General discussion

AIMS

The aims of this thesis were to evaluate overall diet quality in childhood, to study its determinants, and to study its associations with several health outcomes. We evaluated diet quality of children participating in three different population-based cohorts. Main determinants of interest were feeding-related factors and socioeconomic and lifestyle factors. Main outcomes of interest were body composition, cardiometabolic health, and atopic diseases.

MAIN FINDINGS

Diet quality in childhood

To assess overall diet quality of children, we developed a novel food-based diet quality score for school-age children, based on age-specific dietary guidelines. Subsequently, we used this score to evaluate diet quality of children participating in the Generation R, ABCD, and Rhea cohorts. In the first cohort, the Generation R Study, we first assessed the construct validity of the diet quality score, i.e. whether this score actually measures what it is supposed to measure, namely a healthy diet. To do this, we assessed associations of the diet quality score with intake of several nutrients. The score was positively correlated with intake of macronutrients considered to be healthy, including protein, mainly plant protein, dietary fiber, and $n-3$ fatty acids, and inversely correlated with intakes of more unhealthy nutrients, including saturated fat, monosaccharides and disaccharides. The score was also positively correlated with intakes of essential micronutrients, such as vitamins, calcium, and magnesium. These results indicate that the diet quality score has adequate construct validity and that the score may be used as an indicator of a healthy diet. We applied this diet quality score in three different populations of children of different ages, living in different environments, and we observed similar diet qualities among these children. These results add to the validity of our diet quality score and suggest that it could indeed be used as an indicator of healthy diet in children.

Using this diet quality score, we observed that diet quality of children at the ages of 4, 6, and 8 years, living on Crete (Greece), in Amsterdam (the Netherlands), and Rotterdam (the Netherlands), was suboptimal, with median scores in the different populations ranging from 4 to 6 on a continuous scale from 0 to 10, indicating that their dietary intake was not conform current age-specific dietary guidelines. In general, children scored relatively high for their intakes of whole-grains, fruits, and fish, whereas low scores were observed for sugar-containing beverages and red- and processed meat **(Figure 5.1)**. These findings are in line with results from the Dutch National Food Consumption Survey [1] and other studies on diet quality in children [2,3]. Given this low diet quality in

children and its potential effects on later health, dietary intake in children needs to be improved. In order to do this, it is essential to study potential determinants of diet quality to identify children at high risk of poor diet quality.

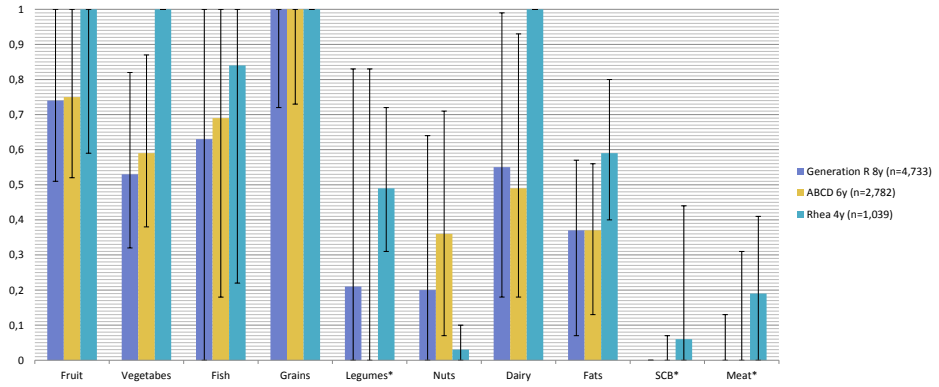

Figure 5.1. Median scores for the individual components of the diet quality score in three cohorts of children

Values are medians and interquartile ranges. Maximum score per component: 1. *median score of 0.

In Chapters 2.1 to 2.4, we studied several potential determinants of diet quality in early and mid-childhood. We observed that children with more screen time, children from lower educated mothers, or from lower-income households have a lower diet quality – all independent of each other. In addition, we observed that women with a history of eating disorders have a relatively good diet quality during pregnancy, which was also observed in their infants. These findings could provide directions for public health interventions to specifically target children at risk of poor diet quality. Other important determinants of dietary intake are eating environment and taste preferences. It has been suggested that taste preferences and eating habits are shaped in early childhood and that they tend to track into adulthood, thereby influencing food choices [4,5]. In Chapter 2.2 we examined associations of parental feeding practices and family eating routines with diet quality in school-age children. Findings of this study suggested that parental monitoring and restrictive feeding is associated with higher diet quality, while pressure to eat and less frequent family meals were associated with lower child diet quality. This suggests that targeting parental feeding strategies could improve diet quality of children. In Chapter 2.3 we evaluated dietary taste patterns in early childhood and its determinants. Children at the age of 1 year obtained most of their energy intake from foods within a neutral cluster, which are low in all basic taste intensities. Once they reach the age of 2 years, their dietary intake becomes more intense in taste, i.e., they have a higher consumption of food products that taste more sweet, sour, or salty. Similar determinants of dietary taste patterns have been identified as for diet quality.

In addition, we observed positive correlations of several taste patterns with diet quality score in infancy, suggesting that intervening in the food products given at an early age could affect taste preferences and thereby diet quality. Still, more research is needed to explore overall dietary taste patterns in early childhood, how these track over time, and how it is related to dietary habits and actual dietary intake in later life.

Diet quality, body composition, and cardiometabolic health

Using this diet quality score, not only adherence to guidelines and its determinants can be studied, but also associations of overall diet with health outcomes, in order to identify important modifiable risk factors of (common) diseases. In this thesis, I examined the associations of diet quality with highly prevalent and important public health problems in childhood: childhood obesity, cardiometabolic risk factors, and atopic diseases. Concerning obesity, we used repeated measures of children's growth and detailed measures of body composition (Chapters 3.1 to 3.3). We observed that a higher diet quality score at different ages throughout childhood was associated with better growth and a higher BMI up to age 12 years. However, we observed that this association may be explained by higher fat-free mass rather than fat mass. These findings therefore suggest that BMI is not an adequate measure to examine associations of dietary intake with adiposity in children. Furthermore, we observed that higher diet quality in childhood was associated with better bone health at the age of 10 years, independent of child BMI. Our findings therefore suggest that dietary intake according to dietary guidelines may have a beneficial impact on growth and body composition throughout childhood. In Chapters 3.4 and 3.5, we examined associations of diet quality with cardiometabolic health in children. Our findings from chapter 3.4 suggest that better diet quality is associated with overall lower cardiometabolic risk in school-age children, which was mainly driven by a lower blood pressure. It has been shown that obesity and other cardiometabolic risk factors tend to track from childhood to adulthood and increase the risk of chronic diseases [6-10]. Hence, targeting these factors during childhood could be a good strategy to prevent later chronic diseases. Certain cardiometabolic risk factors may only become apparent at a later age. Studies with longer follow-up and repeated measurements are crucial to examine associations of diet in childhood with cardiometabolic health over a longer time period.

Overall diet and atopic diseases

Another common health problem in childhood are atopic diseases, including asthma, eczema, and food allergy. We examined associations of overall diet quality in early life, i.e., during pregnancy, infancy, and in childhood, with allergic sensitization or atopic diseases in children around the age of 10 years. Overall, we did not observe associations of diet quality at one of these time points with atopic outcomes at age 10 years. It

has been suggested that children may outgrow some atopic diseases as they become older [11-13]. The long time-window between exposure and outcome in our study and the measurement of atopic outcomes at the age of 10 years may explain the absence of an association in our study. Any potential associations between early-life diet and atopic outcomes may take place within a short time window and may not persist into later childhood. In addition, specific foods or nutrients, such as fish or fatty acids, rather than overall dietary patterns may be more relevant for the prevention of atopic outcomes in children.

In addition to this observational study, we also conducted a systematic review of RCTs on dietary interventions in early childhood. Most interventions yielded inconsistent findings for the development of atopic diseases. However, interventions on allergen avoidance in early life seemed promising for preventing atopic diseases. More high-quality research with proper control groups are needed to confirm these findings.

METHODOLOGICAL CONSIDERATIONS

Study design and populations

The studies in this thesis were embedded in three cohort studies of children and we conducted a systematic review of randomized controlled trials. Most of the studies in this thesis were performed in the Generation R Study, based in Rotterdam, the Netherlands. In addition, data from the ABCD Study (Amsterdam, the Netherlands) and the Rhea Study (Island of Crete, Greece), were analyzed. All three studies are large ongoing population-based prospective cohort studies. Major strengths of population-based studies are the ability to identify potential risk factors of common diseases, and the availability of a wide range of potential covariates. In addition, cohort studies could indicate temporal associations between exposures and outcomes, because participants in a cohort study are known to be disease-free at the timing of exposure assessment. However, all studies in this thesis were of observational nature, which does not allow to directly infer causality of the associations [14]. In addition, prospective cohort studies may require long follow-up periods, which could be accompanied with high rates of loss to follow-up. This loss to follow up during a study as well as the selection of subjects into a study could lead to selection bias. Participants included the Generation R Study tended towards a more healthy population, with participants in general having more healthy habits and were more highly educated than the total population. This selective participation at baseline might influence prevalence rates and thereby affect the external validity of the study, i.e. the generalizability of our results to other populations [15]. Nevertheless, selective loss to follow-up could introduce selection bias, which also threatens internal validity of the study. Selection bias occurs when associations of dietary intake with our outcomes

of interest are different for the children included in our study compared to those who were not included, but would have been eligible [16]. In Chapter 2.4, we reported that non-responders to the FFQ more often had characteristics associated with a lower diet quality score, such as lower educational level. Diet quality may therefore even be lower in children not included in the analysis. This would have consequences for the external validity, as observed results may not be directly generalizable to the general population. However, it could also result in selection bias if the associations of diet quality with health outcomes are different between children who were included in the analysis and children who were not. Other important sources of error in cohort studies are information bias and confounding, which will be discussed later in this chapter.

Some of these limitations of cohort studies could be tackled in RCTs, which are generally considered to provide the best level of evidence [17]. However, RCTs might face other limitations, as we also observed in Chapter 4.2 where we conducted a systematic review of RCTs. Especially in nutritional research, it is challenging to find a proper placebo or control group. For example, dietary interventions of foods can typically not be blinded, leading to the possibility that the observed effect is due to knowledge of intervention assignment. Hence, RCTs of dietary interventions often examine the effects of nutrients by comparing supplements to a placebo. However, the effects of supplements might not be the same as real foods, as nutrients are not consumed in insolation and diets are complex, with interactions and synergistic effects across different nutrients and dietary components. Therefore, cohort study designs remain useful and necessary to study associations of actual dietary intake with health outcomes. Consistent observations of an association between dietary intake and health in different populations and with different study designs and approaches of dietary analysis may also lend support to a real effect.

Dietary assessment

The dietary data from all cohorts used in this thesis were measured using FFQs. An FFQ measures habitual intake rather than intake on one or a few specific days, making them suitable to estimate long-term dietary intake. In addition, FFQs are commonly used in population-based evaluations of dietary patterns in childhood and adulthood and are favored in large-scale studies because they are less burdensome to participants than e.g. food diaries and are relatively easy to process [18]. However, FFQs are self-reported and are therefore prone to measurement errors [19-21]. This measurement error is an important source of information bias in studies on dietary intake, as it may result in misclassification of the exposure [21]. Misclassification can be non-differential or differential. In the case of non-differential misclassification of the exposure, the measurement error is random and not related to the outcome of interest, leading to attenuation of the association. However, in the case of differential misclassification, the measurement error is related to the outcome of interest. It has been suggested that overweight adults tend to

underreport their dietary intake compared to adults with normal weight [22]. Since young children have a limited ability to self-report their food intake, the ability of parents to accurately recall their children's food intake is vital. Although a few studies suggested that parents are capable of accurately reporting dietary intake of their child [23,24], not much is known about potential differential-misclassification of parent-reported dietary intake of children. In our studies, estimated energy intakes from our FFQs were similar to the recommended energy intakes for the specific age groups, suggesting no large under- or over reporting. Also, validation of our FFQ showed reasonable capacity of the FFQ to rank children according to their energy intake [25]. Although exact amounts of nutrients intakes are difficult to estimate with the use of an FFQ due to these measurement errors, it has been shown that FFQs are appropriate for ranking participants according to their dietary intake, making it a suitable method to assess dietary intake in large populations. In addition, in our studies, we used validated, extensive, population-specific FFQs.

A big challenge of FFQs is that they should be tailored to the specific study population. Food items in the FFQ should be chosen in such a way that it covers a large part of the habitual intake in the study population. An FFQ for young children should therefore be different than for older children, as several specific food items are more frequently consumed in particular age groups, e.g. baby formula are only consumed by infants and not by older children. In addition, an extensive FFQ including many food items provides more detail and contributes to a more accurate estimation of dietary intake. In our studies, we used FFQs that were validated using other dietary assessment methods and that showed good results for this validation. For example, the FFQ that was used for school-age children in both the Generation R and ABCD studies was validated against the doubly labeled water method, which is regarded as the golden standard for the determinations of total energy expenditure in individuals. This validation showed a Pearon's correlation of 0.62 for energy intake as estimated from the FFQ and energy expenditure measured with the doubly labeled water method, indicating a reasonable capacity of the FFQ to rank children with regard to their energy intake [25]. However, the FFQ was not validated for intake of specific foods or food groups.

A main limitation of an FFQ is that it is self-reported and it relies on the memory of the respondents. However, all self-report methods to asses dietary intake, including not only FFQs, but also e.g., 24h recalls and food diaries, are challenging [21]. In general, individuals do not remember everything that they or their children consumed, do not know the contents of the foods eaten, and have difficulties to estimate portion sizes accurately. In addition, in parent-reported dietary intakes, parents might not be aware of everything that their child eats outside of the house, for example at school or the day care. Another method to assess dietary intake are the use of biomarkers [26]. These biological indicators of intakes are not limited by errors in self-reporting, but they have other limitations,

including that they often reflect status rather than intake, are highly specific, and are generally expensive and invasive.

In the studies included in this thesis, FFQs were sent to the participants in hard copy. This might have resulted in incompleteness of responses. Technology could offer a wide range of feasible options for dietary assessment, which are easy to incorporate into daily routines. For example, an online FFQ could enhance the completeness of responses, as it is able to prevent unanswered questions or implausible answers. Also, in recent years, the use of image-based dietary assessment has been used to assist traditional dietary assessment methods such as dietary records [27,28]. Images can be taken with handheld devices or wearable cameras, and have been used to assist traditional methods for among others the estimation of portion sizes. These images could further reduce self-report errors by taking and storing food images before and after consumption. Previous studies have suggested that the use of image-based approach complementary to traditional self-report assessments could improve accuracy of dietary assessment and that underreporting is reduced compared to traditional assessment methods only. However, at this moment, this image-based approach cannot yet be used as a dietary assessment method on its own, but can only be used to assist certain traditional, prospective assessment methods such as food diaries, but not for retrospective assessment methods such as 24h recalls or FFQs.

Dietary indices

Over the past few decades, analysis of dietary patterns has emerged as an important research field, complementary to studies focusing on single dietary compounds. An advantage of examining dietary patterns is that the complex correlations between intakes of foods and nutrients are taken into account [29]. Dietary patterns can either be data-driven (i.e., based on the variation of dietary intake data within a study population) or predefined (i.e., based on specific dietary guidelines or recommendations)[30]. The data-driven approach identifies similarities of dietary habits or food groups consumed within a study population, based on their intercorrelations. However, because these dietary patterns are identified on the basis of actual dietary intake from a study population rather than guidelines or existing knowledge, these patterns represent common diets in a population but do not necessarily represent a healthy diet. Predefined dietary patterns are usually based on dietary guidelines or recommendations, and therefore better reflect a desirable dietary pattern [31,32]. In addition, dietary patterns of different populations can be more easily compared. However, disadvantages of such dietary patterns are that the variations between individuals within a population might be small.

For the studies in this thesis, we used predefined diet quality scores to quantify diet quality of pregnant women, infants, and children at different ages, reflecting adherence to age-specific food-based dietary guidelines in the Netherlands. These Dutch dietary

guidelines are unique in the regard that they are completely food-based, since dietary guidelines from other countries often combine recommendations for both foods and individual nutrients. However, the predefined dietary index approach is limited by current scientific evidence and understanding of diet-disease relationships. The Dutch dietary guidelines were based on extensive previous research on nutrients, foods, and dietary patterns in relation to specific diseases that are common in the general Dutch population [33,34], but mostly evident in adults. Although Dutch dietary recommendations from the Netherlands Nutrition Center, based on guidelines form the Health Council, are available for children from age 1 year onwards, these are extrapolated based on evidence of the diet-disease relation in adult populations. An optimal diet for children might be different from an optimal diet in adulthood and may also be different in different phases of childhood. For example, exclusive breastfeeding is the most optimal diet for infants [35]. After this, there is a weaning period in which young children get introduced to foods other than milk, which is also an important period for the development of taste preferences and eating habits. Gradually, children will reach the point where they consume more regular table foods around the age of 1 year. Because children are likely to have different needs than adults, it might not be sufficient to extrapolate evidence from adults to guidelines for children. In addition, the association of adherence to these overall dietary guidelines with health outcomes in childhood has not yet been thoroughly evaluated and it remains unclear whether these associations in adulthood also applies to children. In future development of dietary guidelines, more studies in children are needed, and should be taken into account to develop guidelines that are truly age specific rather than just extrapolation of evidence from adult-based studies.

Constructing an overall diet quality index involves many choices. First, individual components of the score should be selected, and cut-off points have to be defined. Most diet indices are based on intake of nutrients, food groups, or a combination of these, and some indices also include measures of dietary variety [36]. We chose to construct our diet quality score on the basis of intake of food groups only, in line with current Dutch dietary guidelines. As we observed positive associations of the diet score with intake of essential micronutrients, the diet quality score may indeed represent an overall healthy diet. However, these nutrients have been estimated using the same FFQ as used for the development of the diet quality score. Ideally, one would like to validate the score against nutrients assessed with another method or with the use of biomarkers. In addition, our diet quality scores were continuous, which provide more detail and is more accurate in ranking children with respect to dietary quality than a dichotomous scoring system. We included both healthy and unhealthy components in the scores, which may better capture overall diet quality than including healthy or unhealthy components only, as eating healthy foods is not necessarily inversely related to eating unhealthy foods [37]. Although it may have been preferred to ascribe greater weights to components that

have a greater effect on health, not enough information on the overall health effects of individual components was available, so we chose not to apply any weighting.

Studying dietary patterns in relation to health in childhood could provide directions to improve future dietary guidelines specifically targeted at children of different ages. In addition, this diet quality score provides an overall estimation of a healthy diet, which can be used to control for diet quality in epidemiological studies on associations of other dietary or lifestyle factors with health. Dietary pattern analysis will not replace nutrient or food analysis in nutrition research, but instead, it serves as a complementary approach. Evidence for a real effect of dietary intake is supported when the results from multiple approaches (i.e. analysis of nutrients, foods, and dietary patterns) are consistent.

Outcome assessments

The primary outcomes in the studies presented in this thesis were body composition, cardiometabolic health, and atopic diseases. Children participating in the Generation R Study visited our research center at their ages of 6 and 10 years for a detailed physical examination. We measured their height and weight to calculate BMI. The use of BMI as measure of adiposity is practical and low in costs, making it ideal for large-scale studies. However, it has some limitations as BMI includes both fat mass as well as lean mass and bone mass [38-40], and its interpretation among children and adolescents is further complicated by the changes that occur in body composition during growth and development. BMI might therefore be misleading when examining associations of dietary intake with adiposity in children. In the studies included in this thesis, we therefore also examined fat, lean, and bone mass, measured using DXA-scans and BIA. We observed that children with higher diet quality in childhood have higher BMI, but that this higher BMI was fully explained by higher fat-free mass rather than fat mass. Thus, confirming that BMI only is not an adequate measure of adiposity. Reliable and valid body composition assessment is important in both clinical and research settings. Several methods and techniques for the measurement of body composition in children exist, including skinfold thicknesses, BIA, and DXA [41,42]. Skinfold thicknesses are relatively simple measurements to estimate adiposity, however, it has been shown to underestimate body fat in children. BIA is commonly used to assess body composition in research settings. It is a simple, non-invasive, and low-cost method to measure body composition. However, it has been suggested that BIA might be less accurate and underestimates body fatness as compared to DXA-scans, which is considered to be the gold standard for measuring body composition. DXA is also a rapid and non-invasive method to assess body composition. However, DXA requires specialized radiology equipment and is more expensive, and participants as well as researchers are exposed to some radiation.

For cardiometabolic factors, we measured blood pressure and blood concentrations of several metabolic markers, including triacylglycerol, cholesterol and, insulin. The

blood samples were collected in a non-fasting state. If the fasting time of the children before the measurement was randomly distributed and not related to diet in early childhood, this measurement error would only have led to non-differential misclassification of these outcomes. This measurement error of the outcome may therefore have resulted in an underestimation of the associations of diet quality with cardiometabolic factors.

For the atopic outcomes, we examined both sensitization to allergens and physician-diagnosed atopic diseases. Although allergic sensitization was measured objectively using skin-prick tests using the scanned area method, other atopic outcomes were assessed with parents-reported questionnaires, which may have resulted in misclassification. These questionnaires was adapted from the International Study of Asthma and Allergies in Childhood core questionnaire[43] and included questions on physician-diagnosed inhalant or food allergies, eczema, and asthma by any physician, but with no further details. However, for the studies in this thesis, we expect any misclassification to be unrelated to the exposure, i.e. diet quality at earlier time points, and therefore only resulting in random information bias, potentially leading to an underestimation of true associations. Furthermore, results for the associations of diet quality with objectively assessed allergic sensitization with skin prick tests and the parent-reported atopic diseases were consistent.

Confounding

As described earlier in this chapter, all studies included in this thesis are of observational nature, except for one. A major limitation of observational studies is the risk of confounding bias [44], because observational studies are not randomized to ensure equivalent groups for comparison. This is especially important for studies examining lifestyle factors such as dietary intake. It has been suggested that healthy habits tend to cluster. For example, children who have a more healthy diet also tend to have more physical activity and less screen time, as we also reported in Chapter 2.4. These other lifestyle factors may also be associated with health, and could therefore be potential confounders in the association of dietary intake with health outcomes such as body composition and atopic diseases.

Although information on a wide range of potential confounders was available and controlled for in our studies, residual confounding may still be present. These could be caused by unmeasured confounders, but also by measurement errors in the data on confounders that were available. For example, in the associations of diet with body composition in growing children, developmental stage of the children may be a confounder. As the children in the Generation R Study were 10 years at the final body composition measurement, some of the children might have already reached puberty. Unfortunately, we were not able to correct for puberty status in the Generation R Study. However, for

associations of diet with body composition up to age 12 years in children participating in the ABCD study, puberty status did not affect the associations.

Another important aspect when examining associations of a specific component of dietary intake with health, is confounding by other dietary factors. Intakes of foods and nutrients are often highly correlated and could therefore confound each other in diet–disease relationships. Because of these correlations within the diet, it is often difficult to examine the effect of one specific nutrient or food and to draw conclusions for that particular nutrient or food only. Dietary pattern analysis takes these correlations between nutrients and foods into account, and could therefore reduce confounding by other dietary factors.

PUBLIC HEALTH IMPLICATIONS AND FUTURE RESEARCH

Overall, our results suggest that diet quality of children is suboptimal. We observed that especially children with more screen time, children of lower-educated mothers, or from lower-income households had lower diet quality. In general, intakes of sugar-containing beverages and meat were much higher than recommended, whereas intakes of nuts and legumes were much lower than recommended. These findings provide directions for public health interventions to improve dietary intake in children at risk of having poor diet quality. Our results in Chapter 2.4 suggest that these interventions should particularly be targeted at children with more screen time, and children whose mothers have a lower socio-economic background, or who smokes. In addition, we observed that most of the associations were independent of diet quality at another time point in childhood, which emphasizes the importance of adequate dietary intake throughout childhood, not only at specific time windows, for optimal growth and development. Previous studies have shown that dietary intake tends to track from childhood to adulthood [45-48]. In Chapter 2.4 we also observed positive tracking of diet quality throughout childhood, i.e., children with higher diet quality in early childhood tend to have higher diet quality in mid-childhood. Hence, interventions to promote healthy diet should start early in childhood to achieve long-term benefits.

The results of the studies presented in this thesis add to the existing literature on the effects of dietary intake in childhood on body composition, cardiometabolic factors, and atopic diseases. Combined with results from previous studies on specific foods and nutrients, they can provide directions for future studies and public health interventions. For example, previous studies reported that in general, foods and foods groups that are considered to be healthy, e.g., fruit, vegetables, and whole grains, are associated with decreased risk obesity in children [49], whereas unhealthy foods such as sugar-containing beverages and energy-dense, low-fiber foods are associated with childhood obesity [50].

Our findings add to this evidence that these associations also hold when examining overall dietary patterns, and that associations are not driven by specific food groups. Our findings suggest that dietary intake according to current Dutch dietary guidelines may be associated with better body composition and cardiometabolic health in childhood. More research is needed to examine whether these associations persist to adolescence and adulthood, and whether a healthy diet in childhood can thereby indeed help prevent the development of adoposity and cardiometabolic diseases later in life.

Given that children of different ages have low diet quality, which may have adverse effects on health both in childhood and adulthood, it is important to improve diet quality of children. However, it is well known that changing behavior is very challenging. Individuals make many food choices on a daily basis, most of them even unconsciously. These food choices are influenced by many factors, including taste preferences, peers, costs, and availability. Especially in young children, parents have a high degree of control over their food intake, for example through feeding practices [51]. Given that dietary habits are established in early childhood and tend to track over time [52], it might be most effective to intervene already as young as possible. Many intervention programs to improve dietary intake in children have been studied. For young children, parents are the main source of food, but also schools, kindergartens, and day cares are important. Therefore, it is necessary to involve all of them in intervention programs. School gardening programs are considered to be a promising intervention to improve children's dietary intake, in particular intake of vegetables [53]. Previous studies have suggested that school gardening programs improve children's vegetable knowledge and preferences, increase their willingness to try vegetables, and even increase their intake [53,54]. Other school-based interventions seem promising as well, including the healthy school canteen and school policies to decrease sweet treats and to promote drinking water rather than sugar-containing beverages [55-57]. Using school-based interventions, all children could be reached and by making the healthy choice the default at schools, the problem of individual, unhealthy choices will decrease. Another strategy to modify intake of specific nutrients in the population is by food reformulation, which will result in making healthier food choices easier for consumers without them actively choosing for it. However, modifying food products might influence food acceptance, as the taste of food products could change. Studies have suggested that gradually lowering the salt content in bread – a commonly consumed product in the Netherlands – did not lead to lower bread consumption or compensation behaviors [58,59], indicating that food reformulation could be an effective approach to decrease intake of specific nutrients in the general population. In addition to population-wide strategies, it might be effective to specifically target children at high risk of having a poor diet quality, such as children from lower socioeconomic households, as described in Chapter 2.4. Intervention strategies could include education programs to increase knowledge on healthy diets in both

parents and their children. As food choices are influenced by many factors, it is important to involve different stakeholders in intervention programs in order to create a healthy environment for children.

Conclusion

Findings from the studies presented in this thesis suggest that diet quality in childhood is suboptimal and that this may affect body composition and cardiometabolic health. More specifically, we observed that, on average, children only adhered to half of the age-specific dietary guidelines. Especially children of lower socioeconomic households and with more screen time are at higher risk of having lower diet quality. Furthermore, we observed that a higher diet quality may be beneficial for body composition and for certain cardiometabolic markers. In this thesis we observed no associations of overall diet quality with atopic diseases, but our systematic review of RCTs suggested that the avoidance of a combination of allergens in early childhood seems promising for the prevention of atopic diseases. Our findings may be important for public health interventions to improve diet quality in children and for early prevention of chronic diseases such as obesity and cardiometabolic diseases. More studies are needed on diet in different phases of childhood, using repeated dietary and health measurements to examine optimal diet for different age groups for long-term health.

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