General introduction
INTRODUCTION

The childhood obesity epidemic

The obesity epidemic is commonly discussed in the media including topics on its adverse consequences, new dieting methods and advice for healthy lifestyles and exercise. Regardless of all this attention, overweight and obesity rates are still rising, with currently 39% of the adults worldwide being overweight and 13% being obese according to the World Health Organization. Parallel to the rising prevalence of obesity in adults, the prevalence of childhood overweight and obesity also increased dramatically over the last four decades. The global age-standardized prevalence of obesity in children and adolescents increased from 0.7% in 1975 to 5.6% in 2016 in girls, and from 0.9% in 1975 to 7.8% in 2016 in boys. Region-specific results showed that the prevalence of obesity in children and adolescents now plateaued in most high-income countries, but rates in Latin-America and parts of Asia are still increasing. Compared with the global prevalence of childhood obesity, the prevalence of childhood obesity in the Netherlands is slightly lower, estimated at 2.8%, and another 13.5% of the children being overweight in 2017.

Children with overweight or obesity are likely to maintain this high weight status throughout adolescence and adulthood, and this tracking of adiposity starts already early in life. Being small at birth and early postnatal “catch-up growth” predicts more adiposity later in childhood. Furthermore, in a large British population-based cohort, 63% of the children who were overweight at 7 years, were still overweight at 11 years, and 75% of the children with obesity also continued to be obese. Body Mass Index (BMI), calculated as weight (kg)/ height (m)^2, is the widely used measure to indicate relative weight status in children by using sex- and age-adjusted standardized scores. While it is generally assumed that a high BMI is explained by a high adiposity level, it only serves as a proxy for the level of body fat because it cannot distinguish between fat mass and fat free mass. Therefore, the amount and distribution of body fat and fat free mass (i.e. body composition) are now recognized to be important health outcomes in children, though much less frequently studied in children as compared to BMI.

A high weight status in childhood poses a risk for developing related adverse health consequences later in life, such as the metabolic syndrome, type 2 diabetes, cardiovascular disease and cancer. Moreover, psychiatric disorders, such as depression, are also more commonly reported in overweight or obese individuals. First signs of these adverse consequences can already be observed in children with a high weight status, as shown by increased lipid and insulin concentrations and higher blood pressure. Moreover, lower self-esteem and more emotional problems are commonly found in children with overweight. Social problems also occur since these children are more often victims of bullying due to their weight. Accordingly, the elevated risk of maintaining a high weight status through the life course, as well as the physical and psychological burden
of high adiposity, highlight the need for effective prevention and intervention strategies. However, prevention and intervention programs in children have only been mildly effective so far. \(^{27,28}\) Moreover, obesity prevention starting early in life is essential for maintaining a healthy weight throughout the life course and ultimately reversing the obesity epidemic.

**The obesogenic environment**

In order to develop effective prevention and intervention strategies, the complex etiology of childhood obesity needs to be well-understood. This has been a major challenge for researchers given the many underlying factors involving genetic, physiological, environmental and behavioral factors, each accountable for a small proportion of obesity development. However, the global increasing trend in childhood obesity is likely largely due to changes in the environment. \(^{29,30}\) The ‘obesogenic environment’ was defined by Swinburn et al. in 1999 as “The sum of influences that the surroundings, opportunities or conditions of life have on promoting obesity in individuals or populations”. \(^{31}\) In the past decades, our environment markedly changed from an environment characterized by food scarcity and traditional work towards an environment with a tremendous availability of low-priced palatable, high-calorie food, increasing sedentary behaviors due to screen-based entertainments, and reduced physical activity through changes in mechanization and transportation. \(^{32}\) However, despite the fact that every child is exposed to this obesogenic environment, not every child becomes overweight or obese. Individual variability in body weight can be explained by the level of genetic predisposition, consisting of multiple, independent genes, which are all responsible for a small part of genetic susceptibility for obesity. \(^{33}\) The interaction of this genetic predisposition with the obesogenic environment may result in excess weight gain, \(^{32}\) for which the obesogenic environment influences weight gain of children indirectly, partially dependent on parental- and child behaviors.

**Behavioral correlates of childhood adiposity**

Parental and child behaviors related to a healthy lifestyle are of key interest in preventing childhood obesity, because behaviors are considered to be directly modifiable risk factors while genetics and the obesogenic environment are more difficult, if not impossible, to change. One of the child behaviors of interest in preventing obesity are eating behaviors. Eating behaviors can influence energy intake through choices about when and where to eat and the amount and type of food consumed. \(^{34,35}\) The development of children’s eating behaviors depends on many factors such as genetic predisposition, the development of appetite regulation, early food experiences and the family environment. \(^{33,36,37}\) In early life, children are predisposed to preferences for salty and sweet tastes, the tendency to reject new flavors, and learn to eat what is available in their environment. Therefore, children’s dietary intake largely depends on food choices and preferences of the parents, feeding
strategies and the availability of foods. Next to this, parents also serve as role models: children are likely to copy eating habits and can therefore learn healthy or unhealthy eating behaviors. Many cross-sectional studies have reported on the relationship between eating behaviors and weight status in childhood and suggested that children with overweight or obesity show more emotional overeating, food responsiveness and enjoyment of food, and show less satiety responsiveness. However, there is a lack of prospective studies reporting on eating behaviors develop across childhood and its association with body composition.

Another child behavior of interest is sleep. At the moment, there is a lot of debate on sleep deprivation in children and its consequences on child health. Guidelines on sleep duration in children recommend that infants until one year of age should sleep 12 to 16 hours per 24 hours, which decreases with age towards a recommended 8 to 10 hours of sleep in adolescence. Variation in child sleep duration can be due to individual differences in sleep need but can also be due to increasing screen time or parents influencing the sleep-wake cycle. Numerous studies have focused on the relationship between sleep duration and child weight and showed that shorter sleep was associated with a higher weight status. Yet, the influence of sleep duration very early in life (i.e. infancy) on body composition and cardiometabolic health later in childhood and early adolescence remains unclear.

The need for prospective studies examining bi-directionality

The evidence for behavioral determinants of child adiposity mainly derives from cross-sectional studies (i.e. performed at a single time point). These studies described associations between behavioral factors and BMI and assumed that behavior affects weight gain, while no evidence for causal inference can be provided by these studies and information on reversed causality is lacking. Prospective studies, preferably with repeated measurements, can improve our understanding on the direction of associations by examining whether child behaviors can predict changes in weight status and cardiometabolic health. Relationships in the opposite direction – a higher weight status early in life might predict subsequent unhealthy child behavior – are also reasonable but are rarely examined. For instance, children with a higher weight status might be hindered in their physical activity due to decreased mobility or might eat more in response to negative feelings raised by their weight concern. Examining whether behaviors are determinants or consequences of child adiposity is essential for developing effective prevention or intervention strategies, and therefore more insight in the direction of the association between behavioral traits and weight status in children is needed.
THIS THESIS

Aim
The aim of this thesis was to examine the relationship of parental- and child behaviors with adiposity development and cardiometabolic health in childhood and to provide more insight in the direction of the associations by using data of prospective population-based studies in high-income populations. Specifically, the objectives of this thesis were:
1. To provide insight in the development of eating behaviors in children.
2. To examine the association of different child behaviors with body composition and cardiometabolic health, and to determine the direction of associations.
3. To examine the role of maternal feeding practices on children's eating behaviors and body composition.

Setting
The studies presented in this thesis were all embedded in prospective population-based cohort studies in high-income countries, including the Netherlands, the United States, Australia, and Sweden.

Most studies were embedded in The Generation R Study, a population-based cohort from fetal life onward, situated in Rotterdam, the Netherlands. The Generation R Study was designed to investigate genetic and early determinants of children's development, health and disease. All pregnant women living in Rotterdam, the Netherlands, with an expected delivery date between April 2002 and January 2006 were invited to participate (participation rate of 61%). Written informed consent was obtained from all participants at each wave. The Generation R Study was conducted in accordance with the Declaration of Helsinki and was approved by The Medical Ethical Committee of the Erasmus Medical Center. After birth, parents reported repeatedly on different aspects of child development by postal questionnaire and when children were aged 6 and 10 years, mothers and children visited the research center where a range of behavioral and physical examinations took place.

One study was embedded in Project Viva, a pre-birth longitudinal cohort study situated in Eastern-Massachusetts, USA, which originally included 2128 mother-child dyads. Another study was performed using data of the PEAS Kids Growth Study (Parent Education And Support), which started as a prospective quasi-experimental study and was followed-up as an prospective community-based study focused on growth and cardiovascular health in children born in Melbourne and surrounding areas in Australia.

Finally, one study was performed with data of three population-based cohorts, namely The Generation R Study and two twin cohorts: the Nederlands Tweelingen Register and The Swedish Twin Study of Child and Adolescent Development.
Outline

In Part I the development of eating behaviors across childhood and potential predictors of obesogenic eating behaviors are described. In Part II prospective associations of different child behaviors with body composition and cardiometabolic health are studied, including an examination of potential bi-directionality. In Part III, we examined the role of different types of maternal feeding practices on child eating behaviors and body composition.

Part I. The development of eating behaviors in children

In Chapter 2, patterns of food approaching and food avoidant eating behaviors from 4 to 10 years are examined using a person-centered approach. Potential parental and early life predictors of these patterns were subsequently examined in order to identify targets for the prevention of developing obesogenic eating behaviors. In Chapter 3, the extent to which exposure to impaired maternal gestational glucose tolerance might affect eating in the absence of hunger was studied in 13-year-old children.

Part II. Child behavior, body composition and cardiometabolic health

In chapter 4, bi-directional associations between eating behaviors, BMI and body composition were investigated. In chapter 5 and 6, the relationship of infant sleep duration with body composition, metabolic- and cardiovascular health later in childhood and adolescence was studied in two populations. Finally, bi-directional associations between child aggressive behavior and BMI are examined chapter 7, in three population-based cohort studies.

Part III. Maternal feeding practices and child body composition

In chapter 8, the direction of effects between parental restrictive feeding practices and child body composition across childhood was investigated. In chapter 9, the longitudinal relationship of maternal emotional feeding during infancy with body composition across childhood and the role of child emotional overeating in this relationship was studied.
REFERENCES


