and boys are presented in Table 15. When the total energy intake was compared with the required energy intake calculated by a formula of 1.39 × basal metabolic rate (BMR)–2.24 × BMR in boys and 1.30 × BMR–2.10 × BMR in girls (258), 21.9% of girls and 26.4% of boys were considered underreporters of total energy intake.

The median intakes of SFA, sucrose and salt were higher, and intakes of vitamin D and iron were lower than recommended in both girls and boys (Table 15). The energy-adjusted intake of dietary fibre only just reached the lower limit of recommended intake. Boys had a higher energy intake than girls. Moreover, the absolute intakes of dietary fibre, vitamin D, vitamin E, folate, sodium, potassium, calcium, iron, magnesium and zinc were higher among boys. However, girls had higher energy-adjusted intakes of dietary fibre, folate, vitamin C and potassium than boys.

Table 15. Intakes of energy, energy nutrients, dietary fibre, vitamins and minerals in children. Median (interquartile range).

	Unit	**Recommendation** (36)	**All, n=424 Median (IQR)**	**Girls, n=211 Median (IQR)**	**Boys, n=213 Median (IQR)**	***P* value**[a]
Energy	MJ		6.8 (6.0–7.8)	6.4 (5.8–7.2)	7.3 (6.3–8.3)	**<0.001**
Total fat	E%	25–40	29.7 (26.4–33.2)	29.3 (25.8–32.8)	30.5 (26.7–33.9)	0.201
SFA	E%	<10	12.0 (10.1–14.1)	11.9 (10.1–14.0)	12.1 (10.1–14.2)	0.337
MUFA	E%	10–20	9.7 (8.6–11.2)	9.6 (8.7–10.8)	10.0 (8.6–11.4)	0.148
PUFA	E%	5–10	4.7 (4.1–5.7)	4.7 (4.1–5.5)	4.8 (4.0–5.7)	0.443
Protein	E%	10–20	16.7 (15.0–18.4)	16.7 (15.2–18.3)	16.6 (15.0–18.5)	0.522
Carbohydrates	E%	45–60	51.7 (48.4–55.3)	52.5 (49.3–55.4)	51.1 (47.7–55.2)	0.108
Sucrose	E%	<10	12.4 (10.3–14.8)	12.4 (10.5–14.4)	12.5 (10.1–15.0)	0.983
Dietary fibre	g		14.1 (11.6 – 16.6)	13.7 (11.2–15.9)	14.4 (11.9–16.9)	**0.036**
	g/MJ	≥2–3	2.0 (1.7–2.5)	2.1 (1.8–2.5)	2.0 (1.6–2.4)	**0.029**
Vitamin D	µg	10	5.7 (4.4–7.1)	5.5 (4.3–6.5)	6.0 (4.4–7.6)	**0.001**
	µg/MJ	1.3	0.8 (0.7–1.0)	0.8 (0.7–1.0)	0.8 (0.6–1.1)	0.976
Vitamin E	mg	6.0	6.5 (5.5–7.9)	6.3 (5.4–7.4)	7.0 (5.7–8.3)	**<0.001**
	mg/MJ	0.9	1.0 (0.8–1.1)	1.0 (0.8–1.1)	0.9 (0.8–1.1)	0.395
Folate	µg	130	188 (153–223)	185 (153–213)	192 (153–227)	**0.039**
	µg/MJ	45	27.3 (23.4–32.2)	28.5 (24.4–33.1)	26.3 (22.6–30.5)	**<0.001**
Vitamin C	mg	40	77.2 (54.9–111)	75.0 (57.4–114)	78.2 (52.8–108)	0.484
	mg/MJ	8.0	11.3 (8.2–16.3)	11.9 (9.0–17.2)	10.5 (7.3–15.1)	**0.001**
Sodium	mg		2355 (2023–2743)	2238 (1967–2515)	2531 (2128–2981)	**<0.001**
	mg/MJ		349 (311–387)	348 (311–382)	350 (313–390)	0.194
Sodium chloride	g	≤3–4	5.7 (4.9–6.6)	5.4 (4.7–6.0)	6.1 (5.1–7.2)	**<0.001**
	g/MJ		0.8 (0.7–0.9)	0.8 (0.7–0.9)	0.8 (0.8–0.9)	0.194
Potassium	mg	2000	2901 (2481–3370)	2819 (2424–3138)	3047 (2618–3496)	**<0.001**
	mg/MJ	350	426 (373–475)	432 (383–485)	409 (368–464)	**0.047**
Calcium	mg	700	1174 (940–1388)	1095 (899–1297)	1254 (1004–1495)	**<0.001**
	mg/MJ	100	172 (143–201)	170 (145–201)	173 (142–201)	0.901

Table 15 to be continued

Table 15 continues

	Unit	**Recommendation** (36)	**All, n=424 Median (IQR)**	**Girls, n=211 Median (IQR)**	**Boys, n=213 Median (IQR)**	***P* value**[a]
Iron	mg	9.0	8.1 (6.9–9.5)	7.7 (6.7–8.8)	8.6 (7.2–10.0)	**<0.001**
	mg/MJ	1.6	1.2 (1.1–1.3)	1.2 (1.0–1.3)	1.2 (1.1–1.3)	0.706
Magnesium	mg	200	265 (232–306)	254 (224–290)	276 (241–321)	**<0.001**
	mg/MJ	35	38.9 (35.2–43.4)	39.0 (35.7–44.2)	38.7 (34.8–42.0)	0.153
Zinc	mg	7.0	9.7 (8.4–11.3)	9.3 (8.0–10.5)	10.5 (8.9–12.2)	**<0.001**
	mg/MJ	1.1	1.4 (1.3–1.6)	1.4 (1.3–1.6)	1.5 (1.3–1.6)	0.654

IQR, interquartile range; E%, percentage of total energy intake; SFA, saturated fat; MUFA, monounsaturated fat; PUFA, polyunsaturated fat.

[a] Differences in medians between girls and boys tested with Mann-Whitney's U-test.

More than half of children did not meet the recommendations for intake of SFA, unsaturated fat, sucrose, vitamin D, salt and iron (Figure 3). Moreover, approximately half of the children failed to meet the recommended intake of dietary fibre. A higher proportion of boys than girls met the recommended intake of MUFA, vitamin D, vitamin E, iron and zinc. However, a higher proportion of girls than boys met the recommended intake of salt.

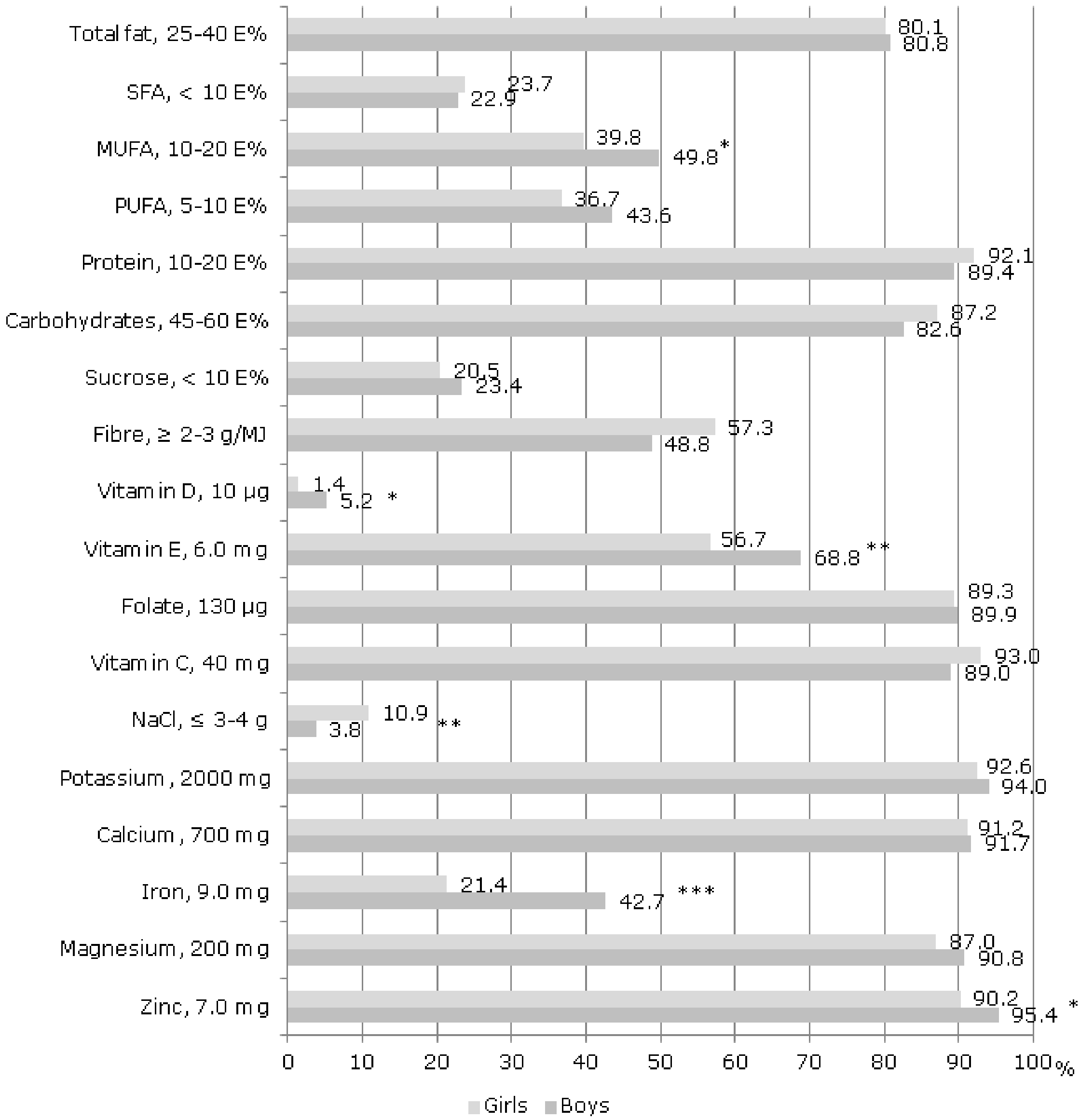

Figure 3. Proportion of children meeting the recommendations for the intakes of energy nutrients, dietary fibre and selected vitamins and minerals (36). SFA, saturated fat; MUFA, monounsaturated fat; PUFA, polyunsaturated fat. Differences between girls and boys tested by Pearson's χ^2 test, * P<0.005, ** P<0.01, *** P<0.001.

6.4.2 Associations of the intakes of energy and energy nutrients with body adiposity

Higher energy intake was related to higher waist and hip circumferences after adjustment for age, sex, physical activity, electronic media time and household income (Table 16). However, when the data were further adjusted for body height, the associations were no longer statistically significant (data not shown). A higher proportion of energy derived from protein was associated with higher body fat percentage, waist circumference and hip circumference adjusted for age, sex, physical activity, electronic media time and household income. Other intakes of macronutrients showed no associations with the measures of body adiposity.

Table 16. Intakes of energy, energy nutrients and dietary fibre and the risk of being overweight and standardised regression coefficients for the associations with body fat percentage and waist and hip circumferences

	Risk of being overweight	**Body fat percentage**	**Waist circumference**	**Hip circumference**
	OR (95 % CI)	**β (*P* value)**	**β (*P* value)**	**β (*P* value)**
Energy, MJ/SD	1.08 (0.81–1.46)	0.03 (0.592)	**0.11 (0.027)**	**0.13 (0.010)**
Total fat, E%/SD	0.90 (0.67–1.21)	-0.02 (0.625)	-0.08 (0.093)	-0.08 (0.104)
SFA, E%/SD	0.85 (0.63–1.14)	<0.01 (0.960)	-0.06 (0.227)	-0.07 (0.166)
MUFA, E%/SD	0.96 (0.72–1.30)	-0.03 (0.561)	-0.08 (0.114)	-0.08 (0.094)
PUFA, E%/SD	0.98 (0.73–1.32)	-0.06 (0.212)	-0.07 (0.157)	-0.05 (0.299)
Protein, E%/SD	1.27 (0.94–1.72)	**0.11 (0.017)**	**0.11 (0.020)**	**0.13 (0.008)**
Carbohydrates, E%/SD	1.00 (0.74–1.34)	-0.03 (0.531)	0.03 (0.594)	0.02 (0.757)
Sucrose, E%/SD	0.93 (0.69–1.25)	-0.01 (0.758)	-0.04 (0.476)	<0.01 (0.941)
Dietary fibre, g/MJ/SD	1.04 (0.77–1.41)	-0.01 (0.816)	<0.01 (0.933)	0.01 (0.904)

SD, standard deviation; E%, percentage of total energy intake SFA, saturated fat; MUFA, monounsaturated fat; PUFA, polyunsaturated fat.
Odds ratios (ORs) and 95% confidence intervals (CIs) are from logistic regression models adjusted for physical activity, electronic media time and household income.
Standardised regression coefficients (βs) are from linear regression models adjusted for age, sex, physical activity, electronic media time and household income.
Statistically significant associations are presented in bold.

6.5 DIETARY QUALITY INDICES (*STUDY IV*)

6.5.1 Dietary quality indices in children

The characteristics of children in the quartiles of the DASH Score, BSDS, MDS, HDI, FCHEI and the DIMERIC Score are presented in Table 17. The proportion of boys was higher in the first and second quartiles of the DASH Score than in other quartiles (Table 17). Moreover, children in the first quartiles of the DASH Score, BSDS, MDS and FCHEI had more electronic media time than children in other quartiles of these indices.

The intakes of energy, energy nutrients and dietary fibre in the quartiles of each dietary quality index are presented in Table 18. The intake of energy decreased across ascending quartiles of the DASH Score, FCHEI and the DIMERIC Score. The intakes of total fat and SFA were highest in the first quartile of the DASH Score, BSDS, MDS, HDI and FCHEI, and the PUFA-to-SFA ratio increased across ascending quartiles of BSDS, MDS, HDI and FCHEI. The intake of protein was lowest in the first quartile of the DASH Score, BSDS and FCHEI and in the fourth quartile of MDS and HDI. The intake of carbohydrates increased across ascending quartiles of the DASH Score, BSDS, MDS and HDI. The intake of dietary fibre increased across ascending quartiles of the DASH Score, BSDS, MDS, HDI and FCHEI. The intake of sucrose decreased across ascending quartiles of the DASH Score, FCHEI and the DIMERIC Score, but increased across ascending quartiles of the HDI.

Table 17. Characteristics of children in the quartiles (Q1–4) of the dietary quality indices. Mean values, standard deviations (SDs) and percentages.

	Quartiles of the dietary quality indices				
	Q1 Mean (SD)	**Q2 Mean (SD)**	**Q3 Mean (SD)**	**Q4 Mean (SD)**	***P* value[a]**
Dietary Approach to Stop Hypertension (DASH) Score					
Number of children	118	104	97	94	
DASH Score range	8–18	19–21	22–24	25–32	
Boys, %	61.9	52.9	43.3	45.7	**0.029**
Low (≤30 000 €/y) household income, %	24.1	16.3	18.9	16.7	0.087
Physical activity, min/d	114.4 (44.2)	117.7 (41.8)	109.1 (38.1)	110.3 (44.5)	0.293
Electronic media time, min/d	113.9 (35.5)	104.5 (65.0)	97.5 (46.0)	89.8 (49.7)	**0.007**
Baltic Sea Diet Score (BSDS)					
Number of children	126	107	89	91	
BSDS range	0–9	10–12	13–15	16–24	
Boys, %	50.8	59.8	43.8	50.5	0.163
Low (≤30 000 €/y) household income, %	25.4	15.9	18.0	14.3	0.099
Physical activity, min/d	112.2 (44.8)	117.0 (41.7)	107.7 (37.7)	114.8 (43.8)	0.461
Electronic media time, min/d	117.4 (58.6)	96.2 (47.8)	102.3 (51.1)	89.1 (44.8)	**0.001**

Table 17 to be continued

Table 17 continues

	Quartiles of the dietary quality indices				
	Q1 Mean (SD)	**Q2 Mean (SD)**	**Q3 Mean (SD)**	**Q4 Mean (SD)**	***P* value[a]**
Mediterranean Diet Score (MDS)					
Number of children	157	107	81	68	
MDS range	0–3	4	5	6–8	
Boys, %	52.2	47.7	53.1	54.4	0.807
Low (≤30 000 €/y) household income, %	18.5	21.5	18.5	16.2	0.582
Physical activity, min/d	107.7 (41.8)	110.9 (37.7)	122.8 (43.6)	116.9 (47.1)	0.054
Electronic media time, min/d	109.7 (58.2)	105.6 (57.2)	94.6 (39.5)	89.1 (39.1)	**0.022**
Healthy Diet Indicator (HDI)					
Number of children	29	211	144	29	
HDI range	0–1	2	3	4–5	
Boys, %	62.1	49.8	52.1	51.7	0.666
Low (≤30 000 €/y) household income, %	20.7	15.6	22.9	20.7	0.747
Physical activity, min/d	112.9 (47.8)	110.8 (41.7)	117.6 (43.4)	106.9 (34.6)	0.417
Electronic media time, min/d	98.6 (53.1)	101.1 (53.4)	107.7 (53.0)	86.5 (34.5)	0.224
Finnish Children Healthy Eating Index (FCHEI)					
Number of children	94	112	94	113	
FCHEI range	0–17	18–23	24–27	28–42	
Boys, %	59.6	47.3	53.2	47.8	0.265
Low (≤30 000 €/y) household income, %	21.7	21.6	12.0	20.9	0.167
Physical activity, min/d	115.6 (42.3)	112.8 (43.1)	104.0 (48.7)	108.8 (39.9)	0.602
Electronic media time, min/d	117.0 (58.0)	100.7 (56.8)	104.0 (48.7)	90.0 (41.6)	**0.003**
Diet to Assess Metabolic Risk in Children (DIMERIC) Score					
Number of children	114	86	94	119	
DIMERIC Score range	1–3	4	5	6–8	
Boys, %	57.9	51.2	45.7	50.4	0.366
Low (≤30 000 €/y) household income, %	15.0	18.1	25.8	19.0	0.454
Physical activity, min/d	112.3 (43.3)	112.6 (42.1)	114.4 (42.7)	113.0 (41.6)	0.987
Electronic media time, min/d	102.0 (56.6)	109.7 (49.1)	106.7 (54.8)	93.4 (47.1)	0.128

[a] Differences in the means of continuous variables across the quartiles of the dietary quality indices were compared using general linear models. The differences in the proportions of dichotomous variables across the quartiles of the dietary quality indices were tested using Pearson's χ^2 test.

A higher dietary quality index indicates a better adherence to the diet.

Table 18. The intakes of energy, energy nutrients and dietary fibre in the quartiles (Q1–Q4) of the dietary quality indices. Mean values and standard deviations (SDs).

	Quartiles of the dietary quality indices				
	Q1 Mean (SD)	**Q2 Mean (SD)**	**Q3 Mean (SD)**	**Q4 Mean (SD)**	***P* value[a]**
Dietary Approach to Stop Hypertension (DASH) Score					
Energy, MJ	7.3 (1.3)	6.9 (1.3)	6.6 (1.2)	6.6 (1.2)	**<0.001**
Total fat, E%	32.5 (4.8)	30.0 (5.2)	28.9 (4.8)	27.8 (4.3)	**<0.001**
SFA, E%	13.4 (2.7)	12.1 (3.1)	11.9 (2.6)	10.9 (2.1)	**<0.001**
MUFA, E%	11.0 (1.8)	9.8 (1.8)	9.5 (1.7)	9.3 (1.8)	**<0.001**
PUFA, E%	5.3 (1.3)	4.9 (1.4)	4.8 (1.2)	4.7 (1.1)	**0.003**
PUFA-to-SFA ratio	0.4 (0.1)	0.4 (0.2)	0.4 (0.1)	0.4 (0.1)	0.269
Protein, E%	16.2 (2.5)	16.7 (2.5)	17.0 (2.4)	17.4 (2.5)	**0.002**
Carbohydrates, E%	50.0 (5.4)	52.0 (5.5)	52.7 (4.6)	53.5 (4.3)	**<0.001**
Sucrose, E%	13.7 (4.2)	12.6 (3.3)	12.3 (3.2)	12.0 (3.6)	**0.002**
Dietary fibre, g	12.7 (3.7)	14.7 (4.4)	14.6 (3.3)	16.6 (3.9)	**<0.001**
Baltic Sea Diet Score (BSDS)					
Energy, MJ	6.8 (1.4)	7.1 (1.3)	6.9 (1.4)	6.7 (1.1)	0.217
Total fat, E%	33.8 (4.3)	30.6 (4.0)	27.7 (3.9)	26.0 (4.1)	**<0.001**
SFA, E%	14.4 (2.4)	12.6 (2.1)	10.9 (1.9)	9.7 (2.0)	**<0.001**
MUFA, E%	11.2 (1.8)	10.0 (1.5)	9.2 (1.5)	8.9 (1.7)	**<0.001**
PUFA, E%	5.1 (1.5)	4.9 (1.2)	4.9 (1.2)	4.7 (1.0)	0.197
PUFA-to-SFA ratio	0.4 (0.1)	0.4 (0.1)	0.5 (0.1)	0.5 (0.1)	**<0.001**
Protein, E%	16.3 (2.3)	16.4 (2.4)	17.0 (2.7)	17.6 (2.3)	**<0.001**
Carbohydrates, E%	48.5 (4.6)	51.6 (4.6)	54.0 (4.5)	54.9 (4.5)	**<0.001**
Sucrose, E%	12.8 (4.2)	12.9 (3.6)	12.6 (3.6)	12.5 (3.2)	0.844
Dietary fibre, g	11.7 (2.7)	14.8 (4.2)	15.4 (3.3)	17.2 (3.9)	**<0.001**
Mediterranean Diet Score (MDS)					
Energy, MJ	6.9 (1.4)	6.8 (1.4)	6.9 (1.2)	6.8 (1.2)	0.739
Total fat, E%	31.3 (4.9)	28.9 (4.6)	30.1 (5.3)	28.3 (5.4)	**<0.001**
SFA, E%	13.4 (2.8)	11.4 (2.2)	12.0 (2.6)	10.7 (2.8)	**<0.001**
MUFA, E%	10.2 (1.8)	9.6 (1.8)	10.1 (2.0)	9.7 (2.0)	0.087
PUFA, E%	4.8 (1.2)	5.0 (1.3)	4.9 (1.2)	5.0 (1.3)	0.613
PUFA-to-SFA ratio	0.4 (0.1)	0.5 (0.2)	0.4 (0.1)	0.5 (0.2)	**<0.001**
Protein, E%	17.0 (2.6)	17.2 (2.4)	16.3 (2.1)	16.1 (2.7)	**0.004**
Carbohydrates, E%	50.3 (4.8)	52.5 (4.9)	52.2 (5.3)	54.3 (5.3)	**<0.001**
Sucrose, E%	12.9 (4.1)	12.5 (3.3)	12.8 (3.1)	12.6 (3.9)	0.831
Dietary fibre, g	12.8 (3.4)	14.5 (3.7)	14.9 (3.4)	17.9 (4.6)	**<0.001**

Table 18 to be continued

Table 18 continues

	Quartiles of the dietary quality indices				
	Q1 Mean (SD)	**Q2 Mean (SD)**	**Q3 Mean (SD)**	**Q4 Mean (SD)**	***P* value[a]**
Healthy Diet Indicator (HDI)					
Energy, MJ	7.3 (1.4)	6.8 (1.3)	6.8 (1.3)	7.2 (1.1)	0.185
Total fat, E%	34.8 (4.9)	31.0 (4.1)	28.5 (5.2)	25.0 (5.4)	**<0.001**
SFA, E%	14.1 (2.6)	12.9 (2.2)	11.3 (2.9)	8.8 (2.5)	**<0.001**
MUFA, E%	11.7 (2.6)	10.2 (1.5)	9.5 (1.8)	8.8 (2.1)	**<0.001**
PUFA, E%	5.8 (2.0)	4.9 (1.2)	4.8 (1.1)	4.8 (1.2)	**0.002**
PUFA-to-SFA ratio	0.4 (0.2)	0.4 (0.1)	0.4 (0.2)	0.6 (0.2)	**<0.001**
Protein, E%	17.9 (2.2)	17.4 (2.1)	16.0 (2.7)	15.1 (2.6)	**<0.001**
Carbohydrates, E%	46.0 (4.7)	50.3 (4.1)	54.1 (4.2)	58.5 (5.2)	**<0.001**
Sucrose, E%	10.5 (3.5)	12.1 (3.3)	13.8 (3.9)	14.1 (3.8)	**<0.001**
Dietary fibre, g	13.9 (3.9)	14.1 (3.5)	14.4 (4.2)	18.4 (5.6)	**<0.001**
Finnish Children Healthy Eating Index (FCHEI)					
Energy, MJ	7.2 (1.3)	7.0 (1.5)	6.8 (1.1)	6.6 (1.2)	**0.005**
Total fat, E%	31.3 (4.9)	31.0 (5.3)	29.3 (5.0)	28.4 (4.6)	**<0.001**
SFA, E%	13.5 (2.8)	12.8 (2.7)	11.7 (2.5)	10.9 (2.4)	**<0.001**
MUFA, E%	10.1 (1.9)	10.3 (2.0)	9.7 (1.9)	9.7 (1.7)	0.052
PUFA, E%	4.7 (1.4)	4.9 (1.2)	5.0 (1.2)	5.1 (1.2)	0.151
PUFA-to-SFA ratio	0.4 (0.2)	0.4 (0.1)	0.4 (0.1)	0.5 (0.2)	**<0.001**
Protein, E%	15.0 (2.1)	16.4 (2.0)	17.4 (2.3)	18.1 (2.4)	**<0.001**
Carbohydrates, E%	52.4 (5.5)	51.2 (5.4)	51.9 (5.3)	52.2 (4.5)	0.380
Sucrose, E%	15.4 (4.0)	12.6 (3.1)	12.2 (3.4)	11.0 (3.0)	**<0.001**
Dietary fibre, g	12.6 (4.1)	14.5 (4.0)	14.5 (3.4)	16.2 (4.0)	**<0.001**
Diet to Assess Metabolic Risk in Children (DIMERIC) Score					
Energy, MJ	7.2 (1.3)	6.9 (1.3)	6.6 (1.4)	6.8 (1.2)	**0.017**
Total fat, E%	29.1 (5.1)	29.8 (5.0)	30.7 (4.9)	30.4 (5.3)	0.103
SFA, E%	11.9 (2.9)	12.1 (2.7)	12.7 (2.8)	12.2 (2.8)	0.235
MUFA, E%	9.7 (1.8)	9.9 (1.9)	10.1 (1.9)	10.1 (2.0)	0.288
PUFA, E%	4.8 (1.2)	4.9 (1.3)	4.9 (1.2)	5.1 (1.3)	0.294
PUFA-to-SFA ratio	0.4 (0.2)	0.4 (0.1)	0.4 (0.2)	0.4 (0.1)	0.424
Protein, E%	17.0 (2.8)	17.0 (2.6)	16.7 (2.4)	16.4 (2.2)	0.236
Carbohydrates, E%	52.5 (5.3)	51.9 (5.6)	51.3 (4.8)	51.8 (5.0)	0.393
Sucrose, E%	13.4 (3.8)	13.0 (4.0)	12.4 (3.6)	12.1 (3.4)	**0.037**
Dietary fibre, g	15.0 (4.3)	14.4 (3.7)	13.6 (3.6)	14.8 (4.3)	0.062

E%, percentage of total energy intake; SFA, saturated fat; MUFA, monounsaturated fat; PUFA, polyunsaturated fat.

[a] Differences in the means of variables across the quartiles of the dietary quality indices were compared using general linear models.

A higher dietary quality index indicates better adherence to the diet.

6.5.2 Associations of dietary quality with body adiposity and cardiometabolic risk

Children in the first quartile of the DIMERIC Score were taller and had higher body weight and BMI-SDS than children in other quartiles (Table 19), while the other dietary quality indices were not associated with body height, body weight or BMI-SDS (data not shown).

The mean metabolic risk score, waist circumference, concentration of fasting serum insulin and diastolic blood pressure were higher in children in the first quartile of the DIMERIC Score than in children in other quartiles (Table 19). Moreover, the concentration of HDL cholesterol was lower in children in the first quartile of the DIMERIC score than in children in other quartiles. There were no differences in the metabolic risk score, waist circumference, fasting serum concentration of insulin, fasting plasma concentration of glucose and triglycerides, or the levels of diastolic blood pressure across the quartiles of the DASH Score, BSDS, MDS, HDI and FCHEI (data not shown). Fasting plasma concentration of HDL cholesterol was higher in children in the lowest quartile of the BSDS (mean (SD) in mmol/l in Q1, 1.68 (0.30); Q2, 1.57 (0.33); Q3 1.57 (0.29); Q4 1.56 (0.29); *P* value for difference among quartiles 0.005) and MDS (mean (SD) in mmol/l in Q1, 1.64 (0.29); Q2, 1.54 (0.33); Q3, 1.63 (0.30); Q4, 1.59 (0.30); *P* value for difference among quartiles 0.042). The levels of systolic blood pressure were higher in children in the lowest quartile of the BSDS (mean (SD) in mmHg in Q1, 101.2 (6.9); Q2, 98.4 (7.2); Q3, 100.2 (7.8); Q4, 100.9 (7.7); *P* value for difference among quartiles 0.027). Adjustment for age, sex, body height, physical activity or electronic media time did not alter these associations (data not shown). After further adjustment for household income, the decrease in the plasma concentration of triglycerides across the ascending quartiles of the DIMERIC Score was statistically significant (*P* value for difference among quartiles 0.001).

Table 19. The metabolic risk score and individual cardiometabolic risk factors among children in the quartiles (Q1–4) of the Diet to Assess Metabolic Risk in Children (DIMERIC) Score

	Quartiles of the Diet to Assess Metabolic Risk in Children (DIMERIC) Score				
	Q1 Mean (SD)	**Q2 Mean (SD)**	**Q3 Mean (SD)**	**Q4 Mean (SD)**	***P* value[a]**
Body height, cm	130.0 (6.0)	128.1 (5.0)	128.2 (5.5)	128.6 (5.5)	**0.042**
Body weight, kg	27.9 (5.1)	26.7 (4.8)	26.3 (4.3)	26.1 (4.5)	**0.015**
BMI-SDS (100)	0.0 (1.0)	-0.1 (1.0)	-0.3 (1.1)	-0.4 (1.0)	**0.015**
Metabolic risk score	1.3 (3.3)	-0.2 (4.0)	-0.5 (3.2)	-1.0 (3.4)	**<0.001**
Waist circumference, cm	57.9 (6.0)	56.7 (5.3)	56.0 (5.2)	55.5 (5.0)	**0.005**
Serum insulin, mU/l	5.2 (2.3)	4.4 (2.5)	4.6 (2.6)	3.9 (2.0)	**0.001**
Plasma glucose, mmol/l	4.9 (0.4)	4.8 (0.4)	4.8 (0.4)	4.8 (0.4)	0.069
Plasma HDL cholesterol, mmol/l	1.53 (0.30)	1.66 (0.31)	1.60 (0.29)	1.62 (0.31)	**0.027**
Plasma triglycerides, mmol/l	0.64 (0.27)	0.59 (0.27)	0.58 (0.22)	0.56 (0.22)	0.085
Systolic blood pressure, mmHg	101 (7.4)	100 (7.9)	100 (7.8)	100 (6.7)	0.186
Diastolic blood pressure, mmHg	63 (8.1)	62 (6.9)	60 (7.3)	61 (6.4)	**0.016**

Q, quartile; BMI-SDS, body mass index standard deviation score; HDL, high density lipoprotein.

[a] Differences in the means of variables across the quartiles of the Diet to Assess Metabolic Risk in Children (DIMERIC) Score were compared using general linear models.

Statistically significant values are presented in bold. A higher DIMERIC Score indicates a better adherence to the diet.

The risk of being in the highest quintile of the metabolic risk score did not differ across the quartiles of BSDS, MDS, HDI or FCHEI adjusted for age and sex (data not shown). However, children in the second quartile of the DASH Score had a 2.1 times higher risk (95% CI 1.02–4.27) of being in the highest quintile of the metabolic risk score than children in the fourth quartile, however, the association diminished after further adjustment for electronic media time (OR 2.18, 95% CI 0.94–4.03). Children in the first quartile of the DIMERIC Score had a 2.8 times higher risk (95% CI 1.46–5.51) of being in the highest quintile of the metabolic risk score than children in the fourth quartile. Further adjustment for body height, physical activity, electronic media time or household income did not substantially alter these results (data not shown).

Children who were in the first quartile of the DIMERIC Score and did not eat all three main meals daily represented 17.4 % of the whole study population and had an almost seven times higher risk of being in the highest quintile of the metabolic risk score than children who were in the fourth quartile and ate all main meals daily adjusted for age and sex (Figure 4). Moreover, children who were in the second quartile of the DIMERIC Score and did not eat all three main meals daily had an almost four times higher risk of being in the highest quintile of the metabolic risk score than children who were in the fourth quartile of the DIMERIC Score and ate all main meals daily. Further adjustments for physical activity and electronic media time did not markedly alter the results (data not shown). After additional adjustment for household income, children who were in the first quartile of the DIMERIC Score and ate all main meals daily had a higher risk of being in the highest quintile of the metabolic risk score than children who were in the fourth quartile and ate all main meals daily (OR 4.39, 95% CI 1.05–18.35).

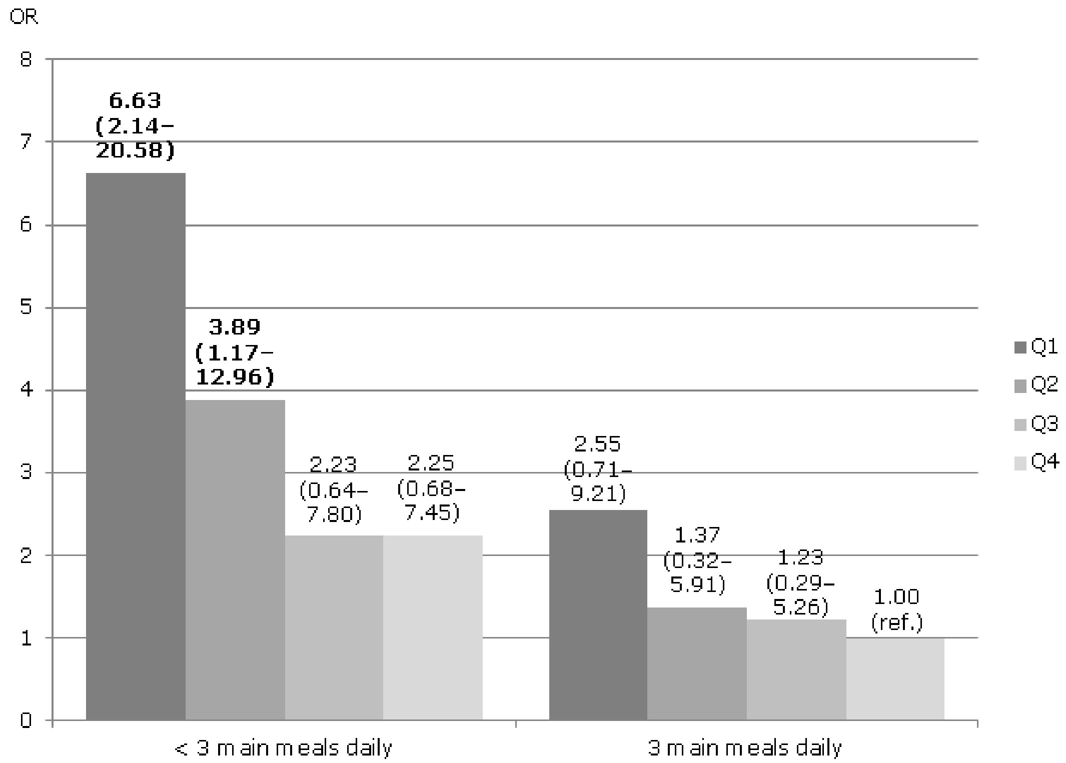

Figure 4. The risk of being in the highest quintile of the metabolic risk score according to the quartiles (Q1–4) of the Diet to Assess Metabolic Risk in Children (DIMERIC) Score and the frequency of main meals. Odds ratios (ORs) and 95% confidence intervals are from logistic regression models adjusted for age and sex. Significant values are presented in bold.

6.6 EATING BEHAVIOUR (*STUDY II*)

6.6.1 Associations of eating behaviour with body adiposity

Higher eating behaviour scores in enjoyment of food, food responsiveness and emotional overeating were associated with an increased risk of being overweight adjusted for total physical activity, electronic media time and household income and with a higher body fat percentage and higher waist and hip circumferences adjusted for age, sex, total physical activity, electronic media time and household income (Table 20). A higher scoring in satiety responsiveness was associated with a decreased risk of being overweight and a lower body fat percentage and lower waist and hip circumferences after these adjustments. A higher scoring in slowness in eating was associated with a decreased risk of overweight and lower waist and hip circumferences. Desire to drink, emotional undereating and food fussiness were not associated with overweight, body fat percentage, waist circumference or hip circumference.

Table 20. Eating behaviour and the risk of being overweight and standardised regression coefficient for the associations with body fat percentage and waist and hip circumferences

	Risk of being overweight OR (95 % CI)	**Body fat percentage β (*P* value)**	**Waist circumference β (*P* value)**	**Hip circumference β (*P* value)**
Enjoyment of food	**1.57 (1.04–2.35)**	**0.13 (0.004)**	**0.14 (0.003)**	**0.15 (0.001)**
Food responsiveness	**4.68 (2.90–7.54)**	**0.30 (<0.001)**	**0.40 (<0.001)**	**0.38 (<0.001)**
Emotional overeating	**2.60 (1.52–4.45)**	**0.09 (0.035)**	**0.19 (<0.001)**	**0.15 (0.001)**
Desire to drink	0.86 (0.58–1.28)	-0.02 (0.741)	-0.06 (0.173)	-0.04 (0.387)
Satiety responsiveness	**0.42 (0.26–0.67)**	**-0.20 (<0.001)**	**-0.26 (<0.001)**	**-0.26 (<0.001)**
Slowness in eating	**0.61 (0.41–0.92)**	-0.09 (0.053)	**-0.16 (0.001)**	**-0.17 (<0.001)**
Emotional undereating	0.72 (0.43–1.21)	-0.05 (0.233)	-0.06 (0.218)	-0.06 (0.195)
Food fussiness	0.79 (0.54–1.15)	-0.05 (0.294)	-0.01 (0.785)	-0.04 (0.369)

Odds ratios (ORs) and 95% confidence intervals (CIs) are from logistic regression models adjusted for total physical activity, electronic media time and household income.
Standardised regression coefficients (βs) are from linear regression analyses adjusted for age, sex, total physical activity, electronic media time and household income.
Statistically significant associations are presented in bold.

7 Discussion

7.1 SUMMARY OF FINDINGS

The results of this doctoral thesis indicate that many components of the diet are not at recommended levels among children. This is alarming, because unfavourable dietary habits seem to be associated with increased body adiposity and cardiometabolic risk already in childhood.

Less than half of children ate all three main meals daily. Particularly, children with a lower socioeconomic position were more likely to skip main meals. Most children consumed the recommended 2–3 snacks daily. However, snacks contained two thirds of daily sucrose intake. Skipping main meals was associated with higher body adiposity and higher cardiometabolic risk among children.

A minority of children consumed vegetables, fruit and berries as recommended. As many as quarter of children consumed sugar-sweetened beverages daily. Boys ate more red meat, sausages and sweets than girls. Children with a lower socioeconomic position were less likely to eat recommended food items than children with a higher socioeconomic position. A higher consumption of sugar-sweetened beverages, red meat and low-fat vegetable oil-based margarine and a lower consumption of vegetable oils were related to higher cardiometabolic risk.

The intakes of SFA, sucrose and salt were higher than recommended. In contrast, the unsaturated-to-saturated fat ratio and the intakes of dietary fibre, vitamin D and iron were lower than recommended. While the absolute intakes of several vitamins and minerals were higher among boys, their energy-adjusted intakes were generally higher among girls. A higher intake of protein was associated with higher body adiposity in children.

Previously published dietary quality indices, the DASH Score, BSDS, MDS, HDI and FCHEI, were not associated with cardiometabolic risk in children in this study. However, a dietary quality index consisting of a high consumption of sugar-sweetened beverages, red meat and low-fat vegetable oil-based margarine and a low consumption of vegetable oils was related to increased cardiometabolic risk in children, particularly when combined with skipping main meals.

Finally, a higher eating rate, enjoyment of food, food responsiveness and emotional overeating, and a lower satiety responsiveness were associated with higher body adiposity.

7.2 STRENGHTS AND LIMITATIONS

7.2.1 Study population and study design

Children 6–8 years of age were invited to participate in the PANIC Study by letters sent to parents of children in public primary schools, which ensured that a representative sample of the whole age group in Kuopio was contacted. Of 736 invited children, 512 participated in the study. The participation rate was relatively high, 70%. Therefore, the results of this study are generalisable to the general population of Finnish primary school children. Based on the available school health examination data, the participating children did not differ in sex distribution, age and BMI-SDS from other children who started school in 2007–2009 in Kuopio. However, no data on diet, physical activity or cardiometabolic risk factors other than BMI-SDS were available for the non-participants. Moreover, the non-participants were not asked for their reasons for non-participating. Therefore, a possibility of selection bias must be taken into consideration. The participating families may have been more motivated and interested in health-related issues and may have had healthier lifestyle habits than non-participating families.

In our sample, 13% of children were the only child of the family and 16% of children had three or more siblings. Similar proportions of the number of siblings was reported in a recent nationwide study of children (42). The same nationwide study reported that approximately a third of parents of school-aged children had a vocational high school degree or higher (42). In this study, however, more than 80% of children had at least one parent with a vocational highschool degree or higher. However, in this study, the parental education level was defined according to the highest level in the family. Moreover, Kuopio is one of the few university cities in Finland, and the education level is therefore expected to be higher than that of the country as a whole.

This large population sample of children enabled the investigation of the associations of dietary factors with body adiposity and cardiometabolic risk free from several confounding factors. For example, the study population was rather homogeneous in age, ethnicity and place of residence, was mainly prepubertal, 96% of whom were at Tanner stage 1, and had not been exposed to smoking or alcohol consumption, excluding the possibility of the confounding effects of these factors. Moreover, the analyses were adjusted for several important confounding factors, including physical activity and electronic media time.

This study had a cross-sectional study design, which hampers the interpretations of the results. The directions of the causality of the observed associations cannot be determined.

7.2.2 Assessments

Diet

In the present study, dietary factors were assessed by food records over four consecutive predefined days and questionnaires completed by the parents. A clinical nutritionist instructed parents on filling out food records and reviewed the food records upon return by a clinical nutritionist. Although self-reported records are often prone to biases, careful work in instructing, reviewing and analysing the records diminishes the misreporting error. Moreover, to provide current and accurate information, periodic updates were made, and new products and recipes were added in the database of the Micro-Nutrica® software.

The food record method has previously been validated against the observation method in primary school children (259,260). Moreover, Hunsberger et al. recently reported that Swedish children aged 6–8 years were able to accurately report their school lunch intake (261). In a previous Finnish study, a food record of four days was shown to be adequate in correctly classifying 6-year-old children according to the intakes of several nutrients, such as protein, dietary fibre, vitamin C, calcium and magnesium, with an accuracy of correlation coefficient ≥0.80 (262). Therefore, the food record method is suggested to provide representative information on the intakes of nutrients in children at a group level.

Despite the careful work, some inaccuracy in the use of food records needs to be taken into account. In case no detailed information was available, standard recipes were used for foods prepared at home. For example, the amount of salt added in preparation of meals at home was in most cases based on standard recipes, which could have led to either underestimation or overestimation of the intake of sodium.

Moreover, four days may not be a long enough period of time to assess the true consumption of dietary factors that have a high day-to-day variation. For example, some nutrients, such as MUFA, PUFA and iron, have been reported to require a longer period of time than four days to assess the intake accurately (262). Therefore, the results concerning the intakes of these nutrients in this study must be interpreted with care. The PANIC Food Consumption Questionnaire was used to complement the information from food records. Using the frequency data based on this questionnaire may have provided more accurate estimates of the consumption of fish and other often infrequently eaten foods than the food record data.

In the present study, a quarter of children were considered underreporters of total energy intake (258). In line, previous British studies have reported that 12–29% of food records of 7–10-year-old children are considered to be underreported as regards energy intake (68). The prevalence of underreporting is reported to increase with age and to be higher among overweight individuals and when records are completed without parental supervision (263). Therefore, because the study population consisted of a population sample of young children and the food records were completed by the parents, the reports can be considered relatively reliable as regards energy intake. Moreover, the true day-to-day variation in food consumption is high among young children (262). We therefore chose not to exclude the potential underreporters from the analyses.

Eating frequency was calculated using food records. Each eating occasion was defined as breakfast, lunch, dinner or snack based on the recorded time and the type of food by the impressions of the clinical nutritionist. This approach was used because there are no feasible, standardised and objective criteria for defining meals and snacks in children. Previous studies have defined meals and snacks based on varying definitions (18). Most commonly, the definitions of eating occasions have based on the time of consumption and the content of energy, nutrients or foods in the meal. The varying definitions cause a problem when comparing the finding with those of other studies. Therefore, there is a need for a widely accepted definition for main meals and snacks.

Five previously used dietary quality indices were calculated based on the food record data. Some modifications in the calculations of the indices were necessary due to differences in food culture and methodological constraints. For example, alcohol consumption was excluded from the BSDS and MDS. Other widely used dietary quality indices, such as the KIDMED index that was developed to detect adherence to the Mediterranean diet among children (26), would have needed data from food frequency questionnaires or other specific questionnaires. Therefore, not all published indices were included in the analyses.

Eating behaviour of children was measured by the CEBQ which was back translated into Finnish. A good internal reliability and repeatability of the original English version has been reported (33). Moreover, three sub-scales of the questionnaire, satiety responsiveness, food responsiveness and enjoyment of food, have been validated against behavioural measures of eating among children 4–5-years of age (34). In this study, the Finnish translation showed good internal consistency within seven of the eight sub-scales. This questionnaire provides a cost- and time-wise usable method for assessing eating behaviour traits in large study populations, like in this study, regardless of its rather subjective nature.

Overweight and body adiposity

Overweight is defined as excess body adiposity (98). Because direct measures of body adiposity can seldom be used in practice, indirect methods are widely used. In this study, excess body adiposity was measured using several methods, both directly and indirectly. The direct methods provide scientifically important knowledge, but the results based on indirect methods may be more interpretable clinically. All measurements were performed by trained study nurses using standardised procedures, excluding the chance of self-reporting bias.

Height and body weight were measured, and BMI was calculated. First, we calculated BMI-SDSs using age- and sex-specific British growth-reference data from 1990s (256), as national references were not available at the time of the baseline examinations. When the Finnish reference data, collected until 2008, were available, they were used (100). The children had slightly lower BMI-SDS when compared to the Finnish reference than when compared to the British reference. The Finnish reference data were based on growth measurements in the city of Espoo, Southern Finland (100). The population in Espoo is seen to be a mixture of that of the whole country because of a high migration from other parts of the country during recent decades. Therefore, children in this study seem to have a slightly lower BMI than Finnish children on average. This can be due to the selection bias, but may also reflect the true regional variation in BMI among Finnish children.

Overweight and obesity were defined according to the age- and sex-specific BMI cutoffs proposed by the IOTF (99). Although cutoffs for overweight are arbitrary, the use of internationally accepted cutoffs enabled comparison of our results with those previously reported. However, the lack of Finnish measurements in the reference data of the IOTF criteria hinders the generalisation of the criteria to the Finnish population. The prevalence of overweight in this study was slightly lower than in previous Finnish reports (42).

Body adiposity was measured directly by the DXA method, which is considered to be the most objective method in assessing body adiposity in children (102). The use of body fat percentage as a continuous variable in the analyses enabled the detection of associations linear in nature.

We also measured waist and hip circumferences, which may be better measures of fat distribution than BMI. Fat accumulation in the visceral depots is associated with cardiometabolic dysfunction more than fat accumulation in lower parts of body, and waist circumference is commonly included in the definitions of metabolic syndrome (186). However, there are no national reference data for waist or hip circumferences in children available at the time. In line with the findings concerning BMI-SDS and the prevalence of overweight, slightly higher waist and hip circumferences have been reported previously among Finnish children (42).

Cardiometabolic risk

At the moment, widely accepted criteria for the definition of paediatric metabolic syndrome are lacking. According to any available criteria, the prevalence rate of metabolic syndrome is low in young age groups (192). Therefore, the lack of statistical power hinders the detection of relevant risk factors for paediatric metabolic syndrome in studies. Moreover, cutoff points for metabolic syndrome are difficult to set because of the continuous nature of most cardiometabolic risk factors. In this study, metabolic risk was measured by a continuous metabolic risk score instead of a dichotomous metabolic syndrome variable. Previous studies have also increasingly used metabolic risk scores (191). The use of a continuous cardiometabolic risk variable enabled the assessment of early state cardiometabolic dysfunctions sensitively, although most children were healthy and had risk factors in the normal range.

The cutoff point at the highest quintile of the metabolic risk score was used to define children with the highest risk of metabolic syndrome in later life in secondary analyses in this study. This cutoff point was chosen to be somewhat equivalent to the estimated prevalence of metabolic syndrome in Finnish adults (264,265). However, the arbitrariness of this cutoff point must be acknowledged when interpreting the results.

Other assessments

A wide range of possible confounding factors were measured. Physical activity and electronic media time were measured by the PANIC Physical Activity Questionnaire filled out by parents with their children. The validity of the questionnaire measuring the time spent in physical activity was tested against the Actiheart monitor combining heart rate and accelerometry measurements (Actiheart, CamNtech, Cambridge, UK) in a subsample of 38 children (251). Total physical activity measured by the questionnaire correlated with total physical activity measured by the Actiheart monitor (correlation coefficient r 0.37, *P* value 0.033). However, the measurement error due to self-report may still be large and introduce residual confounding in the analyses. For example, the parents of overweight children may have overestimated the amount of physical activity of their children.

Socioeconomic status was defined in annual household income and parental education level self-reported by the parents. Partly different associations of these two measures with dietary factors in children were observed. However, we chose to use only household income as a marker of socioeconomic status when adjusting the associations of dietary factors with body adiposity and cardiometabolic risk, because different measures of socioeconomic position correlate with each other.

7.3 INTERPRETATION OF FINDINGS AND COMPARISON WITH PREVIOUS FINDINGS

7.3.1 Eating frequency

Previous studies from other countries have reported that 60–85% of children and adolescents eat breakfast regurlarly (72,266,267). Breakfast has been reported to be skipped more often than other meals (115). In contrast, in this study, almost all children had breakfast every day. About three quarters of the children ate lunch and about half of the children ate dinner daily. However, only a third of girls and less than half of boys ate all three main meals daily. Similar proportions of Finnish adolescents have been reported to eat three main meals daily (47). It seems that a habit of meal skipping starts developing at very early age, and that skipping dinner is most common among children while breakfast skipping becomes more common in adolescence.

According to former Nordic Nutrition Recommendations, children should optimally receive approximately 20% of daily energy from breakfast, 25% from lunch, 25% from dinner and 30% from snacks (37). In previous studies on adolescents from Finland (45) and other European countries (125), 16–21% of daily energy was derived from breakfast, 16–20% from lunch, 26–29% from dinner and 35–41% from snacks. However, there are limited data on energy intake from meals and snacks among younger children. In the present study, 17% of daily energy intake was received from breakfast, 21% from lunch and 21% from dinner, that were slightly lower than recommended. Moreover, 42% of energy was derived from snacks, which was rather high, in comparison to those previously reported among adolescents (45,125). Snacks are an important source of energy and many nutrients for young children, especially, because they cannot eat large amounts at main meals (37). However, this study observed that snacks provided a majority of daily intake of sucrose. Therefore, dietary quality of snacks should be improved to meet the needs of nutrients.

Children from a low socioeconomic position were more likely to skip main meals than other children. Therefore, free school lunch served for every child on school days in Finland may be particularly important for them.

In line with previous studies (43,114), skipping main meals was associated with an increased risk of overweight. Previous studies have suggested that one explanation for the association of skipping meals with a higher risk of overweight could be the confounding effect of other behaviours, such as a lower engagement in sports (127) and physical activity (126) among children who skip meals. In this study, the association of skipping main meals with an increased risk of overweight remained after adjustment for physical activity and electronic media time, assuming that these lifestyle habits do not solely explain the relationship between eating frequency and body adiposity. However, a nutrient composition mainly closer to the dietary recommendations was found in main meals, which may partly explain the association of skipping main meals with a higher risk of overweight.

Previous studies have found that regularly eating five meals daily is related to a reduced risk of having dyslipidaemia among Finnish adolescents (203) and that a regular number of daily meals is associated with a better insulin sensitivity among lean adults (123). However, the literature on the association of the frequency of main meals with clustering of cardiometabolic risk factors among children is limited (201). We found that skipping main meals was associated with an increased metabolic risk score in children, even after controlling for physical activity, electronic media time, energy intake and food consumption. Skipping main meals was particularly associated with a higher waist circumference and increased concentrations of fasting serum insulin and plasma glucose. Skipping main meals was also related to a decreased concentration of plasma HDL cholesterol when household income was taken into account. However, the association of skipping main meals with the increased serum concentration of insulin and plasma glucose weakened when BMI-SDS was taken into account, suggesting that these relationships are partly mediated by body adiposity.

7.3.2 Food consumption

The diet of Finnish children has been reported to have improved during the last decades (38). In line, the diet of children was observed to include several beneficial components in this study. For example, high-fibre bread, skimmed milk and low-fat cold cuts and cheese were commonly consumed, as recommended. However, some common food choices were not as recommended. The frequency of consumption of fish and vegetables, fruit and berries was lower than recommended and the consumption of sugar-sweetened beverages was common. Moreover, although vegetable oil-based margarines were commonly consumed, margarines containing 60–80% of fat, as recommended, were consumed only by a third of children.

Previous studies have reported that several differences in dietary habits exist between men and women (66). However, only minor differences in diet have been reported between sexes at preschool age (38). We found that the consumption of red meat, sausages, sweets and chocolate were higher in boys than in girls. Further research is needed to assess differences between girls and boys in dietary intake at a preschool age and the causes behind them in order to prevent differences in health outcomes between sexes later in life.

Previous studies among Finnish children and adolescents have reported that children with a high socioeconomic position more likely consume healthier foods, such as vegetables and fruit, low-fat milk and vegetable oil-based margarine (44,268). In line with previous findings, we found that children from families with the highest household income more likely consumed skimmed milk and fish as recommended than children from families with the lowest household income. Furthermore, children with the highest parental education more likely consumed fish and high-fibre bread than children with the lowest parental education. However, children with the highest parental education less likely used vegetable oil-based margarine on bread as recommended than children with the lowest parental education. New food trends, such as the reported increase in the consumption of butter and butter-oil mixtures in Finland shortly after the time of data collection (66), may be first adopted by higher socioeconomic groups. Altogether, the effects of parental education and household income on the diet of children were not identical. Parental education may provide better knowledge and household income better economic possibilities for healthy dietary choices in the family. Free school lunch provides a unique opportunity to reduce the differences in food consumption between socioeconomic groups by increasing the consumption of fish, high-fibre bread, skimmed milk and vegetable oil-based margarine across all socioeconomic groups.

A higher intake of sugar from beverages has been associated with higher plasma concentrations of triglycerides, very low-density lipoprotein cholesterol and intermediate-density lipoprotein cholesterol as well as impared insulin secretion among overweight children and adolescents (269,270). Moreover, a recent study reported an association of a higher consumption of sugar-sweetened beverages with the clustering of metabolic risk factors (208). The findings of this study provide further evidence that a higher consumption of sugar-sweetened beverages is associated with increased cardiometabolic risk and particularly with increased fasting concentrations of insulin and glucose in children. One explanation for the association of the consumption of sugar-sweetened beverages with an increased cardiometabolic risk has been suggested to be lower levels of satiety signals after energy intake in a liquid form compared to energy intake in a solid form (271). A lower satiety signalling has been suggested to lead to higher energy intake and weight gain, resulting in an increased cardiometabolic risk. However, controlling for energy intake or BMI-SDS did not alter the findings of this study, suggesting that the inverse health effects of a high consumption of sugar-sweetened beverages are not solely a result of a higher energy intake or body adiposity. A possible explanation for the finding is that sucrose, as well as other rapidly absorbable carbohydrates, increases dietary glycemic load and may thereby increase the risk of development of insulin resistance and glucose intolerance (272). Moreover, the consumption of sugar-sweetened beverages has been associated with a low overall quality of diet and a lower intake of several nutrients in children (273), which may partly explain the adverse health effects of these beverages.

The consumption of solid hydrogenated fats instead of liquid oils in the family has been associated with an increased risk of metabolic syndrome among children (212). In this study, a lower consumption of vegetable oils was associated with a higher metabolic risk score, fasting plasma concentration of glucose and diastolic blood pressure levels. The sufficient intake of unsaturated fat can improve fatty acid composition in cell membranes, and membranes high in unsaturated fat can improve insulin sensitivity by enhancing insulin receptor binding and glucose transporter location (220,221). In this study, also a relationship of a higher consumption of low-fat vegetable oil-based margarine to an increased metabolic risk score, waist circumference and fasting serum concentration of insulin and to a decreased plasma concentration of HDL cholesterol were found, even after controlling for energy intake and other dietary factors. One explanation for our finding may be that low-fat margarines contain too little fat for a sufficient intake of unsaturated fat. Because the consumption of sources of vegetable fat is relatively low among Finnish children, low-fat margarines cannot provide adequate amounts of unsaturated fat. In the analyses, the association of the consumption of low-fat vegetable oil-based margarine with fasting serum concentration of insulin weakened after controlling for BMI-SDS. Therefore, another explanation may be that low-fat margarines are commonly chosen in families with overweight children, as a parent’s attempt to reduce the weight gain of the child.

In contrast to previous findings among children (212,213) and young adults (274), we observed that a higher consumption of non-root vegetables was associated with a higher cardiometabolic risk. Controlling for other dietary factors or total energy intake did not explain the findings. The most plausible explanation for the conflicting finding is that not all possible confounding factors were taken into account in the analyses. Another reason for our observation may be that parents whose children have the highest cardiometabolic risk tend to overreport the consumption of vegetables that are generally known to be healthy. It is also possible that the low consumption of vegetables among children in the study population increased the chance of a random error and resulted in the unexpected relationship of the consumption of non-root vegetables and cardiometabolic risk. Finally, the cross-sectional study design does not allow us to draw conclusions about the causality of the association.

Among adults, a higher consumption of processed meats has been associated with an increased risk of type 2 diabetes and cardiovascular diseases (275). Similar, but weaker, associations have been detected for red meat. Among adolescents, an eating pattern high in the consumption of red meat has been associated with the clustering of cardiometabolic risk factors (276). However, evidence on the association of the consumption of red meat with cardiometabolic risk among children is lacking. In this study, the consumption of red meat was directly associated with the metabolic risk score, fasting serum concentration of insulin and systolic and diastolic blood pressure in children, but the relationships were diminished when total energy intake and BMI-SDS were taken into account. These findings suggest that a higher consumption of red meat impairs cardiometabolic health via increased energy intake and body adiposity.

7.3.3 Intakes of energy and nutrients

The intakes of energy, MUFA, PUFA and dietary fibre were observed to be lower than recommended and the intakes of SFA and sucrose were higher than recommended in children. Similar findings have previously been reported among Finnish (38) and European children (277) at a primary school age. While most of the intakes of vitamins and minerals were adequate in this study, the intakes of vitamin D and iron were lower than recommended. The intake of vitamin D is reported to be lower than recommended also in other European countries (50). Natural food sources of vitamin D are limited and the main sources in the diet of Finnish children are products fortified with vitamin D (49,77). After the time of data collection the vitamin D fortification of milk and margarines have been increased. Therefore, we suggest that the intake of vitamin D in children may have increased since the data collection. The relatively low intake of iron has also been reported in children Europe-wide (50). Among Finnish children, grain products, in particular porridge and breakfast cereals, have been reported to major sources of iron together with meat products (49). An increase in the consumption of high-fibre grain products in children would likely increase the intake of not only iron but also dietary fibre.

In this study, the intake of protein was directly associated with body fat percentage, waist circumference and hip circumference whereas intakes of other nutrients were not related to measures of adiposity. Previous studies have reported that a high protein intake during the weaning period and the first years of life predicts high body adiposity in later childhood (140). It has been suggested that a higher intake of protein stimulates the secretion of IGF-1 (141) resulting in accelerated growth and an increase the amount of both muscle mass and adipose tissue. A higher intake of protein has been associated with higher concentrations of IGF-1 also among schoolchildren (278). However, the knowledge on the association of protein intake with body adiposity among school children is currently limited. It has been suggested that the associations of protein intake in infancy with body adiposity in later childhood would be observable only at the intakes of protein exceeding 15–16 E% (142). In this study, the median intake of protein was almost 17 E%, and a quarter of children derived over 18 E% from protein. Therefore, more studies are needed to confirm the optimal level of protein intake among school-aged children. One possible explanation for our finding could be that the sources of protein in children are often high in fat and sucrose. For example, protein-rich dairy products, such as yoghurts, have been reported to be one of the most significant sources of sucrose in the diet of 7-year-old Finnish school children (279), and a high intake of energy from such foods would predispose to excess body adiposity. However, further adjustment for energy from fat or carbohydrates did not weaken the association between energy from protein and indicators of body adiposity in the present study. A high protein intake can also indicate other unhealthy dietary choices that could increase body adiposity. For example, replacing vegetables with meat or replacing water as a between-meal drink with a protein-rich drink, such as milk or a milk-based drink, could expose to excess weight gain.

In the present study, total energy intake was not associated with overweight or body adiposity, even when the analyses were adjusted for physical activity. This finding can partly be explained by underreporting, which has been reported to be more common among overweight children and adolescents than normal weight peers (263). Moreover, it has been suggested that a positive energy balance is associated with gaining weight, but not after the state when the weight gain has stabilised (280). The increase in energy intake that causes weight gain may also be so small that the current methodology may fail to find the true association between energy intake and body adiposity (280). We found linear associations of total energy intake with waist and hip circumferences, but the associations diminished after controlling for body height. A possible explanation for this may be that taller children have, on average, higher waist and hip circumferences independently of body adiposity.

7.3.4 Dietary quality assessed by indices

A lower DASH Score, BSDS, MDS and HDI were associated with a higher intake of total and saturated fat and a lower BSDS, MDS, HDI and FCHEI were related to a lower PUFA-to-SFA ratio. In contrast, the DIMERIC Score was not associated with the quality of dietary fat. This is plausible as the DIMERIC Score was not developed particularly to measure the quality of dietary fat and the components of the DIMERIC Score did not include the major sources of saturated fat in children, such as dairy products. Although previous studies have shown that a diet low in saturated fat is associated with higher insulin sensitivity and lower concentrations of serum total and LDL cholesterol in children (218,219), a low DIMERIC Score identified children with a high cardiometabolic risk better than other indices. This finding suggests that the poor quality of dietary fat cannot solely explain a higher cardiometabolic risk, but the risk increases when several unhealthy dietary factors exist in the diet.

A lower DIMERIC Score, FCHEI and DASH Score, which all included the consumption of sugar-sweetened beverages or foods as a component, were associated with a higher intake of sucrose in children. A lower HDI was related to a lower intake of sucrose whereas other indices were not related to the intake of sucrose. It may be that a high intake of sucrose may not be indentifiable by other unhealthy dietary components in Finnish children. Therefore, dietary quality indices used to identify a low quality of diet or a poor cardiometabolic health among children should include a component measuring the consumption of sugar-sweetened beverages or foods.

Low scores of dietary quality indices have previously been associated with an increased risk of type 2 diabetes, cardiovascular disease and premature mortality in a number of studies among adults (28,254,255,281,282). Low scores in dietary quality indices have also been related to excess body adiposity in some cross-sectional studies among children (55,149), but there are few reports on the relationships of dietary quality indices to the clustering of cardiometabolic risk factors among children. In this study, the DASH Score, BSDS, MDS, HDI and FCHEI were not associated with the clustering of cardiometabolic risk factors and had weak if any associations with individual cardiometabolic risk factors in children. These findings suggest that dietary quality indices that have primarily been used among adults are not able to identify children with clustering of cardiometabolic risk factors. One explanation for our finding may be that only one of these dietary quality indices was originally developed for children and therefore most of them do not take into account the special characteristics of the diet of children and their health effects. For example, the consumption of vegetables, fruit, high-fibre grain products and low-fat milk, which are included in many dietary quality indices, may be too similar across Finnish children to classify them according to their current cardiometabolic risk. A lower DASH Score, BSDS, MDS, HDI and FCHEI may be related to harmful metabolic changes that occur after a long-term exposure to an unhealthy diet, but not to metabolic changes occurring within a relatively short period of time in childhood.

The results of this study suggest that a low DIMERIC Score, consisting of a high consumption of sugar-sweetened beverages, red meat and low-fat vegetable oil-based margarine and a low consumption of vegetable oil, is a better indicator of an increased cardiometabolic risk than a low DASH Score, BSDS, MDS, HDI or FCHEI in children. It is important to encourage children to consume also vegetables, fruit, high-fibre grain products, low-fat milk and dairy products and fish, that are included in many dietary quality indices, because they have been found to prevent type 2 diabetes, cardiovascular disease and premature mortality later in life (28,254,255,281,282). However, the DIMERIC Score may be more useful in the identification of children with a currently exsiting cluster of cardiometabolic risk factors than other dietary quality indices. Because the DIMERIC Score was developed based on analyses in the PANIC Study, the score should nonetheless be tested in other cohorts of children. Children who had a low DIMERIC Score and who did not eat main meals daily represented almost a fifth of the whole study population and had a markedly higher cardiometabolic risk than other children. These findings suggest that the combination of a low quality of diet and skipping main meals is particularly harmful to cardiometabolic health in children.

7.3.5 Eating behaviour

A higher enjoyment of food, food responsiveness and emotional overeating were found to be associated with a higher prevalence of overweight and other measures of excess body adiposity. A higher satiety responsiveness and slowness in eating were associated with a lower risk of overweight. These findings are in agreement with those of previous studies that have used the same questionnaire (62,153-157) and provide further evidence that children who have adverse eating behaviours that may result in an unregulated food intake have a higher risk of being overweight than those without these problems. Accordingly, an obesogenic environment with unlimited availability to food can be especially harmful for those who have eating behaviours that hinder the regulation of food intake and feelings of satiety. Our findings may also be related to the inverse association of the number of daily main meals with the prevalence of overweight, that is, irregular eating and skipping meals may increase the tendency to be vulnerable to rapid eating, overeating and decreased feelings of satiety. There is some evidence on heritability and tracking of certain eating bahaviours (33,283). Hence, assessing eating behaviour by a short questionnaire could be useful in child health care to identify children with a high susceptibility to overeating and weight gain, and who therefore would benefit most from dietary interventions. Such effective intervention approaches targeted towards children are needed.

8 Conclusions and future perspectives

Overweight and cardiometabolic diseases are a combined result of genetic predisposition and several environmental factors. Diet is one of the few modifiable risk factors for these common conditions. However, only a few dietary factors have convincingly been associated with an increased risk of overweight or cardiometabolic risk in children. It seems clear that new perspectives of diet in a larger context are needed. For example, the use of dietary quality indices or dietary patterns and eating behaviour dimensions may provide new evidence on critical aspects of diet in association with body adiposity and cardiometabolic risk in children.

The results of this doctoral thesis indicate that many components of diet are not at recommended levels among primary school children. Alarmingly, children with a lower socioeconomic position are less likely to eat as recommended than children with a higher socioeconomic position. Moreover, the diets of girls and boys exhibit differences that reflect those reported in women and men. Therefore, inequality in lifestyle habits and future health seem to start developing at an early age.

An irregluar eating frequency, a higher eating rate, enjoyment of food, food responsiveness and emotional overeating, and a lower satiety responsiveness were associated with higher body adiposity. More research is needed to develop tools for identifing children with a high risk of these adverse eating behaviours. Moreover, intervention studies are needed to understand the possibilities of changing adverse eating behaviour dimensions in children.

The present study also contributes to the limited number of studies on dietary factors associated with the clustering of cardiometabolic risk factors. The findings suggest that unhealthy dietary habits affect metabolism and cardiovascular health already at a primary school age. Particularly, the accumulation of several unhealthy dietary habits seems to increase the cardiometabolic risk. A regular consumption of main meals, higher consumption of foods high in vegetable oil-based fat, lower consumption of sugar-sweetened beverages and a moderate consumption of red meat and other high-protein foods should be promoted in primary school children in order to improve their body composition and cardiometabolic health.

In the future, more longitudinal studies on population-based samples of young children are needed to understand the possible effects of diet on body adiposity and cardiometabolic risk. Studying paediatric populations provides a unique possibility to detect early determinants of cardiometabolic dysfunction in the absence of the confounding effects of drugs, diseases and long-term lifestyle habits. In addition, biological mechanisms behind the observed associations of dietary factors with body adiposity and cardiometabolic risk need further investigation. Moreover, studies on the effects of dietary interventions on children with a high cardiometabolic risk are needed.

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Aino-Maija Eloranta

Diet, Body Adiposity and Cardiometabolic Risk in a Population Sample of Primary School Children

This doctoral thesis focused on diet and its associations with body adiposity and cardiometabolic risk in a population sample of children from the Physical Activity and Nutrition in Children (PANIC) Study. The results showed that many components of diet are not at recommended levels in children. Skipping meals, unhealthy food choices and uncontrolled eating behaviour were related to increased body adiposity and cardiometabolic risk. The accumulation of many unhealthy dietary factors predicted the highest cardiometabolic risk in children.

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