LIFESTYLE

OVERWEIGHT

INEQUALITIES

SOCIAL INEQUALITIES IN YOUNG CHILDREN'S LIFESTYLE BEHAVIORS AND CHILDHOOD OVERWEIGHT

THE GENERATION R STUDY - ANNE I. WIJTZES

AND

CHILDHOOD

Social Inequalities in Young Children's Lifestyle Behaviors and Childhood Overweight

The Generation R Study

Anne I. Wijtzes

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The Generation R Study

Sociale verschillen in leefstijlgedragingen en overgewicht bij jonge kinderen
Het Generation R Onderzoek

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Wijtzes AI, Bouthoorn SH, Jansen W, Franco OH, Hofman A, Jaddoe VW, Raat H. Sedentary behaviors, physical activity behaviors, and body fat in 6-year-old children: the Generation R study. *Int J Behav Nutr Phys Act* 2014;11:96.

Chapter 2.2

Wijtzes AI, Jansen W, Bouthoorn SH, van Lenthe FJ, Franco OH, Hofman A, Jaddoe VW, Raat H. Meal skipping behaviors and body fat among 6-year-old ethnically diverse children: the Generation R study. *Submitted for publication.*

Chapter 2.3

Bouthoorn SH, Wijtzes AI, Jaddoe VW, Hofman A, Raat H, van Lenthe FJ. Development of socioeconomic inequalities in obesity among Dutch pre-school and school-aged children. *Obesity (Silver Spring)* 2014;22(10):2230-2237.

Chapter 3.1

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Chapter 3.2

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Chapter 4.2

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Chapter 5.1

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Chapter 5.2

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Chapter 6.1

Wijtzes AI, van de Gaar VM, van Grieken A, de Kroon ML, Mackenbach JP, van Lenthe FJ, Jansen W, Raat H. Effectiveness of interventions aimed to improve lifestyle behaviors or prevent overweight among young socially disadvantaged children in Europe: a systematic review of (randomized) controlled trials. *Submitted for publication.*

INEQUALITIES

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1

GENERAL INTRODUCTION

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IN

Childhood overweight

Childhood overweight and obesity is a major public health concern [1,2]. Adverse health and psychosocial outcomes associated with childhood overweight include elevated blood pressure and hypertension, type 2 diabetes, asthma, sleeping disorders, low self-esteem, and decreased quality of life [1,3]. Long term consequences of childhood overweight include the persistence (or tracking) of overweight from childhood into adulthood and the increased risk of cardiovascular morbidity and premature mortality [4,5].
Over the past three decades, the prevalence of childhood overweight and obesity has risen markedly [6-8]. The current prevalence of overweight varies across continents; North America, Europe, and parts of the Western Pacific have the highest prevalence with 20-30% of all children being overweight [8]. In the Netherlands, regular nationwide growth studies are conducted among children aged 0-21 years [9-11]. Comparison of findings over the past three decades has shown a two- to three-fold increase in overweight prevalence and a four- to six-fold increase in obesity prevalence among native Dutch children [11]. In the most recent study, conducted in 2009, the prevalence of overweight (including obesity) was 13.3% and 14.9% for native Dutch boys and girls, respectively [11].

Childhood overweight and lifestyle behaviors

The social-ecological model postulates that the development of childhood overweight is most directly influenced by lifestyle behaviors, including sedentary behaviors, physical activity behaviors, and dietary behaviors [12]. The effect of these behaviors may differ according to child's characteristics such as child's sex, child's age, and genetic susceptibility to weight gain [12]. In turn, the development of lifestyle behaviors is shaped by family characteristics such as parental lifestyle behaviors, parenting style, parenting practices (e.g. child feeding practices), peer and sibling interactions, and the direct home environment. Both lifestyle behaviors and family characteristics are affected by community, demographic, and societal characteristics, including school characteristics (e.g. physical education programs, school breakfast and lunch programs), characteristics of the physical environment (e.g. neighborhood safety, accessibility of recreational facilities), ethnic background, and socioeconomic position [12].
Based on observational studies, the most consistent lifestyle risk factors for childhood overweight include television (DVD/video) viewing, lack of physical activity (vigorous intensity in particular), breakfast skipping, and consumption of sugar-sweetened beverages [13-17]. Further evidence comes from experimental studies showing that interventions targeting these behaviors have been successful in decreasing body mass

index and childhood overweight [18-28], with the most conclusive evidence for reducing screen-time and consumption of sugar-sweetened beverages. Lifestyle behaviors have shown to cluster (i.e. co-occur) [29-31] and an accumulation of unhealthy lifestyle behaviors is likely to affect the development of overweight more than unhealthy lifestyle behaviors would separately [32]. Previous observational studies are hampered by a lack of control for potential co-occurring lifestyle behaviors, and therefore may suffer from residual confounding. Furthermore, the commonest indicator of children's body fat has been body mass index (BMI), which is unable to distinguish between fat mass and lean mass [33]. Therefore, the first aim of this thesis was to investigate the independent associations between key lifestyle behaviors and children's body fat, using fat mass (as measured by dual energy X-ray absorptiometry [DXA]) as body fat indicator in addition to BMI and weight status.

Social inequalities in childhood overweight

The burden of overweight and obesity is not equally distributed among all children. In developed countries, children of low family socioeconomic position (SEP) and children from ethnic minority groups are at increased risk of childhood overweight and obesity [7,34-38]. In the Netherlands, the most recent growth study showed that BMI was inversely associated with parental educational level [11]. This study also showed that Turkish and Moroccan children have an increased risk of overweight and obesity compared to native Dutch children [39]. In 2009, the prevalence of overweight was 25.2% and 29.1% for Moroccan boys and girls, and 32.5% and 31.7% for Turkish boys and girls, respectively (i.e. almost two-and-a-half times higher than native Dutch children) [39].
The consistent association between low family SEP and childhood overweight seems surprising in light of research that shows children from low SEP families to have a lower birth weight compared with children from high SEP families [40]. Furthermore, in line with these findings, studies among very young children (0-4 years) have reported null-associations or positive associations between family SEP and childhood overweight [41-43]. Taken together, these findings indicate that the association between family SEP and childhood overweight reverses around the preschool period (4-6 years) [41,42]. Insight into the onset of the inverse SEP association in childhood overweight provides information on the preferred timing of interventions aimed to reduce these inequalities. Therefore, the second aim of this thesis was to investigate the onset of the inverse SEP association in overweight and to investigate the contribution of prenatal, perinatal, and postnatal factors in this association.

Social inequalities in lifestyle behaviors

Social inequalities in childhood overweight are likely to be preceded by inequalities in adverse lifestyle behaviors. Indeed, adverse lifestyle behaviors such as excessive amounts of television viewing, breakfast skipping, or lack of participation in sports have been shown to be more common among children from low family SEP and children from ethnic minority groups [44-50]. Based on evidence that adverse lifestyle behaviors seem to establish around the preschool period [51] and that lifestyle behaviors are relatively stable throughout childhood [52-54], these inequalities may originate in early childhood. However, most of the studies on the associations of family SEP and ethnic background with children's lifestyle behaviors have been conducted in (older) school-aged children and adolescents and less is known on these associations among younger children. Furthermore, there is a paucity of studies investigating the pathways underlying social inequalities in young children's lifestyle behaviors. In order to design effective interventions, knowledge on these pathways is essential [55].
Therefore, the third aim of this thesis was to assess the existence and underlying pathways of social inequalities in lifestyle behaviors among young ethnically diverse urban children (2-6 years). Socioeconomic position and ethnic background are hypothesized to influence health and lifestyle behaviors indirectly, i.e. through more proximal determinants that are unequally distributed among socioeconomic and ethnic groups [12,55,56]. In accordance with the social ecological model, potential explanatory factors from different domains were investigated [12]. Because previous research has underlined the importance of parents and the direct home environment in shaping children's lifestyle behaviors, especially among young children, an emphasis was placed on variables related to the family environment [12]. The final aim of this thesis was to assess the effectiveness of interventions aimed to improve lifestyle behaviors and/or prevent overweight among young socially disadvantaged children in Europe.

Research questions

The overall aim of this thesis was to develop a further understanding of social inequalities in young children's lifestyle behaviors and childhood overweight (Figure 1). For this purpose, the following research questions were formulated:

1. To what extent are young children's lifestyle behaviors independently associated with body fat? (*Chapter 2*)
2. To what extent do social inequalities in childhood overweight exist and how can these inequalities be explained? (*Chapter 2*)

3. To what extent do social inequalities in young children's lifestyle behaviors exist and how can these inequalities be explained? (*Chapters 3-5*)
4. What is the effectiveness of interventions aimed to improve lifestyle behaviors or prevent overweight among socially disadvantaged children (0-12 years) in Europe? (*Chapter 6*)

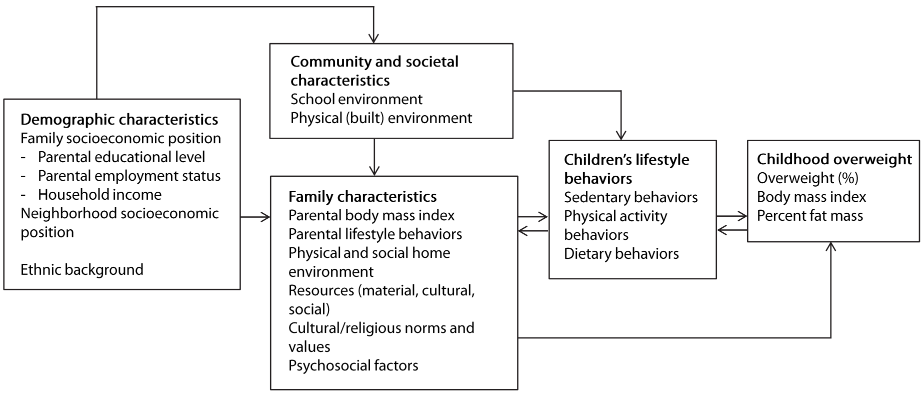

Figure 1. Conceptual model of potential pathways through which low socioeconomic position and ethnic minority background may influence childhood overweight. Model based on social-ecological model by Davison and Birch [12].

Methods

The first three study questions of this thesis have been explored within the Generation R Study. The Generation R Study is a population-based prospective cohort study from fetal life until adulthood, designed to identify early environmental and genetic determinants of normal and abnormal growth, development, and health [57]. Pregnant women with an expected delivery between April 2002 and January 2006, residing in Rotterdam, the Netherlands, were eligible for this study. Enrollment was aimed in early pregnancy (<18 weeks of gestation), but was possible until birth of the child. The offspring of these children form a prenatally-recruited birth cohort. Assessments in pregnancy were planned in early pregnancy, mid-pregnancy, and late pregnancy, and included physical examinations, pregnancy complications and outcomes, biological samples, fetal ultrasound examinations, and self-administered questionnaires. Data collection for the children in the preschool period (birth to 4 years of age) included a home visit at the age of 3 months, questionnaires at the ages of 2, 6, 12, 18, 24, 39, 36, 48 months, and regular visits to routine child health centers at the ages 2, 3, 4, 6, 11, 14, 18, 24, 36, and 45 months. More detailed assessments were conducted in a randomly selected subgroup of Dutch children at a gestational age of 32 weeks and at the ages of 1.5, 6, 14, 24, 36,

and 48 months. Data collection in the school aged period (5 years and onwards) included regular detailed hands-on assessments performed on all children in a dedicated research center (median age 72 months) and questionnaires at age 72 months.
The final study question of this thesis was addressed by performing a systematic review of the scientific literature. A systematic literature search was conducted in PubMed, EMBASE, Web of Science, Medline (OvidSP), Google Scholar, and Cochrane Database of Systematic Reviews. Additionally, references of manuscripts were searched for additional studies not identified by the original search strategy. Titles and abstracts were independently reviewed by two authors to make the selection of relevant intervention studies and in case of discrepant findings, a third party was consulted until consensus was achieved. The selection process was guided by pre-defined inclusion and exclusion criteria.

This thesis is the result of a collaborate effort within CEPHIR, Center of Effective Public Health in the greater Rotterdam area, one of the largest academic work places for public health in the Netherlands. Main partners participating in CEPHIR are the Center of Youth and Families Rijnmond, the municipality of Rotterdam, the Generation R Study, and the department of Public Health of the Erasmus Medical Center Rotterdam [58]. CEPHIR aims to communicate and implement findings from science in public health practice in order to contribute to reducing socioeconomic and ethnic inequalities in health in an evidence-based way. Conversely, input from practice may aid in setting research priorities [58].

Outline of this thesis

Following this introductory chapter, *chapters 2.1* and *2.2* describe the independent associations of sedentary and physical activity behaviors and meal skipping behaviors with childhood overweight. *Chapter 2.3* focuses on the emergence of the inverse socioeconomic gradient in childhood overweight and the explanation of this gradient at the age of 6 years. *Chapters 3-5* of this thesis address the third aim of this thesis and describe social inequalities in young children's sedentary behaviors, physical activity behaviors, and dietary behaviors, respectively. *Chapters 3.1* and *3.2* describe social inequalities in sedentary behaviors. Social inequalities in physical activity behaviors are presented in *chapters 4.1* and *4.2*. *Chapters 5.1* and *5.2* present social inequalities in dietary behaviors. *Chapter 6* covers the last study aim of this thesis. In *chapter 6.1*, a systematic review on the effectiveness of interventions aimed to improve lifestyle behaviors or prevent overweight among young socially disadvantaged children in Europe is presented. *Chapter 7* provides an overall discussion, including a description of the main findings of this thesis, methodological considerations, implications for policy and practice, and directions for future research. An overview of the studies presented in this thesis is shown in Table 1.

Table 1. Overview of the studies presented in this thesis

Chapter	Study sample	Age	N	Study design	Main exposures	Main outcomes
2. Social inequalities in childhood overweight						
2.1	Generation R	6 years	5913	Cross-sectional	Sedentary behaviors and physical activity behaviors	Childhood overweight, BMI SDS, % fat mass
2.2	Generation R	6 years	5913	Longitudinal‡	Meal skipping behaviors	Childhood overweight, BMI SDS, % fat mass
2.3	Generation R (Dutch only)	6 years	3656	Longitudinal†	Maternal educational level, household income	BMI SDS, % fat mass
3. Social inequalities in children's sedentary behaviors						
3.1	Generation R (Dutch only)	4 years	2786	Longitudinal	Maternal educational level	Television viewing time
3.2	Generation R	4 years	3452	Longitudinal	Ethnic background	Television viewing time
4. Social inequalities in children's physical activity behaviors						
4.1	Generation R (Subsample)	2 years	347	Longitudinal	Multiple exposures	Objectively measured physical activity
4.2	Generation R	6 years	4726	Cross-sectional	Different SEP indicators, ethnic background	Sports participation, outdoor play
5. Social inequalities in children's dietary behaviors						
5.1	Generation R (Dutch only)	4 years	2814	Longitudinal	Maternal educational level	Consumption of high-calorie snacks, consumption of sugar-containing beverages
5.2	Generation R	6 years	4704	Cross-sectional	Different SEP indicators, ethnic background	Meal skipping behaviors
6. Public health interventions						
6.1	Systematic literature review	0-12 years	13	Not applicable	Interventions aimed to improve lifestyle behaviors or prevent overweight among socially disadvantaged children (0-12 years) in Europe	

SEP = socioeconomic position. BMI = body mass index. SDS = standard deviation score.
† Repeatedly measured outcome.
‡ Repeatedly measured exposure and outcome.

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2

SOCIAL INEQUALITIES IN CHILDHOOD OVERWEIGHT

CHAPTER

2.1

SEDENTARY BEHAVIORS, PHYSICAL ACTIVITY BEHAVIORS, AND BODY FAT IN 6-YEAR-OLD CHILDREN: THE GENERATION R STUDY

ANNE I. WIJTZES
SELMA H. BOUTHOORN
WILMA JANSEN
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Abstract

Objective: Childhood overweight and obesity is a major public health concern. Knowledge on modifiable risk factors is needed to design effective intervention programs. This study aimed to assess associations of children's sedentary behaviors (television viewing and computer game use) and physical activity behaviors (sports participation, outdoor play, and active transport to/from school) with three indicators of body fat, i.e., percent fat mass, body mass index (BMI) standard deviation scores, and weight status (normal weight, overweight).

Methods: Cross-sectional data from 5913 6-year-old ethnically diverse children were analyzed. Children's weight and height were objectively measured and converted to BMI. Weight status was defined according to age- and sex-specific cut-off points of the International Obesity Task Force. BMI standard deviation scores were created, based on Dutch reference growth curves. Fat mass was measured my dual-energy X-ray absorptiometry (DXA). Sedentary and physical activity behaviors were assessed by parent-reported questionnaires. Series of logistic and linear regression analyses were performed, controlling for confounders (i.e., socio-demographic factors, family lifestyle factors, and other sedentary behaviors and physical activity behaviors).

Results: Sports participation was inversely associated with fat mass ($p<0.001$), even after adjustment for socio-demographic factors, family lifestyle factors, and other sedentary behaviors and physical activity behaviors. No other independent associations were observed.

Conclusion: The results of this study indicate that sports participation is inversely associated with percent body fat among ethnically diverse 6-year-old children. More research in varied populations including objective measurements and longitudinal designs are needed to confirm these current results.

Introduction

Childhood overweight and obesity is currently one of the major challenges in public health[1]. Childhood overweight is associated with a wide range of adverse physical and psychological outcomes including asthma, hypertension, type 2 diabetes, sleeping disorders, and low self-esteem [1,2]. Furthermore, childhood overweight has been shown to adversely affect cardiovascular morbidity and premature mortality in adulthood, either through tracking of overweight into adulthood or through independent effects of childhood overweight [3]. In order to tackle the current childhood overweight epidemic, insight into the underlying modifiable determinants is essential.

The increased prevalence of childhood overweight has been previously attributed to reductions in physical activity and increases in sedentary behaviors among children [4,5]. Television viewing especially is highly prevalent among young children [6], and both cross-sectional and longitudinal studies support the association between children's television viewing time and overweight [7]. The evidence for a similar association has been less consistent for computer use, possibly due to the more active nature of this activity [7]. Studies on cross-sectional associations between children's physical activity and overweight generally support the hypothesis that physical activity is protective against childhood overweight and obesity [8]; however, there is inconsistent evidence on the longitudinal associations between physical activity and childhood adiposity [9-11].

Only few studies in children have used dual energy X-ray absorptiometry (DXA) instead of proxy measures for body fat such as skinfolds and body mass index (BMI) [12-17]. Furthermore, earlier studies have been inconsistent in adjusting for dietary behaviors known to affect childhood overweight, such as consumption of breakfast and sugar-sweetened beverages [12-14,16]. Therefore, confounding by these factors cannot be ruled out. In this study we aimed to assess the independent associations of children's sedentary behaviors and physical activity behaviors with three indicators of body fat, i.e., percent fat mass, body mass index (BMI), and weight status in 6-year-old children. This study used data from the Generation R Study, a large, multiethnic, birth cohort in Rotterdam, the Netherlands.

Methods

Study design

This cross-sectional study was embedded in the Generation R Study, a population-based cohort study from fetal life onwards. The Generation R Study was designed to identify early environmental and genetic determinants of growth, development and health, and has been described previously in detail [18]. The study was conducted in accordance with the guidelines proposed in the World Medical Association Declaration of Helsinki and has been approved by the Medical Ethical Committee at Erasmus MC, University Medical Center Rotterdam. Written informed consent was obtained from all parents.

Study population

Invitations to participate in the study were made to all pregnant women who had an expected delivery date between April 2002 and January 2006 and who lived in the study area (Rotterdam, the Netherlands) at time of delivery. In total, 8305 children from the original 9749 known live born children of the Generation R cohort participate in the school aged period (5 years onwards). At the age of 6 years, participating children and their mothers were invited to a well-equipped and dedicated research center in the Erasmus Medical Center- Sophia's Children's Hospital. Of those, 6690 children visited the research center where information on body composition of the children was collected [18]. We excluded participants with missing information on BMI or fat mass (n=330). To avoid clustering of data, we furthermore excluded second (n=441) and third children (n=6) of the same mother, leaving a study population of 5913 participants (Figure 1).

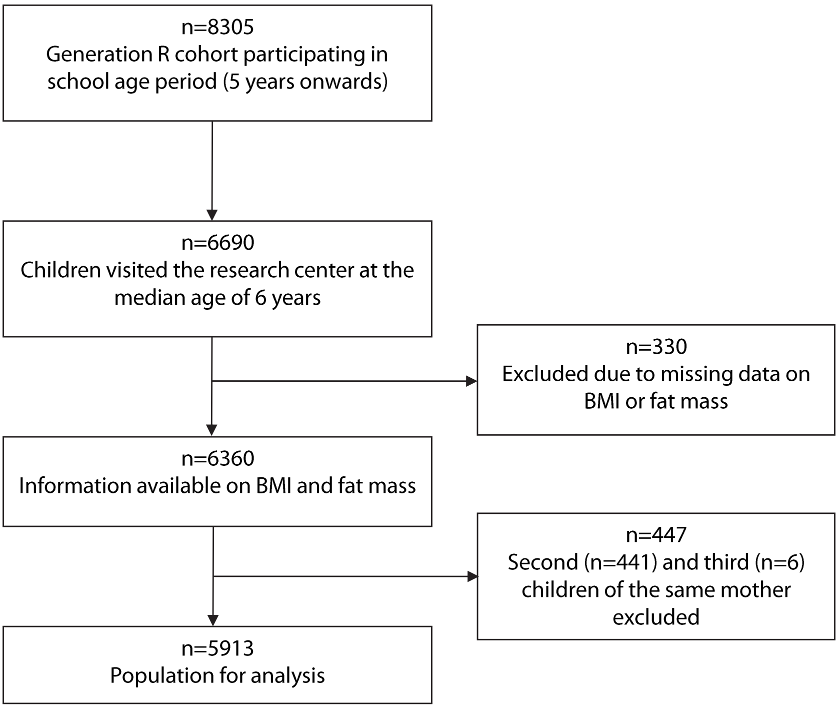

Figure 1. Flowchart of participants.

Indicators of body fat

Children's weight and height were measured in the research center using standardized procedures and devices. Weight was measured in lightweight clothes and without shoes with a mechanical personal scale (SECA) and height was measured using a Harpenden stadiometer (Holtain Limited) in standing position, both of which were calibrated on a regular basis. BMI (kg/m2) was calculated as [weight (kg)]/ [height (m)]2. Using the Growth Analyzer program (Growth Analyzer 3.0, Dutch Growth Research Foundation, Rotterdam, the Netherlands.), standard deviation scores (SDS) adjusted for age and gender were constructed based on Dutch reference growth curves [19]. Children's weight status was defined according to age- and sex-specific cut-off points proposed by the International Obesity Task Force [20]. DXA scans (iDXA; General Electric, formerly Lunar Corp., Madison, WI) were used to obtain percent fat mass of the children. The DXA scans provide measurements of bone and soft tissue for the total body and sub regions, including bone mineral content (g), fat mass (g), and lean mass (g). Percent fat mass was calculated as 100% x [total body fat mass (g)]/ [total body mass (fat mass + lean mass + bone mass of total body) (g)]. Children were scanned in a supine position with their feet together in a neutral position and hands flat by their sides. All DXA scans were obtained using the same device and software (enCORE2010) and were performed by well-trained and certified research staff.

Sedentary behaviors and physical activity behaviors

Sedentary behaviors and physical activity behaviors were assessed by parent-reported questionnaire when the child was 6 years old. Key sedentary behaviors included television viewing (including video/DVD) and computer game use (including video games). For both of the variables, frequency (i.e., number of days) and duration (i.e., minutes) were asked for weekdays and weekend days separately. These variables were combined to estimate daily television viewing by using the following formula: daily use= ([(days per week) * (hours on a weekday)] + [(days per weekend) * (hours on a weekend day)])/ 7. Average daily television viewing was then dichotomized into ≥2 hours/day versus <2 hours/day, based on current recommendations on screen-based entertainment for young children [6,21,22]. Average daily computer game use was dichotomized into ≥1 hour/day versus <1 hour/day, since only a small percent of children used the computer (games) for 1 or more hours per day.

Key physical activity behaviors included outdoor play, sports participation, and active transport to/from school. Similar to television viewing and computer game use, frequency and duration of outdoor play were assessed for weekdays and weekend days separately and combined to estimate daily outdoor play using the same formula (i.e., estimated total weekly hours divided by 7 days). Daily outdoor play was dichotomized into <1 hour/day versus ≥1 hour/day according to physical activity guidelines stating that children should acquire at least one hour of moderate to vigorous physical activity (MVPA) per day [23-25]. For active transport, number of days on which the children walked to/from school (0-5 days) and number of days children cycled to/from school (0-5 days) were assessed. Days per week of active transport was calculated by adding these numbers and dichotomized into < 5 days/week versus 5 days/week. For sports participation (no, yes), the following question was used: "Does your child take part in sports (for example, soccer, judo, gymnastics, jazz ballet, tennis, etc)?". School sports activities such as physical education lessons and swimming lessons were not included in this question.

Potential confounders

The following risk factors for childhood overweight were selected as potential confounders based on previous literature [26-28]: child's sex, age, and ethnic background, family socioeconomic position (SEP), parental BMI, and children's dietary behaviors. Indicators of family SEP were assessed by questionnaire when the child was 6 years old and included maternal educational level (highest level attained), maternal employment status (paid job, no paid job), household income (<€1600/$2166 per month, ≥€1600/$2166 per month), and single parenthood (single parent, two parents). The Dutch Standard Classification of Education was used to categorize four levels of education: low (no education, primary school, or three years or less general secondary school), mid-low (more than three years general secondary school), mid-high (higher vocational training) and high (university or PhD degree) [29]. In accordance with Statistics Netherlands, ethnic background of the child was defined according to country of birth of the child's parents [30]. Children with both parents born in the Netherlands were considered native Dutch, children with at least one parent born in Europe (Turkey excluded), North-America, Oceania, Indonesia, and Japan were assigned an other-Western ethnic background, and children with at least one parent born in another country were assigned a non-Western ethnic background [30]. Maternal BMI was calculated on the basis of self-reported pre-pregnancy weight and measured height at enrollment (kg/m2). Maternal BMI was assessed again when the child was 6 years old. The correlation between these two variables was high (Pearson's correlation coefficient: 0.83; p<0.000). Maternal pre-pregnancy was used in the analyses because data were less often missing for this variable. Paternal BMI was calculated on the basis of measured weight and height at enrollment. Children's dietary behaviors included breakfast skipping (yes, no), consumption of sugar-containing beverages (e.g., soft drinks, fruit juices, lemonade, and sweetened milk products such as chocolate milk) (into ≥ 3 glasses/day, <3 glasses per day), and consumption of high-calorie snacks (e.g., sweets, potato chips, chocolate bars, ice cream) (≥ 2 times/day, < 2 times/day) [28].

Statistical analyses

Descriptive statistics were used to characterize the total study population and children with and without overweight. Differences in variables between children with normal weight and children with overweight (including obesity) were evaluated using ANOVAs or Kruskal-Wallis tests for continuous variables and Chi-square tests for categorical variables. The correlation between BMI SDS and fat mass was assessed by Pearson's correlation coefficient. Series of multiple logistic and linear regression models were used to assess the associations of sedentary behaviors and physical activity behaviors with overweight (including obesity), BMI SDS, and percent fat mass, respectively. Associations between the behaviors and each of the three indicators were first assessed in crude models. The second set of models (model 1), was adjusted for socio-demographic factors. The third set of models (model 2) was additionally adjusted for family lifestyle factors (i.e., parental BMI and children's dietary behaviors). Sedentary behaviors and physical activity behaviors associated with the outcomes in model 2 with a p value <0.20 were simultaneously entered into fully adjusted models (model 3) to assess their independent associations with the outcomes. Multinomial logistic regression analyses, using the same models, were performed to assess associations with overweight and obesity separately. Previous studies conducted in older school aged children (i.e. ≥ 8 years) have shown different effects for boys and girls [5,31,32]. However, less is known about potential effect modification by child's sex in younger children [28,33]. Therefore, interactions with child's sex were explored. When significant, stratified analyses were performed. To handle missing data, multiple imputation was applied [34]. Missing data ranged between 0% for child's age, sex, and outcome variables, and 31.3% for paternal BMI (Table 1). Five imputed datasets were generated using a fully conditional specified model, thus taking into account the uncertainty of the imputed values. Pooled estimates from these five imputed datasets were used to report ORs, beta's, and their 95% confidence intervals (CIs). Imputations were based on the relationships between all the variables included in this study. All analyses were conducted in 2012 with Statistical Package for Social Sciences (SPSS) version 20.0 for Windows (SPSS Inc., Chicago, IL, USA). A significance level of $p<0.05$ was used to indicate significant associations.

Results

Table 1 shows characteristics of the study population and according to child's weight status. Nearly 20% of all children were overweight (including obesity). One quarter of overweight children were obese. Overweight children were older ($p<0.001$), more often girls ($p<0.001$), more often of Non-Western ethnicity ($p<0.001$), and more often of low family SEP (all $p<0.001$) compared with normal weight children. Overweight children

Table 1. Descriptive characteristics of the total study population and according to child's weight status (n=5913)

Characteristics		Total (n=5913)	Normal weight (n=4870) (82.4%)	Overweight (including obesity) (n=1043) (17.6%)	P-value*
Socio-demographic characteristics					
Child's sex	Girl (%)	50.3	48.5	58.7	<0.001
Child's age (years)	(Median, 90% range)	6.0 (5.7-7.4)	6.0 (5.7-7.2)	6.1 (5.8-7.8)	<0.001
Child's ethnic background	Dutch (%)	56.1	59.8	38.9	<0.001
	Other-western (%)	9.1	9.2	8.4	
	Non-western (%)	34.8	31.0	52.7	
Maternal educational level	High (%)	27.2	29.5	15.6	<0.001
	Mid-high (%)	27.2	28.3	21.7	
	Mid-low (%)	32.2	30.7	39.7	
	Low (%)	13.4	11.5	23.0	
Maternal employment status	No paid job (%)	25.2	23.7	33.3	<0.001
Household income	<€1600/$2166 per month (%)	17.6	16.1	25.7	<0.001
Single parenthood	Single parent (%)	14.9	14.0	19.6	<0.001
Parental anthropometric measures					
Maternal pre-pregnancy BMI (kg/m^2)	(Mean, SD)	23.6 (4.2)	23.1 (3.8)	25.9 (5.2)	<0.001
Paternal BMI (kg/m^2)	(Mean, SD)	25.3 (3.5)	24.9 (3.2)	27.1 (4.1)	<0.001
Child anthropometric measures					
Weight (kg)	(Mean, SD)	23.3 (4.3)	22.1 (2.8)	29.1 (5.1)	<0.001
Height (cm)	(Mean, SD)	119.6 (6.0)	119.0 (5.7)	122.3 (6.6)	<0.001
BMI SDS	(Mean, SD)	0.3 (0.9)	-0.0 (0.7)	1.7 (0.6)	<0.001
Fat mass (%)	(Mean, SD)	25.0 (5.7)	23.3 (4.1)	32.7 (5.6)	<0.001
Child sedentary behaviors					
Television viewing	≥ 2 hours/day (%)	19.9	18.5	27.6	<0.001
Computer game use	≥ 1 hour/day (%)	7.6	7.5	8.2	0.53
Child physical activity behaviors					
Outdoor play	< 1 hour/day (%)	34.5	33.4	41.0	<0.001
Sport participation	No (%)	55.6	54.5	60.8	<0.01
Active transport	<5 days/week (%)	57.4	58.9	49.3	<0.001

Table is based on non-imputed dataset. Missings were 0 for child's sex, 0 for child's age, 155 (2.6%) for child's ethnicity, 915 (15.5%) for maternal educational level, 1186 (20.1%) for maternal employment status, 1196 (20.2%) for household income, 892 (15.1%) for single parenthood, 1500 (25.4%) for maternal pre-pregnancy BMI, 1852 (31.3%) for paternal BMI, 1340 (22.7%) for TV viewing, 1357 (22.9%) for computer game use, 1765 (29.8%) for playing outside, 938 (15.9%) for sport participation, and 1273 (21.5%) for active transport to/ from school.

*Differences between normal weight and overweight (including obesity) children were evaluated using ANOVA. and Kruskal-Wallis tests for continuous variables, and Chi-square tests for categorical variables.

had a higher percent fat mass than normal weight children (p<0.001). Pearson's correlation coefficient for the correlation between BMI SDS and percent fat mass was moderate (r=0.65; p<0.001).

We did not find significant interactions of child's sex with any of the outcomes; therefore results are presented for the total study population. Television viewing was significantly positively associated with all three outcomes in the crude models (all p<0.001) (Tables 2, 3, and 4). However, these associations disappeared after adjustment for socio-demographic factors (for outcomes weight status and BMI-SDS) or following additional adjustment for family lifestyle factors (for outcome percent fat mass). Computer game use was positively associated with BMI SDS in the crude model only (p<0.05) (Table 3). Outdoor play was significantly inversely associated with BMI SDS and weight status (both p<0.001) and fat mass (p<0.01) in the crude models, but these associations disappeared after adjustment for socio-demographic factors (for outcome percent fat mass) or additional adjustment for family lifestyle factors (for outcomes weight status and BMI SDS). Sports participation was significantly inversely associated with percent fat mass in all models, including the fully adjusted model (all p<0.001) (Table 4). Sports participation was also positively associated with children's weight status, but only in the crude model (p<0.01) (Table 2). Active transport was inversely associated with all three outcomes in the crude models (all p<0.01), but these associations attenuated following correction for socio-demographic factors. Results from the multinomial analyses presenting associations with overweight and obesity separately were highly similar (Table 5).

Table 2. Associations of sedentary behaviors and physical activity behaviors with overweight (including obesity) (n=5913)

Child lifestyle behaviors	Crude model OR (95% CI)	Model 1* OR (95% CI)	Model 2** OR (95% CI)	Model 3*** OR (95% CI)
TV viewing (≥ 2 hrs/d)	**1.75 (1.47,2.08)‡**	1.13 (0.94,1.35)¥	1.08 (0.89,1.31)	-
Computer game (≥ 1 hr/d)	1.22 (0.87,1.69)	0.88 (0.63,1.24)	0.86 (0.60,1.24)	-
Outdoor play (< 1 hr/d)	**1.40 (1.19,1.64)‡**	**1.23 (1.06,1.44)‡**	1.16 (0.97,1.39)¥	1.16 (0.97,1.39)¥
Sport participation (no)	**1.29 (1.11,1.50)‡**	1.09 (0.93,1.27)	1.08 (0.91,1.28)	-
Active transport (<5 d/week)	**0.72 (0.59,0.87)‡**	0.92 (0.76,1.10)	0.94 (0.78,1.13)	-

Table is based on imputed dataset. ¥ p value <0.20, † p value <0.10; ‡ p value <0.05. Values in bold indicate statistical significance (p<0.05). Values represent odds ratios and 95% confidence intervals derived from multiple logistic regression analyses.

* Adjusted for socio-demographic factors: child's sex, child's age, child's ethnicity, maternal educational level, household income, and maternal employment status.

** Additionally adjusted for family lifestyle factors: child's breakfast skipping, consumption of high-calorie snacks, consumption of sugar-containing beverages, maternal BMI, and paternal BMI.

*** Additionally adjusted for other sedentary behaviors and physical activity behaviors.

Table 3. Associations of sedentary behaviors and physical activity behaviors with BMI SDS (n=5913)

Child lifestyle behaviors	Crude model β (95% CI)	Model 1* β (95% CI)	Model 2** β (95% CI)	Model 3*** β (95% CI)
TV viewing (≥ 2 hrs/d)	**0.19 (0.12,0.27)‡**	0.03 (-0.05,0.11)	0.01 (-0.07,0.09)	-
Computer game (≥ 1 hr/d)	**0.12 (0.01,0.24)‡**	-0.01 (-0.12,0.11)	-0.01 (-0.12,0.09)	-
Outdoor play (< 1 hr/d)	**0.12 (0.06,0.18)‡**	**0.07 (0.02,0.13)‡**	0.04 (-0.02,0.11)¥	0.04 (-0.02,0.11)¥
Sport participation (no)	0.04 (-0.02,0.09)¥	-0.04 (-0.09,0.02)¥	-0.04 (-0.09,0.01)¥	-0.04 (-0.09,0.01)¥
Active transport (<5 d/week)	**-0.09 (-0.15,-0.03)‡**	-0.01 (-0.07,0.05)	0.00 (-0.05,0.05)	-

Table is based on imputed dataset. ¥ p value <0.20, † p value <0.10; ‡ p value <0.05. Values in bold indicate statistical significance (p<0.05). Values represent beta's and 95% confidence intervals derived from multiple linear regression analyses.
* Adjusted for socio-demographic factors: child's ethnicity, maternal educational level, household income, and maternal employment status.
** Additionally adjusted for family lifestyle factors: child's breakfast skipping, consumption of high-calorie snacks, consumption of sugar-containing beverages, maternal BMI, and paternal BMI.
*** Additionally adjusted for other sedentary behaviors and physical activity behaviors.

Table 4. Associations of sedentary behaviors and physical activity behaviors with percent fat mass (%) (n=5913)

Child lifestyle behaviors	Crude model β (95% CI)	Model 1* β (95% CI)	Model 2** β (95% CI)	Model 3*** β (95% CI)
TV viewing (≥ 2 hrs/d)	**1.42 (0.98,1.86)‡**	**0.43 (0.02,0.84)‡**	0.31 (-0.08,0.70)¥	0.29 (-0.11,0.68)¥
Computer game (≥ 1 hr/d)	0.19 (-0.64,1.02)	0.10 (-0.58,0.78)	0.04 (-0.59,0.68)	-
Outdoor play (< 1 hr/d)	**0.75 (0.23,1.27)‡**	0.35 (-0.02,0.72)†	0.20 (-0.20,0.61)	-
Sport participation (no)	**0.94 (0.58,1.29)‡**	**0.62 (0.33,0.91)‡**	**0.59 (0.31,0.87)‡**	**0.58 (0.30,0.87)‡**
Active transport (<5 d/week)	**-0.68 (-1.07,-0.28)‡**	-0.02 (-0.34,0.30)	0.02 (-0.27,0.31)	-

Table is based on imputed dataset. ¥ p value <0.20, † p value <0.10; ‡ p value <0.05. Values in bold indicate statistical significance (p<0.05). Values represent beta's and 95% confidence intervals derived from multiple linear regression analyses.
* Adjusted for socio-demographic factors: child's sex, child's age, child's height, child's ethnicity, maternal educational level, household income, and maternal employment status.
** Additionally adjusted for family lifestyle factors: child's breakfast skipping, consumption of high-calorie snacks, consumption of sugar-containing beverages, maternal BMI, and paternal BMI.
*** Additionally adjusted for other sedentary behaviors and physical activity behaviors.

Discussion

This study aimed to assess the independent associations of key sedentary and physical activity behaviors with three different indicators of body fat, including percent fat mass, BMI SDS, and weight status. Sports participation was independently inversely associated with percent fat mass, but not with BMI SDS or weight status. No other independent associations were observed.

Table 5. Associations of lifestyle behaviors with overweight and obesity (n=5913)

	Overweight (excluding obesity) (n=782)			
Child lifestyle behaviors	Crude model OR (95% CI)	Model 1* OR (95% CI)	Model 2** OR (95% CI)	Model 3*** OR (95% CI)
TV viewing (≥ 2 hrs/d)	**1.60 (1.34,1.91)**‡	1.13 (0.92,1.37)	1.09 (0.89,1.34)	-
Computer game (≥ 1 hr/d)	1.09 (0.72,1.64)	0.83 (0.54,1.28)	0.82 (0.53,1.28)	-
Outdoor play (< 1 hr/d)	**1.38 (1.16,1.66)**‡	**1.26 (1.06,1.49)**‡	1.20 (0.99,1.45)†	1.20 (0.99,1.45)†
Sport participation (no)	**1.29 (1.10,1.52)**‡	1.12 (0.95,1.33)¥	1.12 (0.94,1.33)	-
Active transport (<5 d/week)	**0.74 (0.60,0.92)**‡	0.92 (0.74,1.14)	0.93 (0.74,1.15)	-
	Obesity (excluding overweight) (n=261)			
Child lifestyle behaviors	Crude model OR (95% CI)	Model 1* OR (95% CI)	Model 2** OR (95% CI)	Model 3*** OR (95% CI)
TV viewing (≥ 2 hrs/d)	**2.23 (1.60,3.12)**‡	1.13 (0.80,1.59)	1.06 (0.71,1.57)	-
Computer game (≥ 1 hr/d)	1.61 (0.98,2.64)†	1.01 (0.59,1.72)	0.99 (0.56,1.78)	-
Outdoor play (< 1 hr/d)	**1.44 (1.08,1.92)**‡	1.17 (0.86,1.59)	1.05 (0.73,1.51)	-
Sport participation (no)	1.29 (0.98,1.68)†	0.96 (0.72,1.28)	0.93 (0.67,1.28)	-
Active transport (<5 d/week)	**0.65 (0.49,0.85)**‡	1.05 (0.78,1.41)	1.06 (0.78,1.43)	-

Table is based on imputed dataset. ¥ p value <0.20, † p value <0.10; ‡ p value <0.05. Values in bold indicate statistical significance (p<0.05). Values represent odds ratios and 95% confidence intervals derived from multivariable multinomial regression analyses (reference category is normal weight).
* Adjusted for socio-demographic factors: child's sex, child's age, child's ethnicity, maternal educational level, household income, and maternal employment status.
** Additionally adjusted for family lifestyle factors: child's breakfast skipping, consumption of high-calorie snacks, consumption of sugar-containing beverages, maternal BMI, and paternal BMI.
*** Additionally adjusted for other sedentary behaviors and physical activity behaviors.

Television viewing

Although television viewing was positively associated with all indicators of body fat in the unadjusted models, the associations with weight status and BMI SDS disappeared after correction for socio-demographic factors such as family socioeconomic position and child's ethnicity. Analyses using percent fat mass, the most accurate measure of body fatness, showed that the association with television viewing remained significant after adjustment for socio-demographic factors but disappeared after adjustment for family lifestyle factors such as children's dietary behaviors and parental BMI. These results contradicts previous research that has shown consistent cross-sectional and longitudinal associations between children's television viewing and risk of overweight and obesity [7]. As an explanation for our results, we hypothesize that children of this age may only start to show excessive weight gain after extended exposure to high levels of television viewing. Alternatively, for the purpose of this study, we defined family lifestyle factors as potential confounders in the associations between each of the sedentary behaviors and physical activity behaviors and the three outcomes. However, previous studies have suggested that unhealthy dietary behaviors (i.e., increased consumption of snacks and sugar-sweetened beverages during and following screen time) may mediate part of the effects of television viewing on childhood obesity [35-37]. Therefore, if we assume that children's consumption of snacks and sugar-sweetened beverages are part of the causal pathway linking television viewing with children's body fatness, television viewing may also be considered a modifiable risk factor of children's percent fat mass.

Computer game use

Computer game use was associated with BMI SDS in the crude model only. No other associations were observed. Similarly to television viewing, longer exposure to this sedentary activity may be necessary to detect any effects on children's body fat. Also, computer game use included active video games and higher energy expenditure during such activities may not pose a risk for weight gain [7]. Alternatively, the lack of variation in this variable (i.e., a vast majority of children uses computers <1 hour/day) might have led to a lack of power to detect an association.

Sports participation

No independent associations were found between sports participation and BMI SDS or weight status; however, a significant inverse association was found between sports participation and percent fat mass, even after adjustment for socio-demographic factors, family lifestyle factors, and other sedentary behaviors and physical activity behaviors. Previous studies on the associations between children's physical activity intensity and adiposity have shown that moderate-to-vigorous physical activity, vigorous physical activity in particular, is associated with decreased adiposity [12,38-40]. High levels of physical activity are most often reached during sports activities [41], and the examples stated in our question assessing sports participation (e.g., gymnastics, tennis, and soccer) can be considered moderate-to-vigorous intense activities in this age group [42]. Since percent fat mass is a more accurate measure of body fatness compared to BMI or weight status, associations may be more easily detected with this indicator. Contrary to the present study, Drenowatz et al. did find an inverse association between sports participation and the odds of being overweight [43]. This discrepancy in findings may be explained by the age difference between their study (8 year old children) and the present study (6 year old children); older children may have spent more years participating in sports, which may result in demonstrable effects on weight status. Furthermore, children aged 8 years may have a higher weekly frequency of sports participation, or may engage in higher intensity levels during sports activities compared with younger children [41,44]. Alternatively, sports participation may be an indicator of an overall healthy lifestyle. However, the association between sports participation and percent fat mass remained significant after adjustment for other lifestyle behaviors, including television viewing and important dietary behaviors. Due to the many comparisons made in this study, it is also possible that spurious associations may have occurred as a result of multiple testing [45]. However, since the association was highly significant (p=0.000), this explanation is rather unlikely.

Outdoor play

Outdoor play was not independently associated with any of the outcome measures. These findings are consistent with a previous study conducted among 5-6 year-old Dutch children[28]. For 6-year-old children, physical activity guidelines state that children should be active for at least 60 minutes per day at a moderate to vigorous level in order to convey beneficial health effects [23-25]. Since we did not have any information on actual physical activity levels during outdoor play, it is possible that children were not physically active enough during outdoor play to find any effects on children's body fat [41]. A recent study among 4- to 5-year-old preschool children suggests that children playing outdoor spend under 21% of time in moderate to vigorous physical activity [46]. Also, similar to sedentary activities, it may be that more extended exposure to low levels of physical activity is needed before any effects become visible.

Active transport to and from school

In the unadjusted models, children using active transport less than 5 days per week were significantly less likely to be overweight, and had significantly lower BMI SDS and percent fat mass. These associations disappeared after taking into account socio-demographic characteristics of the child and the family. Indeed, additional analyses showed that native Dutch children and children from high socioeconomic families, children shown to be at decreased risk of overweight and obesity [47-49], were more likely to use active transport less than 5 days per week compared to children of ethnic minority groups and children from lower socioeconomic families (data not shown). In addition, we did not account for distance to school. Children using active modes of transport may live closer to schools, and active transportation over a short distance may not be enough to change indicators of body fat [50]. These results are in concordance with the literature [51,52], also showing no associations between children's active transport and body weight.

Study strengths and limitations

Strengths of this study are the size of the study population and the measurement of important confounders. Furthermore, we were able to use percent fat mass as indicator of body fat, which is generally considered a highly accurate measure of body fat in young children [53]. In addition, the young age of the study population allowed us to assess modifiable risk factors of overweight and body fatness in a population that may still benefit from intervention programs. Several limitations should also be considered. First, the data for this study were cross-sectional, which precludes inferences about causality. Second, extended exposure to unfavorable lifestyle behaviors may be necessary before any effects on adiposity become measurable. Children with severe overweight (i.e., obesity) are likely to be exposed over a longer period of time. However, given that the multinomial logistic regression analyses yielded highly similar results, we have no indications that duration of exposure plays, or lack thereof, is a prominent explanation for the current results. Third, sedentary behaviors and physical activity behaviors were measured by parent-reported questionnaires. Although the questionnaires did not specifically refer to leisure time only, parents are likely to have reported on behaviors displayed outside school hours. As a consequence, time spent in sedentary behaviors and physical activity behaviors are likely to have been underestimated for weekdays. Also, the items measuring these behaviors were derived from questionnaires used by local and nation municipalities in the Netherlands and have not been tested for validity and reliability in children of this age [54]. Future studies should aim at incorporating objectively measured physical activity (i.e., by accelerometry and direct observation) in order to obtain more information about time spent in different activity levels and physical activity behaviors across the whole day. Finally, data on sedentary behaviors and physical activity behaviors were dichotomized according to current guidelines and recommendations [6,22-25]. This may have potentially led to a loss of information and statistical power to detect associations. We have re-analyzed our data using continuous exposure variables (data not shown). These analyses yielded highly similar results, with the exception of an additional significant independent association between outdoor play and percent body fat (beta=-0.18, $p<0.05$).

Conclusion

The results of this study indicate that sports participation is inversely associated with percent body fat among ethnically diverse 6-year-old children. More research in varied populations including objective measurements and longitudinal designs are needed to confirm these current results. In the meantime, health professionals should be aware that even at a young age attention should be given to children's participation in organized sports or other high intensity physical activities.

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CHAPTER 2.2

MEAL SKIPPING BEHAVIORS AND BODY FAT AMONG 6-YEAR-OLD ETHNICALLY DIVERSE CHILDREN: THE GENERATION R STUDY

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Abstract

Objective: Breakfast consumption is often considered an important risk factor of childhood overweight. However, most evidence for this association is based on cross-sectional research and less is known about the associations between skipping of other meals and children's body fat. We aimed to assess the associations of breakfast skipping, lunch skipping, and dinner skipping at age 4 years with body fat (body mass index [BMI], weigh status, and percent fat mass) at age 6 years.

Methods: Repeatedly measured data from 5913 ethnically diverse children were analyzed. At age 4 and 6 years, meal skipping behaviors were measured by parent-reported questionnaires. At both ages, children's weight and height were objectively measured and converted to BMI standard deviation scores. Weight status (overweight, normal weight) was defined according to age- and sex-specific cut-off points of the International Obesity Task Force. Percent fat mass was assessed by dual-energy X-ray absorptiometry. Linear and logistic regression analyses were performed, adjusting for covariates and BMI at age 4 years.

Results: The prevalence of meal skipping behaviors ranged between 3% and 10%. Tracking between the ages of 4 and 6 years was moderate for breakfast skipping (ρ=0.30) and weak for lunch (ρ=0.21) and dinner skipping (ρ=0.12). Breakfast skipping at age 4 years was associated with a higher percent fat mass at age 6 years (β:1.38, 95% CI: 0.36,2.40). No associations were found with BMI SDS or weight status. Furthermore, no associations were found between lunch and dinner skipping and any of the body fat indicators.

Conclusion: Results showed that children's breakfast skipping at age 4 years is associated with a higher percent fat mass at age 6 years. Further prospective studies, including experimental research, are warranted to assess the causality and directionality of this association.

Introduction

Over the past decades, the worldwide prevalence of childhood overweight and obesity has increased dramatically [1,2]. The increase in childhood overweight has coincided with a decline in daily breakfast consumption [3], which has led to the hypothesis that breakfast skipping may be involved in the current overweight epidemic. This hypothesis is supported by empirical studies that show positive associations between breakfast skipping and the risk of childhood overweight [4-6]. However, most of these studies are cross-sectional [7], and therefore conclusions about causality and directionality of the association are hampered.

Proposed pathways to explain the association between breakfast skipping and overweight include increased consumption of unhealthy snacks, lower overall diet quality (e.g. less grains and vegetables), irregular eating patterns, and eating late at night among breakfast skippers [5,6,8]. Alternatively, energy intake during breakfast may help sustain or boost engagement in physical activity [9,10]. Based on these premises, skipping lunch and dinner may also lead to childhood overweight. However, only few studies have examined the associations of lunch skipping and dinner skipping with children's weight status [11,12]. Furthermore, these studies did not adjust for other meal skipping behaviors or other lifestyle behaviors (e.g., sedentary and physical activity behaviors) [11,12], and thus results may be challenged by residual confounding.

In the present study, we aimed to assess the prevalence of children's meal skipping behaviors (i.e., breakfast skipping, lunch skipping, and dinner skipping) at age 4 and 6 years, to evaluate 2-year tracking of these meal skipping behaviors between the ages of 4 and 6 years, and to evaluate the associations between meal skipping behaviors at age 4 years and body fat at age 6 years (i.e., body mass index [BMI], weight status, and percent fat mass).

Methods

Study design

This study was embedded in the Generation R Study, a population-based prospective cohort study from fetal life onwards. The Generation R Study was designed to identify early environmental and genetic determinants of growth, development, and health, and has been described previously in detail [13]. The study was conducted in accordance with the guidelines proposed in the World Medical Association Declaration of Helsinki and has been approved by the Medical Ethical Committee at Erasmus MC, University Medical Center Rotterdam. Written informed consent was obtained from all parents.

Study population

Invitations to participate in the study were made to all pregnant women who had an expected delivery date between April 2002 and January 2006 and who lived in the study area (Rotterdam, the Netherlands) at time of delivery. Of 9749 known live born children of the Generation R cohort, 8305 children still participate in follow up studies from 5 years. At the age of 6 years, 6690 children visited a dedicated research center in the Erasmus Medical Center- Sophia's Children's Hospital where information on children's body fat was collected [13]. Participants with missing information on BMI or fat mass (n=330) were excluded from the current analyses. To avoid clustering of data, we furthermore excluded second (n=441) and third children (n=6) of the same mother, leaving a study population of 5913 participants.

Meal skipping behaviors

Meal skipping behaviors were assessed by parent-reported questionnaires when the children were 4 years and 6 years of age. At age 4 years, children's weekly consumption of breakfast, lunch, and dinner was assessed with answer categories including 'never', '1-2 days per week', '3-4 days per week', '5-6 days per week', and 'every day (7 days per week)' (Supplement Table 1). At age 6 years, number of days on which children consumed breakfast, lunch, and dinner was assessed for weekdays and weekend days separately. Weekly consumption in number of days was calculated by adding the number of days during the week and during the weekend on which children consumed a meal (Supplement Tables 2a-2b). At both ages, skipping a meal was defined as consumption <7 days per week.

Body fat

BMI of the children was measured at age 4 years and 6 years. At age 4 years, children's weight and height were measured at community child health centers according to standard schedules and procedures by a well-trained staff. Height was measured in supine position without shoes by a Harpenden stadiometer (Holtain Limited). Weight was measured without clothing and shoes using a mechanical personal scale (SECA). BMI was calculated as weight divided by height squared (kg/m2). Using the Growth Analyzer program (Growth Analyzer 3.0, Dutch Growth Research Foundation, Rotterdam, the Netherlands), BMI standard deviation scores (SDS) adjusted for age and gender were constructed based on Dutch reference growth curves [14]. At age 6 years, children height and weight (in lightweight clothes and without shoes) were measured in the Generation R research center in the Erasmus Medical Center-Sophia's Children's Hospital. Children's weight status (overweight including obesity versus normal weight) was defined according to age- and sex-specific cut-off points proposed by the International Obesity Task Force [15]. Dual energy X-ray absorptiometry (DXA) scans were used to obtain percent fat mass of the children (iDXA; General Electrics, formerly Lunar Corp., Madison, WI, USA). The DXA scans provide measurements of bone and soft tissue for the total body and sub regions, including bone mineral content (g), fat mass (g), and lean mass (g). Percent fat mass was calculated as 100% x [total body fat mass (g)]/ [total body mass (fat mass + lean mass + bone mass of total body) (g)]. Children were scanned in a supine position with their feet together in a neutral position and hands flat by their sides. All DXA scans were obtained using the same device and software (enCORE2010) and were performed by well-trained and certified research staff.

Covariates

Based on earlier studies on risk factors of childhood overweight [7,16,17], child's sex, child's age, socio-demographic variables (i.e., child's ethnic background and family socioeconomic position), parental BMI, and children's lifestyle behaviors were considered important covariates. The following indicators were used for family socioeconomic position: maternal educational level (high, mid-high, mid-low, low) [18], maternal employment status (paid job, no paid job), and household income (<€2000/month [i.e. below modal income [19]], €2000-€3200/month, >€3200/month). In line with Statistics Netherlands [20], child's ethnic background was based on country of birth of the parents, and categorized in one of three categories: native Dutch, other-Western, and non-Western ethnic background. Maternal pre-pregnancy BMI was calculated on the basis of self-reported pre-pregnancy weight and measured height at enrollment. Paternal BMI was calculated on the basis of measured weight and height at enrollment. Children's physical activity behaviors (i.e., sport participation, outdoor play, active transport to/from school), sedentary behaviors (i.e., television viewing and computer game use), and dietary behaviors (i.e., consumption of sugar-containing beverages and high-calorie snacks), were assessed in parent-reported questionnaires at child ages 4 and 6 years.

Statistical analyses

Descriptive statistics were used to characterize the study population. Differences between boys and girls in socio-demographic variables, meal skipping behaviors, and body fat were tested, using Chi-square tests for categorical variables and one way ANOVAs for normally distributed continuous variables. To compare the prevalence of meal skipping at age 4 and 6 years, McNemar tests were performed.

Two-year tracking of children's meal skipping behaviors was evaluated in two different ways [21]. First, Spearman's rho correlation coefficients were calculated to assess the correlation between children's relative rank positions in number of days of meal skipping from 4 years to 6 years (Supplement Tables 1-2). Second, tracking patterns were generated using cross-tabulation of dichotomized meal skipping behaviors at age 4 and 6 years (yes, no), in which children were allocated to one of four categories: stable no meal skipping (no meal skipping at both ages), stable meal skipping (meal skipping at both ages), decrease in meal skipping (meal skipping at age 4, no meal skipping at age 6), and increase in meal skipping (no meal skipping at age 4, meal skipping at age 6).

Associations between meal skipping behaviors at age 4 years and body fat at age 6 years were assessed using series of multiple linear and logistic regression models. Separate crude models contained meal skipping behaviors at age 4 years as independent variable and indicators of body fat at age 6 years as dependent variables. In the first set of models, effect estimates are adjusted for the first group of covariates, including family socioeconomic position, ethnic background, and parental BMI. In the second set of models, effects estimates are additionally adjusted for other meal skipping behaviors. In the third set of models, effects estimates are additionally adjusted for children's lifestyle behaviors that may act as mediators is the associations between meal skipping behaviors and children's body fat. In the final set of full models, BMI SDS at age 4 years was added to the models. The same analyses were performed using tracking patterns as independent variable. Interaction effects of meal skipping behaviors with child's sex, BMI SDS at age 4 years, and ethnic background were assessed in the full models. Additionally, we conducted two sensitivity analyses. First, tests for trends were examined by repeating our analyses using the original meal skipping variables at age 4 years as a continuous independent variables (see Supplement Table 1). Second, we performed cross-sectional analyses using meal skipping behaviors at age 6 as independent variables and indicators of body fat as dependent variables.

To handle missing data in the meal skipping behaviors, potential confounders, and BMI at age 4 years, multiple imputation was applied [22]. Five imputed datasets were generated using a fully conditional specified model, thus taking into account the uncertainty of the imputed values. Pooled estimates from these five imputed datasets were used to report beta's, odds ratios (ORs) and their 95% confidence intervals (CIs). Imputations were based on the relationships between all the variables included in this study. All analyses were conducted with Statistical Package for Social Sciences (SPSS) version 21.0 for Windows (SPSS Inc., Chicago, IL, USA). A significance level of $p<0.05$ was used to indicate significant associations.

Results

Table 1 shows characteristics of the study population. The majority of children had a Dutch ethnic background (56.1%). About half of the children had a mother with a (mid-) low educational level (45.6%) and a little over half of the children lived in households with a middle or low household income (51.6%). The prevalence of meal skipping ranged from 3.1% (dinner skipping at age 6 years) to 10.3% (lunch skipping at age 6 years). Significant differences between boys and girls were found for breakfast skipping at both ages (more often among girls) and for dinner skipping at age 4 years (more often among boys). At the age of 6 years, children less often skipped breakfast (p<0.001), more

Table 1. Characteristics of the study population and according to child's sex (n=5913)

		Total (n=5913) n (%)	Missing n (%)	Boys (n=2939,49.7%) n (%)	Girls (n=2974,50.3%) n (%)	P-value*
Socio-demographic variables						
Child's ethnic background	Dutch	2332 (56.1)	0	1608 (56.1)	1624 (56.2)	0.38
	other-Western	522 (9.1)		246 (8.6)	276 (9.5)	
	non-Western	2004 (34.8)	155 (2.6)	1013 (35.3)	991 (34.3)	
Maternal educational level	High	1360 (27.2)	915 (15.5)	674 (27.0)	686 (27.4)	0.62
	Mid-high	1360 (27.2)		688 (27.6)	672 (26.9)	
	Mid-low	1609 (32.2)		814 (32.6)	795 (31.8)	
	Low	669 (13.4)		320 (12.8)	349 (13.9)	
Maternal employment status	Paid job	3536 (74.8)	1186 (20.1)	1755 (74.3)	1781 (75.3)	0.46
	No paid job	1191 (25.2)		606 (25.7)	585 (24.7)	
Household income	>€3200	2281 (48.4)	1196 (20.2)	1140 (48.3)	1141 (48.4)	0.92
	€2000-<€3200	1257 (26.6)		624 (26.5)	633 (26.8)	
	<€2000	1179 (25.0)		595 (25.2)	584 (24.8)	
Meal skipping behaviors (4 years)						
Breakfast skipping	No	3426 (92.1)	2193 (37.1)	1714 (93.0)	1712 (91.2)	<0.05
	Yes	294 (7.9)		129 (7.0)	165 (8.8)	
Lunch skipping	No	3429 (92.6)	2210 (37.4)	1704 (93.0)	1725 (92.2)	0.34
	Yes	274 (7.4)		128 (7.0)	146 (7.8)	
Dinner skipping	No	3416 (92.9)	2237 (37.8)	1676 (92.1)	1740 (93.8)	<0.05
	Yes	260 (7.1)		144 (7.9)	116 (6.2)	
Meal skipping behaviors (6 years)						
Breakfast skipping	No	4665 (93.5)	925 (15.6)	2358 (94.5)	2307 (92.6)	<0.01
	Yes	323 (6.5)		138 (5.5)	185 (7.4)	
Lunch skipping	No	4394 (89.7)	1015 (17.2)	2196 (89.7)	2198 (89.7)	0.99
	Yes	504 (10.3)		252 (10.3)	252 (10.3)	
Dinner skipping	No	4679 (96.9)	1082 (18.3)	2334 (96.5)	2345 (97.2)	0.19
	Yes	152 (3.1)		84 (3.5)	68 (2.8)	
Indicators of body fat (6 years)						
BMI SDS	Mean (sd)	0.3 (0.9)	0	0.3 (0.9)	0.3 (1.0)	0.46
Fat mass (%)	Mean (sd)	25.0 (5.7)	0	22.7 (5.0)	27.2 (5.4)	<0.001
Weight status	Normal weight	4870 (82.4)	0	2508 (85.3)	2362 (79.4)	<0.001
	Overweight	1043 (17.6)		431 (14.7)	612 (20.6)	

Table is based on non-imputed dataset.
* P-values derived from Chi-square tests for categorical variables and one way ANOVAs for normally distributed continuous variables comparing boys and girls.

often skipped lunch ($p<0.01$), and less often skipped dinner ($p<0.001$) compared with age 4 years (Supplement Table 3).

Table 2 shows tracking among children with data on both time points. Spearman's rho coefficients were 0.30 (moderate), 0.21 (weak), and 0.12 (weak) for breakfast skipping, lunch skipping, and dinner skipping, respectively (all $p<0.001$). The majority of children remained stable with respect to their meal skipping behaviors, with most children being stable no meal skippers (proportions ranging between 86% and 91%). About three quarter (77%) of children were 'stable no meal skippers' for all three dietary behaviors (data not shown). Tracking patterns for breakfast and dinner skipping differed between boys and girls (both $p <0.05$).

Analyses between meal skipping behaviors at age 4 years and body fat at age 6 years are presented in Tables 3-4. No interaction effects were observed; therefore, results are presented for the total study population. Breakfast skipping at age 4 years was associated with all indicators of body fat at age 6 years in the crude models. Following adjustment for all covariates and BMI SDS at age 4 years, breakfast skipping was significantly associated with percent fat mass (β:1.38; 95% CI: 0.36,2.40) only. Similar results were found when tracking patterns were used as independent variables; compared to stable no

Table 2. Tracking of meal skipping behaviors from 4 years to 6 years*

		Total n (%)	Boys n (%)	Girls n (%)	P-value**
Breakfast skipping	Stable no meal skipping	3118 (89.8)	1576 (91.2)	1532 (88.5)	<0.05
(n=3472)	Stable meal skipping	68 (2.0)	30 (1.7)	38 (2.2)	
	Decrease meal skipping	193 (5.6)	87 (5.0)	106 (6.1)	
	Increase meal skipping	93 (2.7)	36 (2.1)	57 (3.3)	
	Spearman's rho	0.30 (p<0.001)			
Lunch skipping	Stable no meal skipping	2928 (86.1)	1465 (86.6)	1463 (85.6)	0.65
(n=3402)	Stable meal skipping	72 (2.1)	32 (1.9)	40 (2.3)	
	Decrease meal skipping	166 (4.9)	77 (4.6)	89 (5.2)	
	Increase meal skipping	236 (6.9)	118 (7.0)	118 (6.9)	
	Spearman's rho	0.21 (p<0.001)			
Dinner skipping	Stable no meal skipping	3039 (91.2)	1496 (90.0)	1543 (92.3)	<0.05
(n=3333)	Stable meal skipping	21 (0.6)	15 (0.9)	6 (0.4)	
	Decrease meal skipping	208 (6.2)	118 (7.1)	90 (5.4)	
	Increase meal skipping	65 (2.0)	33 (2.0)	32 (1.9)	
	Spearman's rho	0.12 (p<0.001)			

Table is based on non-imputed dataset.

* Table is based on data from children with measurements at both time points (4 years and 6 years), i.e., n=3472 for breakfast skipping, n=3402 for lunch skipping, and n=3333 for dinner skipping.

** P-values derived from Chi-square tests comparing boys and girls.

Table 3. Associations of meal skipping behaviors at age 4 years with body fat at age 6 years (n=5913)

Percent fat mass (%)[#]	Crude model β (95% CI)	Model 1* β (95% CI)	Model 2** β (95% CI)	Model 3*** β (95% CI)	Full model**** β (95% CI)
Breakfast skipping (yes)	**2.61 (1.80,3.42)**	**1.40 (0.63,2.17)**	**1.36 (0.54,2.17)**	**1.34 (0.50,2.18)**	**1.38 (0.36,2.40)**
Lunch skipping (yes)	**1.73 (1.02,2.44)**	**0.65 (0.05,1.26)**	0.20 (-0.58,0.98)	0.20 (-0.59,0.98)	-0.31 (-0.99,0.36)
Dinner skipping (yes)	0.55 (-0.66,1.76)	0.37 (-0.58,1.31)	-0.09 (-1.10,0.91)	-0.14 (-1.11,0.83)	0.04 (-0.69,0.77)
BMI SDS	Crude model β (95% CI)	Model 1* β (95% CI)	Model 2** β (95% CI)	Model 3*** β (95% CI)	Full model**** β (95% CI)
Breakfast skipping (yes)	**0.25 (0.11,0.38)**	0.11 (-0.05,0.27)	0.10 (-0.08,0.29)	0.11 (-0.08,0.31)	0.13 (-0.05,0.32)
Lunch skipping (yes)	**0.25 (0.16,0.33)**	**0.10 (0.01,0.19)**	0.09 (-0.04,0.22)	0.09 (-0.04,0.22)	-0.06 (-0.15,0.04)
Dinner skipping (yes)	0.06 (-0.12,0.23)	-0.02 (-0.16,0.13)	-0.08 (-0.23,0.08)	-0.06 (-0.21,0.08)	-0.01 (-0.09,0.07)
Overweight (including obesity)[‡]	Crude model OR (95% CI)	Model 1* OR (95% CI)	Model 2** OR (95% CI)	Model 3*** OR (95% CI)	Full model**** OR (95% CI)
Breakfast skipping (yes)	**1.82 (1.29,2.57)**	1.24 (0.73,2.11)	1.18 (0.68,2.02)	1.19 (0.68,2.10)	1.28 (0.51,3.26)
Lunch skipping (yes)	**1.97 (1.61,2.42)**	**1.34 (1.03,1.74)**	1.34 (0.96,1.88)	1.38 (0.99,1.93)	1.05 (0.67,1.66)
Dinner skipping (yes)	1.22 (0.71,2.09)	1.00 (0.57,1.74)	0.83 (0.47,1.47)	0.84 (0.49,1.43)	0.87 (0.48,1.60)

Table is based on imputed dataset. Bold print indicates statistical significance ($p<0.05$). Values represent betas, odds ratios, and 95% confidence intervals derived from (multiple) linear regression analyses and (multiple) logistic regression analyses.
* Adjusted for indicators of family SEP, ethnic background, and parental BMI.
** Additionally adjusted for other meal skipping behaviors at age 4 years.
*** Additionally adjusted for children's lifestyle behaviors.
**** Additionally adjusted for BMI SDS at age 4 years.
[#] All models (except for crude model) also adjusted for child's sex, child's age, and child's height.
[‡] All models (except for crude model) also adjusted for child's sex and child's age.

breakfast skippers, children in all three breakfast skipping categories had a significantly increased percent fat mass at age 6 years. The largest difference was found between stable no breakfast skippers and stable breakfast skippers (β:1.80; 95% CI: 0.75,2.85). Children who decreased in breakfast skipping or increased in breakfast skipping did not differ significantly from stable breakfast skippers (data not shown). Results from the trend analyses and cross-sectional analyses are presented in Supplement Tables 4 and 5, respectively. Children who eat breakfast more frequently had lower levels of percent fat mass. In addition, children who ate breakfast more frequently had lower BMI SDS. In the cross-sectional analyses, breakfast skipping was significantly associated with all indicators of body fat; no other associations were observed.

Table 4. Associations of meal skipping tracking patterns with body fat at age 6 years

Percent fat mass (%)[#]	Crude model β (95% CI)	Model 1* β (95% CI)	Model 2** β (95% CI)	Model 3*** β (95% CI)	Full model**** β (95% CI)
Breakfast skipping (n=3472)					
Stable no meal skipping (ref)	0.00	0.00	0.00	0.00	0.00
Stable skipping	**3.90 (2.71,5.10)**	**2.44 (1.40,3.48)**	**2.48 (1.43,3.54)**	**2.42 (1.37,3.48)**	**1.80 (0.75,2.85)**
Decrease meal skipping	**1.79 (1.06,2.51)**	**1.09 (0.38,1.64)**	**1.04 (0.39,1.70)**	**1.00 (0.35,1.66)**	**1.24 (0.56,1.92)**
Increase meal skipping	**2.86 (1.84,3.88)**	**1.55 (0.67,2.42)**	**1.55 (0.67,2.42)**	**1.50 (0.63,2.38)**	**0.92 (0.11,1.74)**
Lunch skipping (n=3402)					
Stable no meal skipping (ref)	0.00	0.00	0.00	0.00	0.00
Stable skipping	**1.41 (0.24,2.58)**	0.36 (-0.63,1.35)	-0.08 (-1.09,0.94)	-0.10 (-1.11,0.91)	-0.33 (-1.24,0.58)
Decrease meal skipping	**1.17 (0.39,1.95)**	0.26 (-0.42,0.94)	-0.13 (-0.84,0.58)	-0.15 (-0.86,0.56)	-0.59 (-1.26,0.08)
Increase meal skipping	0.59 (-0.07,1.26)	0.33 (-0.24,0.90)	0.26 (-0.30,0.83)	0.23 (-0.34,0.80)	0.01 (-0.49,0.51)
Dinner skipping (n=3333)					
Stable no meal skipping (ref)	0.00	0.00	0.00	0.00	0.00
Stable skipping	0.27 (-1.88,2.42)	0.92 (-0.90,2.74)	-0.15 (-0.78,0.48)	0.24 (-1.58,2.06)	0.17 (-1.45,1.79)
Decrease meal skipping	0.29 (-0.44,0.97)	0.21 (-0.38,0.81)	0.39 (-1.43,2.21)	-0.19 (-0.82,0.43)	-0.10 (-0.68,0.48)
Increase meal skipping	**1.31 (0.08,2.54)**	**1.05 (0.01,2.10)**	1.01 (-0.03,2.05)	1.02 (-0.01,2.06)	0.65 (-0.39,1.68)

Table 4. Associations of meal skipping tracking patterns with body fat at age 6 years (continued)

BMI SDS	Crude model β (95% CI)	Model 1* β (95% CI)	Model 2** β (95% CI)	Model 3*** β (95% CI)	Full model**** β (95% CI)
Breakfast skipping (n=3472)					
Stable no meal skipping (ref)	0.00	0.00	0.00	0.00	0.00
Stable skipping	**0.48 (0.28,0.69)**	**0.30 (0.10,0.50)**	**0.30 (0.09,0.51)**	**0.31 (0.11,0.52)**	0.13 (-0.09,0.34)
Decrease meal skipping	0.10 (-0.02,0.23)	0.01 (-0.11,0.14)	0.01 (-0.12,0.14)	0.02 (-0.11,0.15)	0.12 (-0.03,0.27)
Increase meal skipping	**0.29 (0.11,0.47)**	**0.18 (0.01,0.35)**	**0.18 (0.01,0.35)**	**0.19 (0.36,0.03)**	0.01 (-0.13,0.15)
Lunch skipping (n=3402)					
Stable no meal skipping (ref)	0.00	0.00	0.00	0.00	0.00
Stable skipping	0.12 (-0.08,0.32)	0.00 (-0.19,0.19)	-0.02 (-0.22,0.18)	-0.02 (-0.22,0.18)	-0.09 (-0.22,0.04)
Decrease meal skipping	**0.18 (0.05,0.31)**	0.07 (-0.06,0.21)	0.06 (-0.08,0.20)	0.06 (-0.08,0.20)	-0.09 (-0.21,0.04)
Increase meal skipping	0.11 (0.00,0.23)	0.07 (-0.04,0.18)	0.07 (-0.05,0.18)	0.07 (-0.04,0.19)	0.01 (-0.06,0.08)
Dinner skipping (n=3333)					
Stable no meal skipping (ref)	0.00	0.00	0.00	0.00	0.00
Stable skipping	0.18 (-0.19,0.54)	0.15 (-0.21,0.50)	0.10 (-0.26,0.45)	0.10 (-0.26,0.46)	0.09 (-0.14,0.33)
Decrease meal skipping	0.05 (-0.07,0.17)	-0.01 (-0.13,0.11)	-0.05 (-0.17,0.07)	-0.04 (-0.17,0.08)	-0.00 (-0.10,0.10)
Increase meal skipping	0.18 (-0.03,0.39)	0.14 (-0.06,0.34)	0.13 (-0.07,0.34)	0.14 (-0.06,0.34)	0.04 (-0.14,0.33)

Table 4. Associations of meal skipping tracking patterns with body fat at age 6 years (continued)

Overweight (including obesity)‡	Crude model OR (95% CI)	Model 1* OR (95% CI)	Model 2** OR (95% CI)	Model 2** OR (95% CI)	Full model**** OR (95% CI)
Breakfast skipping (n=3472)					
Stable no meal skipping (ref)	1.00	1.00	1.00	1.00	1.00
Stable skipping	**3.16 (1.87,5.35)**	**1.98 (1.11,3.55)**	**1.89 (1.04,3.44)**	**1.97 (1.08,3.61)**	1.70 (0.60,4.83)
Decrease meal skipping	1.41 (0.95,2.09)	1.01 (0.65,1.57)	0.95 (0.59,1.52)	0.95 (0.59,1.53)	1.07 (0.54,2.12)
Increase meal skipping	**2.33 (1.44,3.77)**	1.64 (0.96,2.80)	1.61 (0.94,2.75)	1.61 (0.94,2.76)	1.00 (0.47,2.11)
Lunch skipping (n=3402)					
Stable no meal skipping (ref)	1.00	1.00	1.00	1.00	1.00
Stable skipping	1.71 (0.95,3.10)	1.20 (0.63,2.30)	1.20 (0.61,2.35)	1.23 (0.63,2.43)	0.88 (0.34,2.27)
Decrease meal skipping	**2.03 (1.39,2.98)**	1.47 (0.95,2.28)	1.48 (0.93,2.35)	1.51 (0.95,2.41)	1.14 (0.54,2.39)
Increase meal skipping	1.36 (0.95,1.96)	1.25 (0.84,1.85)	1.24 (0.84,1.85)	1.26 (0.84,1.88)	1.07 (0.65,1.76)
Dinner skipping (n=3333)					
Stable no meal skipping (ref)	1.00	1.00	1.00	1.00	1.00
Stable skipping	1.10 (0.32,3.75)	1.17 (0.31,3.35)	0.94 (0.24,3.61)	0.95 (0.24,3.68)	0.34 (0.05,2.20)
Decrease meal skipping	1.20 (0.81,1.77)	0.99 (0.64,1.54)	0.81 (0.50,1.31)	0.79 (0.49,1.29)	0.81 (0.43,1.52)
Increase meal skipping	1.34 (0.70,2.59)	1.23 (0.61,2.49)	1.21 (0.60,2.45)	1.20 (0.59,2.44)	0.95 (0.29,3.09)

Table is based on imputed dataset. Bold print indicates statistical significance ($p<0.05$). Values represent betas, odds ratios, and 95% confidence intervals derived from (multiple) linear regression analyses and (multiple) logistic regression analyses.
* Adjusted for indicators of family SEP, ethnic background, and parental BMI.
** Additionally adjusted for other meal skipping behaviors at age 4 years.
*** Additionally adjusted for children's lifestyle behaviors.
**** Additionally adjusted for BMI SDS at age 4 years.
[#] All models (except for crude model) also adjusted for child's sex, child's age, and child's height.
[‡] All models (except for crude model) also adjusted for child's sex and child's age.

Discussion

The current study aimed to assess the prevalence of children's meal skipping behaviors at age 4 and 6 years, to evaluate 2-year tracking of these meal skipping behaviors, and to evaluate the associations between children's meal skipping at age 4 years and body fat at age 6 years. The prevalence of meal skipping ranged from 3% to 10%. Tracking of these behaviors was moderate for breakfast skipping and weak for lunch and dinner skipping. Breakfast skipping at age 4 years was associated with a higher percent fat mass at age 6 years. No associations were found with BMI SDS or weight status. Furthermore, no associations were found between lunch and dinner skipping at age 4 years and any of the body fat indicators at age 6 years.

Prevalence of meal skipping behaviors

The prevalence of breakfast skipping is similar to those found in previous studies conducted among 4-7 year-old children [4,5,17,23], but lower compared to those found in studies among older school-aged children and adolescents [9-11,24-28]. Research on lunch skipping and dinner skipping in young children is scarce; however, studies among older children show a higher prevalence of lunch skipping and dinner skipping [11,26,27]. Meal skipping is known to increase as children move into and through adolescence and young adulthood [9,10], and thus the age difference may explain why we found a lower prevalence of lunch and dinner skipping.

In this study, we showed a decline in breakfast skipping between the ages of 4 and 6 year. In the Netherlands, children can enter primary schools from 4 years onwards, with compulsory education starting at the age of 5 years [29]. With the transition from pre-schools or home care to primary schools especially, family life may become more structured thereby facilitating daily breakfast consumption. Furthermore, breakfast consumption may become a more important meal for young primary school children due to the need for academic performance. Further transition into adolescence and young adulthood may lead to an increase in breakfast skipping as adolescents become more independent or use breakfast skipping as a weight loss strategy [9,10,28]. The same arguments may hold for our findings with respect to dinner skipping. Conversely, we found an increase in lunch skipping between the ages of 4 and 6 years. An explanation for this finding may be that with the transition to primary school, a substantial part of the children will start eating lunch at school instead of home with their parent(s) and therefore parents may be able to exert less control over their children's eating. Alternatively, children may have to start taking care of their own lunch and may be less inclined to do so in comparison with their parents. Further research on changes in meal skipping behaviors during important life transitions is merited.

In agreement with earlier findings [11,12,26], breakfast skipping was most often found among girls, and dinner skipping most often among boys. Girls may skip breakfast more often due to societal pressure and expectations [4]; however, this seems unlikely in this age group. Boys are more often fussy eaters [30-32], i.e., highly selective about the range of foods that are accepted [32], and fussy eating has been associated with a decreased intake of whole grain products, vegetables, fish, and meat [31]. Since these foods are mainly consumed during dinner, higher levels of fussy eating may explain why boys more often skip dinner compared with girls.

Tracking of meal skipping behaviors

This study showed weak to moderate tracking coefficients (Spearman's rho: 0.12-0.30) [33], with the largest tracking coefficient found for breakfast skipping. Tracking patterns showed that approximately 90% of children displayed similar meal skipping behaviors (yes, no) between the ages of 4 and 6 years, with most children being stable no meal skippers. Taken together, these findings indicate that meal skipping, and breakfast skipping in particular, seem to track moderately during early childhood. Tracking patterns in breakfast skipping and dinner skipping differed significantly between boys and girls. For breakfast skipping, girls were less often stable no meal skippers, and more often stable meal skippers, decrease in meal skippers, and increase in meal slippers. For dinner skipping, the results were mirrored. These findings support the overall notion that girls are more likely to skip breakfast and boys more likely to skip dinner. We also found that tracking between the ages of 4 and 6 years was greatest for breakfast skipping. It is possible that the factors underlying breakfast consumption are more structural than those underling lunch or dinner skipping. For example, factors underlying breakfast skipping may be related to sleep routines, whereas factors for skipping lunch or dinner may be more incidental.

Associations between meal skipping behaviors and body fat

The present study found an association between children's breakfast skipping at age 4 and percent fat mass, but not with BMI SDS or overweight, at age 6 years. Similar results were found when using tracking patterns as independent variable; compared with stable no breakfast skippers, all other groups of children had significantly higher percent fat mass. The discrepancy in findings between different indicators of body fat may be explained by their accuracy to capture children's adiposity. In this study, percent fat mass was measured by DXA, which is generally considered a highly accurate measure of body fatness in young children [34].

Previous prospective research among adolescents and young adults have shown positive associations of breakfast skipping with BMI [9,10,28,35] and overweight [25], although a negative association with BMI has also been reported [35]. Furthermore, a prospective study among Australian children found an association between less frequent breakfast consumption and higher odds of overweight among children aged 10-12 but not among children ages 5/6 years [36]. Taken together, it is possible that due to higher rates of breakfast skipping at older ages, as well as more variability in breakfast skipping, these studies had more power to detect any associations with BMI or overweight.

No associations were found between children's lunch or dinner skipping at age 4 years and body fat at age 6 years. Research on the associations between body fat and meal skipping behaviors other than breakfast skipping is scarce [11,12] and therefore results cannot be easily compared. In line with our findings, a cross-sectional study among 9-11 year-old Finnish children found that school lunch and dinner were not associated with BMI [11]. In contrast, a European study among 0-12 year-olds found that both breakfast skipping and dinner skipping were cross-sectionally associated with higher odds of overweight [12]. Given that these analyses were adjusted for child's sex and ethnicity only [12], results can be confounded.

Given that the pathways underlying the association of breakfast skipping with body fat are hypothesized to be similar to those underlying the associations of lunch and dinner skipping with body fat, the current findings seem unexpected. We propose several potential explanations for our results. First, it may be that not breakfast consumption per se, but rather the types of food consumed during breakfast, are important determinants of adiposity trajectories [9,37]. In previous research, (ready to eat) cereal consumption during breakfast or other times of the day have been shown to be associated with a lower BMI [37-40]. Under the assumption that children's meal skipping behaviors are causally related to body fat, a more prolonged exposure to these factors would bring about higher levels of body fat. Therefore, the observed association between breakfast skipping and body fat may also be due to the (more) persistent nature of breakfast skipping [9]. This notion is substantiated by the gradients in percent fat mass, BMI SDS, and weight status according to breakfast tracking patterns. Although children in the stable breakfast skipping group did not significantly differ in percent fat mass from children in the unstable (increase in/decrease in) breakfast skipping groups, low numbers of children in the latter groups and thus less power may explain why we were unable to find these differences. Moreover, due to the definition of breakfast skipping (i.e., breakfast consumption on 0-6 days) the breakfast skipping group and consequently the different groups of children making up the breakfast tracking patterns are heterogeneous, which may have diluted the effects. Finally, consumption of breakfast may be an important marker or an overall healthy lifestyle [28]. However, following adjustment for a wide range of covariates, the associations between breakfast skipping and percent fat mass remained significant. This reduces the possibility that (residual) confounding by socio-demographic factors, parental BMI, or other meal skipping behaviors explain the current results.

Although outside the scope of this study, our study provides some preliminary insights on the pathways underlying the associations between meal skipping and body fat. Based on previous research, we hypothesized that children's sedentary behaviors, physical activity behaviors, and consumption of high-calorie snacks and sugar-containing beverages may act as mediators in the association between meal skipping and body fat [5,6,8-10]. However, adjustment for these factors only slightly attenuated the results and thus our findings do not suggest a substantial contribution of these factors in explaining the associations between breakfast skipping and body fat. One explanation would be that lifestyle behaviors were poorly measured in the current study and therefore their mediating role is underestimated. Alternatively, other potential mediating variables not included in the current study may add to the explanation of the observed associations.

Study strengths and limitations

Strengths of this study include the large and ethnically diverse study population, the availability of different indicators of family SEP, and the availability of a wide range of potential confounders. Furthermore, data on both meal skipping behaviors and BMI SDS were repeatedly measured, enabling longitudinal analysis of the data. Third, several objectively measured indicators of children's body fat were available for the present study, including percent fat mass as assessed by DXA, which is generally considered a sensitive measure of body fatness in young children [34]. A limitation of this study was the use of parent-reported questionnaires to assess children's meal skipping behaviors, which may have led to social desirable answers (i.e., under reporting of unhealthy behaviors). Also, the validity of the short items assessing meal skipping behaviors has not been assessed. Furthermore, information on total energy intake and expenditure, types of food children consumed during breakfast, lunch, or dinner [10,37-40], and information on the context in which meal consumption occurred (e.g., meal consumption during television viewing [36] or duration of meal [41]), was not collected. Tracking of meal skipping behaviors was evaluated over a 2-year period and further research is necessary to assess tracking over a longer period. Finally, causation cannot be proven due to the observational design of the study. Despite the adjustment for many potential confounders, residual confounding by unmeasured or poorly measured variables is still possible. However, the positive association between children's breakfast skipping at age 4 years and percent fat mass at age 6 years found in the present study provides complimentary evidence to that found in earlier cross-sectional research.

Conclusion

The prevalence of breakfast skipping, lunch skipping, and dinner skipping among young ethnically diverse children ranged between 3% and 10%. Girls were more likely to skip breakfast and boys were more likely to skip dinner. Two-year tracking between the ages of 4 and 6 years was moderate for breakfast skipping and weak for lunch and dinner skipping. Breakfast skipping at age 4 years was associated with a higher percent fat mass at age 6 years. Further prospective studies, including experimental research, is warranted to assess the causality and directionality of this association.

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Supplement Table 1. Assessment of meal skipping behaviors at age 4 years

Question	Original variables - Categorical #		New variables - Categorical		
	Value labels	n (%)	Value labels	Values	n (%)
How often does your child eat breakfast?	Never	18 (0.4)	Skipping	1	294 (7.9)
(n=3720)	1-2 days per week	52 (1.4)			
	3-4 days per week	88 (2.4)			
	5-6 days per week	136 (3.7)			
	Every day	3426 (92.1)	No skipping	0	3426 (92.1)
How often does your child eat at lunch time?	Never	12 (0.3)	Skipping	1	274 (7.4)
(n=3703)	1-2 days per week	19 (0.5)			
	3-4 days per week	55 (1.5)			
	5-6 days per week	188 (5.1)			
	Every day	3429 (92.6)	No skipping	0	3429 (92.6)
How often does your child have an evening meal?	Never	3 (0.2)	Skipping	1	260 (7.1)
(n=3676)	1-2 days per week	19 (0.5)			
	3-4 days per week	60 (1.6)			
	5-6 days per week	178 (4.8)			
	Every day	3416 (92.9)	No skipping	0	3416 (92.9)

Table is based on non-imputed dataset.

Spearman's rho coefficients were calculated using these variables.

Supplement Table 2a. Assessment of meal skipping behaviors at age 6 years

Question	Original variables - Categorical	
	Value labels	n (%)
On weekdays, how often does your child eat breakfast?	Never	40 (0.7)
(n=5012)	1 day per week	9 (0.2)
	2 days per week	48 (1.0)
	3 days per week	84 (1.7)
	4 days per week	102 (2.0)
	5 days per week	4729 (94.4)
On weekend days, how often does your child eat breakfast?	Never	7 (0.2)
(n=5007)	1 day in the weekend	76 (1.5)
	2 days in the weekend	4924 (98.3)
On weekdays, how often does your child eat at lunch time?	Never	24 (0.5)
(n=4934)	1 day per week	20 (0.4)
	2 days per week	26 (0.5)
	3 days per week	29 (0.6)
	4 days per week	86 (1.7)
	5 days per week	4749 (96.3)
On weekend days, how often does your child eat at lunch time?	Never	39 (0.8)
(n=4920)	1 day in the weekend	336 (6.8)
	2 days in the weekend	4545 (92.4)
On weekdays, how often does your child eat an evening meal?	Never	7 (0.1)
(n=4885)	1 day per week	8 (0.2)
	2 days per week	17 (0.3)
	3 days per week	22 (0.5)
	4 days per week	81 (1.7)
	5 days per week	4750 (97.2)
On weekend days, how often does your child eat an evening meal?	Never	7 (0.1)
(n=4902)	1 day in the weekend	47 (1.0)
	2 days in the weekend	4848 (98.9)

Table is based on non-imputed dataset.

Supplement Table 2b. Assessment of meal skipping behaviors at age 6 years

Question	Composed variables – Scale* #		New variables - Categorical		
		n (%)	Value labels	Values	n (%)
Breakfast	0	5 (0.1)	Skipping	1	323 (6.5)
(n=4988)	1	3 (0.1)			
	2	34 (0.7)			
	3	14 (0.3)			
	4	52 (1.0)			
	5	79 (1.6)			
	6	136 (2.7)			
	7	4665 (93.5)	No skipping	0	4665 (93.5)
Lunch	0	7 (0.1)	Skipping	1	504 (10.3)
(n=4898)	1	6 (0.1)			
	2	18 (0.4)			
	3	15 (0.3)			
	4	32 (0.7)			
	5	59 (1.2)			
	6	367 (7.5)			
	7	4394 (89.7)	No skipping	0	4394 (89.7)
Dinner	0	5 (0.1)	Skipping	1	152 (3.1)
(n=4831)	1	1 (0.0)			
	2	3 (0.1)			
	3	9 (0.2)			
	4	20 (0.4)			
	5	21 (0.4)			
	6	93 (1.9)			
	7	4679 (96.9)	No skipping	0	4679 (96.9)

Table is based on non-imputed dataset.
*The composed variables (number of days on which children consumed a meal) were calculated by adding the number of days on which children consumed a meal on weekdays and on weekend days.
[#] Spearman's rho coefficients were calculated using these variables.

Supplement Table 3. Prevalence of meal skipping behaviors for children with data on both time points

Breakfast (n=3472)	Yes n (%)	No n (%)	P-value*
Breakfast skipping at 4 years	261 (7.5)	3211 (92.5)	<0.001
Breakfast skipping at 6 years	161 (4.6)	3311 (95.4)	
Lunch (n=3402)	**Yes n (%)**	**No n (%)**	**P-value***
Lunch skipping at 4 years	238 (7.0)	3164 (93.0)	<0.01
Lunch skipping at 6 years	308 (9.1)	3094 (90.9)	
Dinner (n=3333)	**Yes n (%)**	**No n (%)**	**P-value***
Dinner skipping at 4 years	229 (6.9)	3104 (93.1)	<0.001
Dinner skipping at 6 years	86 (2.6)	3247 (97.4)	

Table is based on non-imputed dataset.
* P-values derived from McNemar tests comparing prevalence of meal skipping behaviors at ages 4 and 6 years.

Supplement Table 4. Trend analyses of associations between meal skipping behaviors at age 4 years and body fat at age 6 years (n=5913)

Percent fat mass (%)[#]	Crude model β (95% CI)	Model 1* β (95% CI)	Model 2** β (95% CI)	Model 3*** β (95% CI)	Full model**** β (95% CI)
Breakfast[§]	**-1.35 (-1.71,-1,00)**	**-0.58 (-0.90,-0.25)**	**-0.52 (-0.84,-0.20)**	**-0.52 (-0.84,-0.20)**	**-0.64 (-0.88,-0.41)**
Lunch[§]	**-1.27 (-1.70,-0.83)**	**-0.44 (-0.79,-0.10)**	-0.27 (-0.57,0.03)	-0.26 (-0.57,0.05)	0.01 (-0.33,0.35)
Dinner[§]	-0.36 (01.02,0.30)	-0.16 (-0.72,0.40)	0.05 (-0.52,0.62)	0.09 (-0.49,0.66)	0.03 (-0.29,0.36)
BMI SDS	Crude model β (95% CI)	Model 1* β (95% CI)	Model 2** β (95% CI)	Model 3*** β (95% CI)	Full model**** β (95% CI)
Breakfast[§]	**-0.14 (-0.22,-0.07)**	-0.04 (-0.12,0.04)	-0.03 (-0.11,0.05)	-0.04 (-0.11,0.04)	**-0.08 (-0.13,-0.02)**
Lunch[§]	**-0.17 (-0.24,-0.09)**	**-0.06 (-0.13,-0.00)**	-0.06 (-0.12,0.01)	-0.06 (-0.12,0.00)	0.02 (-0.03,0.06)
Dinner[§]	-0.07 (-0.18,0.04)	-0.01 (-0.11,0.09)	0.02 (-0.08,0.11)	0.01 (-0.09,0.11)	-0.01 (-0.05,0.04)
Overweight (including obesity)[‡]	Crude model OR (95% CI)	Model 1* OR (95% CI)	Model 2** OR (95% CI)	Model 3*** OR (95% CI)	Full model**** OR (95% CI)
Breakfast[§]	**0.69 (0.60,0.78)**	0.90 (0.76,1.06)	0.93 (0.78,1.09)	0.93 (0.78,1.10)	0.83 (0.67,1.02)
Lunch[§]	**0.63 (0.54,0.74)**	**0.82 (0.69,0.97)**	**0.83 (0.70,0.98)**	**0.82 (0.69,0.97)**	0.85 (0.79,1.21)
Dinner[§]	0.85 (0.70,1.03)	1.01 (0.83,1.23)	1.10 (0.89,1.37)	1.10 (0.89,1.36)	1.08 (0.84,1.39)

Table is based on imputed dataset. Bold print indicates statistical significance (p<0.05). Values represent betas, odds ratios, and 95% confidence intervals derived from (multiple) linear regression analyses and (multiple) logistic regression analyses.

* Adjusted for indicators of family SEP, ethnic background, and parental BMI.

** Additionally adjusted for other meal skipping behaviors at age 4 years.

*** Additionally adjusted for children's lifestyle behaviors.

**** Additionally adjusted for BMI SDS at age 4 years.

[#] All models (except for crude model) also adjusted for child's sex, child's age, and child's height.

[‡] All models (except for crude model) also adjusted for child's sex and child's age.

[§] 1= never, 2=1-2 days per week, 3=3-4 days per week, 4=5-6 days per week, 5= every day.

Supplement Table 5. Associations of meal skipping behaviors at age 6 years with body fat at age 6 years (n=5913)

Percent fat mass (%)[#]	Crude model β (95% CI)	Model 1* β (95% CI)	Model 2** β (95% CI)	Model 3*** β (95% CI)
Breakfast skipping (yes)	**3.29 (2.58,4.01)**	**1.74 (0.17,2.31)**	**1.56 (0.89,2.24)**	**1.55 (0.87,2.23)**
Lunch skipping (yes)	**0.89 (0.41,1.37)**	0.29 (-0.12,0.71)	-0.17 (-0.59,0.26)	-0.17 (-0.61,0.27)
Dinner skipping (yes)	**1.83 (1.00,2.65)**	1.51 (0.73,2.29)	0.86 (-0.08,1.79)	0.89 (-0.04,1.81)
BMI SDS	Crude model β (95% CI)	Model 1* β (95% CI)	Model 2** β (95% CI)	Model 3*** β (95% CI)
Breakfast skipping (yes)	**0.36 (0.24,0.47)**	**0.18 (0.08,0.28)**	**0.17 (0.05,0.29)**	**0.18 (0.06,0.30)**
Lunch skipping (yes)	**0.13 (0.05,0.21)**	0.04 (-0.04,0.12)	0.00 (-0.08,0.08)	0.00 (-0.08,0.08)
Dinner skipping (yes)	**0.20 (0.02,0.37)**	0.11 (-0.07,0.28)	0.03 (-0.18,0.23)	0.03 (-0.18,0.23)
Overweight (including obesity)[‡]	Crude model OR (95% CI)	Model 1* OR (95% CI)	Model 2** OR (95% CI)	Model 3*** OR (95% CI)
Breakfast skipping (yes)	**2.45 (1.82,3.31)**	**1.58 (1.16,2.16)**	**1.56 (1.08,2.24)**	**1.59 (1.10,2.29)**
Lunch skipping (yes)	**1.37 (1.09,1.73)**	1.09 (0.83,1.43)	0.97 (0.73,1.27)	0.96 (0.72,1.29)
Dinner skipping (yes)	**1.63 (1.14,2.34)**	1.36 (0.90,2.05)	1.10 (0.69,1.76)	1.12 (0.70,1.79)

Table is based on imputed dataset. Bold print indicates statistical significance ($p<0.05$). Values represent betas, odds ratios, and 95% confidence intervals derived from (multiple) linear regression analyses and (multiple) logistic regression analyses.

* Adjusted for indicators of family SEP, ethnic background, and parental BMI.

** Additionally adjusted for other meal skipping behaviors at age 4 years.

*** Additionally adjusted for children's lifestyle behaviors.

[#] All models (except for crude model) also adjusted for child's sex, child's age, and child's height.

[‡] All models (except for crude model) also adjusted for child's sex and child's age.

CHAPTER 2.3

DEVELOPMENT OF SOCIOECONOMIC INEQUALITIES IN OBESITY AMONG DUTCH PRE-SCHOOL AND SCHOOL-AGED CHILDREN

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Abstract

Objective: To investigate the emergence of the inverse socioeconomic gradient in body mass index (BMI) in the first 6 years of life. Furthermore, associations of socioeconomic position (SEP) with BMI and total fat mass (%) were assessed at age 6, and potential mediating factors in the pathway between SEP and children's body composition were investigated.

Methods: Nearly 3,656 Dutch children participating in a prospective cohort study in Rotterdam, the Netherlands, were included from 2002 to 2006. Maternal educational level and net household income were used as indicators of SEP. BMI and fat mass were both outcome measures. Associations and mediation analyses were investigated using linear mixed models and linear regression analyses.

Results: The lowest SEP groups showed a larger increase in BMI over time as compared to the highest SEP groups ($p<0.001$), which resulted in the emergence of the inverse SEP gradient around 3-4.5 years of age. In 6-year-old children, both BMI and total fat mass were significantly higher for children of low educated mothers (difference in BMI SDS: 0.24; 95% CI: 0.15, 0.33; and in total fat mass (%): 2.68; 95% CI: 2.19, 3.17), which was also shown for children with a low household income. This was mainly explained by parental BMI and prenatal smoking.

Conclusion: The inverse socioeconomic gradient in obesity emerges during the preschool period, and widens with increasing age. A public health strategy aimed at tackling the development of inequalities in obesity in early childhood needs to start before birth and should include the prevention of prenatal smoking and obesity of parents.

Introduction

Childhood obesity and its associated adverse health effects is a major public health concern [1]. There is consistent evidence showing that school-aged children from low socioeconomic position (SEP) are more likely to be overweight and obese compared with children from high SEP [2], and these disparities may even be growing [3]. This consistent inverse association is remarkable against the background of research showing that mothers from high SEP give birth to heavier babies as compared to mothers from low SEP [4,5]. These findings suggest that the inverse association between SEP and child weight/BMI emerges in the period after birth and before school-age, that is during the preschool period. Indeed, two studies conducted in the United Kingdom and Germany, suggest that the inverse SEP gradient became manifest between 2 and 6 years of age [6,7]. In a previous study, we found that 2- to 3-year-old children from lower educated mothers had lower body mass index (BMI) z-scores and were at decreased risk for childhood overweight compared with children from high educated mothers [8]. To improve our understanding of the exact onset of the inverse socioeconomic gradient in childhood overweight and obesity, the current study extends the follow up period until the school period.

Moreover, SEP probably not directly affects the risk of childhood obesity, but is likely to act through more proximal risk factors, or mediators [9,10]. Mediating factors contributing to social inequalities in obesity in children are still largely unknown. Several factors, such as prenatal smoking, paternal BMI, birth weight, physical activity and television viewing, vary by SEP and are associated with childhood obesity [10-12]. These factors might mediate the relationship between SEP and childhood obesity.

The aims of this study were threefold. First, we aimed to investigate the association between SEP and BMI from early childhood (1 month) to the school period (6 years). Because associations between SEP and BMI vary by indicator of SEP [2], maternal education and family income are used as indicators of SEP. Second, we aimed to assess the association between SEP and children's body composition (i.e. BMI and total fat mass) at the age of 6 years. We included body fat mass as additional measure of children's body composition since BMI may underestimate the educational gradient of childhood adiposity [13]. Third, we conducted mediation analysis to identify factors in the causal pathway from SEP to children's body composition at the age of 6 years, and we investigated to what extent these mediators explained the association between SEP and body composition.

Methods

Study design

This study was embedded within the Generation R Study, a population-based prospective cohort study from fetal life until young adulthood that has previously been described in detail [14]. All children were born between April 2002 and January 2006 and form a prenatally enrolled birth-cohort that is currently being followed-up until young adulthood. The study was conducted in accordance with the guidelines proposed in the World Medical Association Declaration of Helsinki and has been approved by the Medical Ethical Committee of the Erasmus MC, University Medical Centre Rotterdam. Written consent was obtained from all participating parents [15].

Study population

We restricted our analyses to the subgroup of children with a native Dutch mother, because the association between SEP and overweight may differ between ethnic subpopulations [16]. Consent for postnatal follow-up during the preschool period (0-4 years) or the school period (6 years) was available for 4331 children with a native Dutch mother (14). Twins (n=140) were excluded from analyses to avoid clustering and because they more often have impaired fetal and postnatal growth patterns. Also, to avoid clustering, data on the second and third pregnancy of any woman participating in The Generation R Study with more than one child (n=396) were excluded. Also excluded were participants without information on educational level (n=113), as well as children without any information on BMI in preschool and school period (n=26). In total, 3,656 children were eligible for the present study.

Socioeconomic position

Maternal educational level and net household income were used as indicators of SEP. The highest educational level attained by the mother was established by questionnaire at enrollment using the Dutch Standard Classification of Education, categorized in four levels: high (university degree), mid-high (higher vocational training, Bachelor's degree), mid-low (>3 years general secondary school, intermediate vocational training) and low (no education, primary school, lower vocational training, intermediate general school, or 3 years or less general secondary school) [17]. Data on monthly net household income was obtained at enrollment and categorized into three groups (< e 1600/month, e 1600 - e 2200/month,>e 2200/month).

Body composition

In the preschool period, height and weight were measured with standardized methods at each visit to the Child Health Centers. Standard visits at the Child Health Centers take place at 1, 2, 3, 4, 6, 11, 14, 18, 24, 36, and 46 months. At the age of 6 years, weight and height were measured at a well-equipped and dedicated research center in the Erasmus Medical Center—Sophia Children's Hospital [14]. BMI was calculated using the formula: weight (kg)/height $(m)^2$. BMI values were expressed as age- and gender-adjusted standard- deviation scores (SDS) from Dutch reference growth curves, using the Growth Analyzer program [18,19]. Percentage body fat was measured by DXA scan and calculated as total body fat mass divided by total body mass (lean mass+ fat mass+ bone mass of total body) x 100. A more detailed description of the measurements is given in Supplement 1.

Potential mediators

The following factors were considered to be potential mediators in the pathway between SEP and body composition at the age of 6 years, based on previous literature on early determinants of childhood overweight and obesity [20-22].

Prenatal factors

Information on pre-pregnancy weight and smoking during pregnancy (no, until confirmed pregnancy and continued during pregnancy) was obtained by questionnaires. Maternal height was measured during visits at our research center. On the basis of height and prepregnancy weight, we calculated mother's pre-pregnancy body mass index (BMI) (weight/height2). Father's BMI was calculated from measured height and weight at enrollment.

Perinatal factors

Birth weight and gestational age at birth were obtained from midwife and hospital registries.

Postnatal factors

Information on breastfeeding (ever/never) was obtained by questionnaires at 2, 6, and 12 months. Change in BMI SDS between 1 and 6 months after birth was calculated as: BMI SDS at 6 months after birth—BMI SDS at 1 month after birth.

Lifestyle factors

Information on television viewing time (<2 h day^{-1}, ≥ 2 h day^{-1}) as indicator of sedentary behavior, playing sports (yes/no) as indicator of physical activity, and having breakfast daily (yes/no) were obtained from questionnaires at the age of 6 years.

Potential confounders

Child's sex and exact age at measurement were treated as confounders.

Statistical analyses

Associations between maternal educational level and all covariates, BMI, and body fat were explored using Chi-square tests and ANOVAs. Linear mixed models ("PROC MIXED" procedure in SAS) were used to assess the association between maternal educational level with longitudinally measured BMI SDS from 1 month to age 6 (Supplement 1).

Linear regression models were used to assess the associations of maternal educational level with BMI-for-age adjusted SDS and total fat mass (%) at 6 years of age (90% range: 5.7-6.8 years) (model 1). To evaluate the mediating effects of all potential mediators Baron and Kenny's causal step approach was used [23]. Only those factors that were significantly associated with the outcome (independent of maternal educational level; Supplement Table 1) and unequally distributed across SEP groups (Table 1) were added to model 1. The order in which selected mediators were added to the previous model was based on a hierarchical approach, accounting for the hierarchical relationships between these factors (Supplement Figure 1), starting with the most distal mediators [24]. To assess their explanatory effects, the corresponding percentages of attenuation of effect estimates were calculated by comparing differences between model 1 and the models including the mediators (100% ($\beta_{\text{model 1}} - \beta_{\text{model with mediators}}$)/($\beta_{\text{model 1}}$)). Finally, a full model containing maternal educational level and all mediators assessed the joint effects of the mediators. In this way, the total effect of maternal educational level on the outcome is defined as the effect of maternal educational level on the outcome that is explained by the mediators (indirect effect) and the effect of the exposure unexplained by those mediators (direct effect) [9]. All analyses were repeated with household income as indicator of SEP. Interaction terms between maternal educational level and child's sex were not significant; therefore analyses for BMI SDS and total fat mass (%) were not stratified for sex.

Multiple imputation was used to deal with missing values in the covariates. Five imputed datasets were created and analyzed together [25]. A 95% confidence interval (CI) was calculated around the mediating effects using a bootstrap method with 1000 resamplings per imputed dataset in the statistical program R [26]. The remaining statistical analyses were performed using Statistical Package of Social Science (SPSS) version 20.0 for Windows (SPSS, Chicago, IL) and Statistical Analysis Software (SAS) version 9.3 for Windows (SAS Institute, Cary, NC).

Results

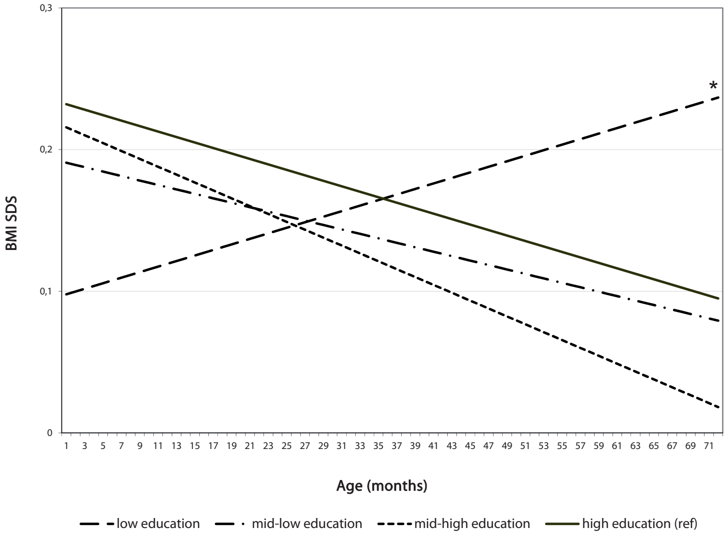
Table 1 shows maternal and child characteristics of the study population. Of the 3,656 children, 32.5% of their mothers had a high educational level and 15.4% had a low educational level. Low educated mothers were heavier, had heavier partners and more

Table 1. Characteristics of the study population (n=3656)

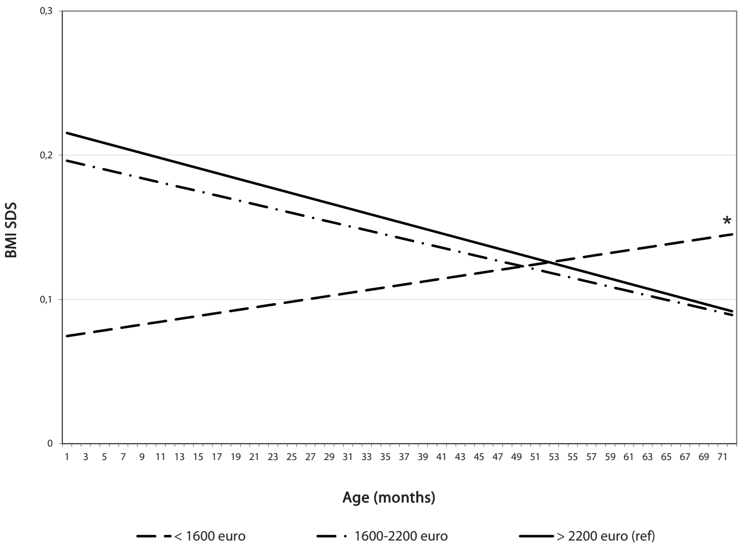
	Maternal educational level					
	Total n=3656	High n=1187	Mid-high n=937	Mid-low n=968	Low n=564	P-value[a]
Net household income (%)						
<1600 euro	11.9	2.0	8.7	15.3	38.3	<0.001
1600-2200 euro	14.2	5.1	14.5	21.3	23.9	
>2200 euro	73.9	92.9	76.8	63.4	37.8	
Prenatal factors						
Mother's pre-pregnancy BMI (kg/m^2)	23.2 (4.0)	22.6 (2.9)	22.7 (3.4)	23.7 (4.4)	24.4 (5.2)	<0.001
Father's BMI (kg/m^2)	25.2 (3.3)	24.8 (3.0)	24.8 (3.0)	25.5 (3.5)	26.0 (4.1)	<0.001
Maternal smoking during pregnancy (%)						
None	74.4	85.8	80.0	69.5	50.4	<0.001
Until confirmed pregnancy	9.5	8.7	9.8	10.5	8.9	
Continued during pregnancy	16.1	5.5	10.2	20.0	40.8	
Perinatal factors						
Gestational age (weeks)	40.1 (37.0-42.1)	40.3 (37.1-42.1)	40.3 (37.1-42.1)	40.1 (37.0-42.0)	39.9 (36.0-41.9)	<0.001
Birth weight (grams)	3479 (558)	3541 (538)	3510 (572)	3443 (572)	3354 (582)	<0.001
Postnatal factors						
Breastfeeding (% yes)	90.0	95.8	94.3	84.1	76.1	<0.001
Change in BMI SDS between 1-6 months	-0.32 (1.0)	-0.38 (1.0)	-0.34 (1.0)	-0.26 (1.1)	-0.22 (1.0)	0.077
Life style factors at 6 years of age						
Watching television (% ≥2 hours/day)	11.0	5.3	8.8	14.7	24.1	<0.001
Playing sports (% yes)	49.1	57.4	46.8	45.0	39.3	<0.001
Having breakfast daily (% yes)	97.1	98.2	97.4	96.8	93.9	<0.001
Childhood characteristics						
Sex (% girls)	49.6	49.0	49.9	50.7	48.0	0.746
Childhood characteristics at 6 years						
Height (cm)	119.5 (5.7)	119.6 (5.3)	119.0 (5.5)	119.5 (5.8)	120.0 (6.9)	0.030
BMI (kg/m^2)	15.9 (1.5)	15.8 (1.3)	15.8 (1.3)	16.0 (1.6)	16.4 (2.0)	<0.001
Total fat mass (%)	23.9 (4.8)	23.1 (4.2)	23.4 (4.4)	24.6 (5.0)	25.8 (5.7)	<0.001

Values are percentages, means (SD) or medians (90% range) for the total population and by level of maternal education. Data was missing for mother's pre-pregnancy BMI (21.1%), father's BMI (19.0%), smoking during pregnancy (6.1%), gestational age (0.1%), birth weight (0.1%), breastfeeding (14.1%), change in BMI SDS between 1 and 6 months (46.5%), watching television (19.7%), playing sports (15.3%), having breakfast daily (15.2%) and height (17.7%).

[a] P-values are calculated with the Chi-square test for categorical variables and ANOVA for continuous variables.



A. Maternal educational level



B. Net household income

Figure 1. Association between maternal educational level and net household income and longitudinally measured BMI (in SDS). Results are based on linear mixed models and reflect the standard deviation scores of BMI (based on 28027 measurements for educational level and 23459 measurements for net household income) in the first 6 years of life in **A**. Children from mothers with low, mid-low, mid-high and high educational level and in **B**. Children from families with a household income of < 1600 euro, 1600-2200 euro and > 2200 euro. High educational level and a household income of >2200 euro are the reference groups. *P value for educational level*age and for household income*age is <0.0001.

frequently smoked during pregnancy than high educated mothers ($p<0.001$). Their children had lower birth weights and a shorter gestational duration ($p<0.001$).

Linear mixed models with maternal educational level and BMI SDS patterns (Figure 1A) and with household income and BMI SDS patterns (Figure 1B) showed that BMI SDS of children from low educated and low income families is lower than high educated and high income families in the first months of life ($p<0.001$). In all the educational and income subgroups there was a decrease of BMI SDS over time, except for the lowest educational and the lowest income subgroup, where a significant increase in BMI SDS was observed ($p<0.001$). As a result, BMI SDS values of the lowest and highest subgroups cross between the ages of 34-38 months for educational level and around 50-54 months for household income. From then on, an inverse socioeconomic gradient in BMI emerges and widens with increasing age. Regression coefficients for age independent (intercept) and age-dependent differences (interaction educational level/household income 3 age) are given in Supplement Table 2.

Multivariable linear regression analyses showed that both BMI SDS and total fat mass at age 6 are higher for children of lower educated mothers than children of high educated mothers (Tables 2 and 3). The correlation between BMI and total fat mass was moderate ($r=0.58$; $p<0.001$) (Supplement Figure 2). Of all potential mediators, the following were selected in the association between maternal education and BMI SDS at age 6 based on Baron and Kenny's approach: parental BMI, maternal smoking during pregnancy, birth weight, gestational age and having breakfast daily (Supplement Table 1). Hierarchical linear models fitted on BMI and total fat mass are shown in Tables 2 and 3. Parental BMI and smoking during pregnancy contributed most to educational inequalities in BMI (attenuation 54% (95% CI: 298% to 233% in the lowest educational group). All selected mediators together contributed 42% (95% CI: 277% to 221%) to the educational inequalities in BMI SDS (Table 2). For educational inequalities in total fat mass, the following mediators were selected: parental BMI, birth weight, watching television, playing sports and having breakfast daily. Parental BMI and life style factors appeared to contribute most to the educational inequalities in fat mass, and all mediators together explained 25% (95% CI: 236, 217) of these educational inequalities (Table 3). After inclusion of all selected mediators in the model with either BMI and fat mass as outcome, all mediators remained significant (data not shown).

Supplement Tables 3 and 4 show the results from the linear regression analyses using household income as SEP indicator. Smoking during pregnancy explained most of the associations of household income with children's BMI, but after adjustment for all selected mediators the association between household income and BMI remained unexplained. For fat mass the selected mediators contributed 34% (95% CI: 267, 213) to the income inequalities, with smoking during pregnancy and life style factors being the most important contributors.

Table 2. Multiple linear regression analyses for associations between maternal educational level and child's BMI SDS at 6 years of age (n=3010)

		Maternal educational level					
Models[b]	High	Mid-high β (95% CI)	Mid-low β (95% CI)	Attenuation a[a] (95% CI)	Low β (95% CI)	Attenuation b[a] (95% CI)
Model 1	Ref	-0.01 (-0.09,0.07)	0.08 (0.004,0.16)		0.24 (0.15,0.33)	
Model 2	Ref	-0.02 (-0.10,0.05)	0.02 (-0.06,0.09)	-77% (-436,-32)	0.15 (0.05,0.24)	-38% (-69,-23)
Model 3	Ref	-0.03 (-0.10,0.05)	0.003 (-0.07,0.08)	-97% (-511,-41)	0.11 (0.01,0.21)	-54% (-98,-33)
Model 4	Ref	-0.02 (-0.09,0.05)	0.03 (-0.05,0.10)	-65% (-339,-20)	0.15 (0.06,0.24)	-38% (-71,-18)
Fully adjusted model	Ref	-0.02 (-0.09,0.05)	0.03 (-0.05,0.10)	-68% (-354,-22)	0.14 (0.05,0.24)	-42% (-77,-21)

β =effect estimate, CI=confidence interval, BMI=body mass index.

[a] Attenuation a and attenuation b represent the attenuations of effect estimates for mid-low and low education relative to model 1 after additional adjustment for the selected mediators (100 x ($\beta_{model\ 1} - \beta_{model\ with\ mediators}$) / ($\beta_{model\ 1}$)). High maternal educational level is the reference group. No BMI SDS differences were observed for the mid-high educational subgroup as compared to the high educational subgroup, therefore attenuations in effect estimates for mid-high education are not presented.

[b] Model 1: unadjusted.

Model 2 : model 1+ mother's pre-pregnancy BMI and father's BMI.

Model 3: model 2 + maternal smoking during pregnancy.

Model 4: model 3 + birth weight and gestational age.

Fully adjusted: model 4 + having breakfast daily.

Table 3. Multiple linear regression analyses for associations between maternal educational level and child's total fat mass (%) at 6 years of age (n=2934)

		Maternal educational level					
Models[b]	High	Mid-high β (95% CI)	Attenuation a[a] (95% CI)	Mid-low β (95% CI)	Attenuation b[a] (95% CI)	Low β (95% CI)	Attenuation c[a] (95% CI)
Model 1t	Ref	0.49 (0.10,0.89)		1.50 (1.11,1.90)		2.68 (2.19,3.17)	
Model 2	Ref	0.43 (0.04,0.82)	-12% (-45,3)	1.24 (0.85,1.63)	-17% (-26,-11)	2.29 (1.80,2.79)	-14% (-22,-9)
Model 3	Ref	0.43 (0.04,0.82)	-13% (-46,3)	1.23 (0.84, 1.62)	-18% (-27,-11)	2.27 (1.77,2.77)	-15% (-23,-9)
Fully adjusted model	Ref	0.35 (-0.04,0.74)	-29% (-93,-10)	1.11 (0.72,1.50)	-26% (-38,-18)	2.00 (1.50,2.50)	-25% (-36,-17)

β =effect estimate, CI=confidence interval, BMI=body mass index.

[a] Attenuation a, b and c represent the attenuations of effect estimates for mid-low and low education relative to model 1 (includes confounders: age, sex and height) after additional adjustment for the selected mediators (100 x ($\beta_{model\ 1} - \beta_{model\ with\ mediators}$) / ($\beta_{model\ 1}$)). High maternal educational level is the reference group.

[b] Model 1: adjusted for confounders age at measurement, sex and height.

Model 2 : model 1+ mother's pre-pregnancy BMI and father's BMI.

Model 3: model 2 + birth weight.

Fully adjusted: model 3 + life style factors at 6 years of age (watching television, playing sports and having breakfast daily).

Discussion

This study adds to the small body of literature showing the inverse SEP gradient in body composition to emerge in the preschool period around 3-4.5 years of age. At 6 years of age, marked socioeconomic inequalities were observed in both children's BMI and total body fat mass (%). Moreover, the pathway between SEP and body composition depended slightly on SEP indicator and measure of body composition.

Socioeconomic position and body composition

In line with previous research we found less educated mothers to give birth to children with lower birth weights as compared to more educated mothers [5], which may be caused by more frequent smoking among less educated women [27]. This might also explain the lower BMI until the age of 3 years among low SEP children [8]. However, children from low SEP families had a higher rate of weight gain in the first 6 years of life than children from high SEP families, which resulted in the emergence of the inverse SEP gradient around 3-4.5 years of age. This is in line with previous research which also showed the inverse SEP gradient to emerge between 2 and 6 years of age [6,7]. Also, in line with our study, a previous Dutch study found a higher BMI and fat mass among 5/6 year old children of low educated mothers, as well as among children in low income families. They also found that maternal smoking during pregnancy and maternal pre-pregnancy BMI were the most important contributors to these inequalities [28]. Our findings also agree with results from a recent nationwide survey, investigating the prevalence of overweight and obesity in Dutch children (0-21 years), which showed an inverse association between overweight/obesity and parental educational level [29]. Thus, our study adds to the evidence of the emergence and existence of socioeconomic inequalities in body composition in early childhood in the Netherlands. Furthermore, our results suggest that socioeconomic inequalities in BMI are widening with increasing age, which may result in even wider socioeconomic inequalities in adolescence and adulthood.

For both education and income, we found similar longitudinal BMI patterns across different SEP groups during the first 6 years of life. It has been hypothesized that SEP indicators may operate through different pathways to influence the development of adiposity, with education influencing knowledge and beliefs and income influencing access to resources [30]. Our results support this hypothesis; while BMI was an important explanation in the pathway from maternal educational level to body composition, it was not important in the pathway from household income to body composition. This may be due to a lack of variation in paternal BMI as a function of household income (data not shown). Life style factors appeared to play a more important role in the association between SEP and total fat mass as compared to the association between SEP and

BMI. This might be explained by the fact that total fat mass is a more direct and precise measure of adiposity, because it can discriminate between fat mass and lean body mass [31].

The contribution of parental BMI to childhood adiposity has been found in previous literature as well and may act through the inheritance of genes or through a shared family eating and activity environment [32,33]. Smoking during pregnancy was one of the most important and consistent contributors in the associations of both SEP indicators with children's BMI and fat mass. This is in line with previous literature showing smoking during pregnancy to be associated with childhood obesity [20,34,35]. A major issue regarding maternal smoking and offspring obesity is whether the association is causal; confounding by sociodemographic and environmental factors is a leading alternative. Some studies suggest that smoking may influence childhood obesity through its contribution to lower birth weights, which are followed by periods of rapid weight gain in the first months of life [20]. However, this could not be confirmed in our study, since smoking during pregnancy was not associated with change in BMI between 1 and 6 months (data not shown). Alternative pathways leading to obesity may be an influence of prenatal smoking on neural regulation, which may cause increased appetite and reduced physical activity in the offspring [36]. Other studies suggest that smoking during pregnancy is a proxy for an unhealthy lifestyle in the child's postnatal environment, such as unfavorable dietary behaviors and low physical activity levels [37]. So far, the exact underlying mechanisms are still far from clear and need to be investigated in future research [34]. Our results with respect to the protective effects of healthy lifestyles such as playing sports, television watching<2 h day^{-1} and daily breakfast are supported by previous research [7].

Study strengths and limitations

The strengths of this study are the availability of repeated measurements of height and weight in the first 6 years of life which allowed us to investigate BMI development across different socioeconomic groups in a crucial time period, and the measurement of total body fat mass (%) at age 6. The latter is a more sensitive measure to discriminate between fat mass and lean mass as compared to BMI. Several limitations should be considered. Although the initial participation rate in The Generation R Study was relatively high (61%), there was some selection towards a relatively higher educated and healthier study population [38]. As a result, socioeconomic inequalities reported in the study may be an underestimation of socioeconomic inequalities in the total population. Information on many covariates in this study was self-reported, which may have resulted in underreporting of adverse lifestyle-related determinants. If underreporting was more severe in the lower socioeconomic groups, this may have biased our results towards an underestimation of the contribution of these factors to the observed socioeconomic inequalities. Unmeasured factors related to both SEP and body composition, such as sleep patterns and consumption of energy-dense foods, could not be taken into account and may explain some of the remaining effects of SEP on body composition [39,40]. Finally, some assumptions are necessary for our approach of mediation analysis in order to be valid, which include assumptions of causality, absence of mediator-outcome confounding and absence of exposure-mediator interaction [9]. In our study, interactions were tested between exposure and all the mediators and were not statistically significant. Measured confounders have been taken into account in the relation between mediators and outcomes; unmeasured confounders, and particularly unmeasured confounders unrelated to education or income were difficult to imagine, but their existence cannot be excluded.

Conclusion

The inverse association between SEP and childhood BMI emerges during the preschool period, and significant socioeconomic inequalities in body composition are observed in 6-year-old children. A public health strategy aimed at low SEP families should already start during the preconception period and should include the prevention of prenatal smoking and promoting healthy life styles among parents-to be, such as increasing physical activity. Promoting healthy lifestyles prior to conception will not only lower parental BMI, but will also affect their offspring's BMI, since this may result in creating a healthy eating and activity environment for their future children.

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Supplement 1

Body composition

At the age of 6 years, participating children and their mothers were invited to a well-equipped and dedicated research center in the Erasmus Medical Center - Sophia Children's Hospital between March 2008 and January 2012. At the research center, weight was measured in lightweight clothes and without shoes using a mechanical personal scale (SECA) and height was measured in children by a Harpenden stadiometer (Holtain Limited) in standing position, which were both calibrated on a regular basis.

The DXA scans provided quantifications of bone and soft tissue measurements for the total body and sub regions, including bone mineral content (g), fat mass (g), and lean mass (g) (iDXA; General Electric, formerly Lunar Corp., Madison, WI). Children were scanned in a supine position with their feet together in a neutral position and hands flat by their sides. All scans were performed by well-trained and certified research staff who repositioned the regions of interest when appropriate. All DXA scans were obtained using the same device and software (enCORE2010).

Unbalanced repeated measurement regression models

The best fitting model structure was: BMI (in SDS) = $ß_0$ + ß1 * educational level + $ß_2$ * age + $ß_3$ * educational level * age. In this model, the interaction term educational level * age was added with a significance of $p < 0.001$. In this model, age reflects the time of BMI measurement.

Supplement Table 1. Associations between potential mediators and BMI (SDS) and fat mass (%) at 6 years of age

	BMI (SDS)		Fat mass (%)	
	β (95% CI)	P-value	β (95% CI)	P-value
	Maternal educational level			
Prenatal factors				
Mother's pre-pregnancy BMI (kg/m^2)	0.04 (0.03,0.04)	<0.001	0.19 (0.15,0.24)	<0.001
Father's BMI (kg/m^2)	0.04 (0.03,0.06)	<0.001	0.19 (0.13,0.25)	<0.001
Maternal smoking during pregnancy (%)				
None	Ref			
Until confirmed pregnancy	-0.04 (-0.14,0.06)	0.46	0.15 (-0.44,0.74)	0.63
Continued during pregnancy	0.12 (0.03, 0.21)	0.007	0.35 (-0.18,0.89)	0.20
Perinatal factors				
Gestational age (weeks)	0.03 (0.01,0.05)	0.001	0.00 (-0.10,0.10)	0.99
Birth weight (grams)	0.00 (0.00,0.00)	<0.001	0.00 (0.00,0.00)	<0.001
Postnatal factors				
Breastfeeding (0=no, 1=yes)	-0.06 (-0.17,0.06)	0.31	-0.63 (-1.28,0.03)	0.06
Change in BMI SDS between 1-6 months	0.02 (-0.02,0.06)	0.35	0.26 (0.07,0.45)	0.009
Life style factors at 6 years of age				
Watching television (0= <2 hours/day, 1 = ≥2 hours/day)	0.08 (-0.03,0.19)	0.16	0.74 (0.16,1.32)	0.01
Playing sports (0=no, 1=yes)	0.02 (-0.04,0.08)	0.54	-0.37 (-0.72,-0.02)	0.04
Having breakfast daily (0=yes, 1=no)	0.29 (0.11,0.48)	0.002	1.60 (0.41,2.79)	0.009
	Household income			
Prenatal factors				
Mother's pre-pregnancy BMI (kg/m^2)	0.04 (0.03,0.04)	<0.001	0.22 (0.18,0.27)	<0.001
Father's BMI (kg/m^2)	0.05 (0.04,0.06)	<0.001	0.22 (0.16,0.29)	<0.001
Maternal smoking during pregnancy (%)				
None	Ref			
Until confirmed pregnancy	-0.04 (-0.14,0.07)	0.48	0.21 (-0.43,0.85)	0.52
Continued during pregnancy	0.16 (0.07, 0.25)	<0.001	0.86 (0.31,1.42)	0.002
Perinatal factors				
Gestational age (weeks)	0.03 (0.01,0.04)	0.003	-0.04 (-0.14,0.06)	0.45
Birth weight (grams)	0.00 (0.00,0.00)	<0.001	0.00 (0.00,0.00)	<0.001
Postnatal factors				
Breastfeeding (0=no, 1=yes)	-0.10 (-0.21,0.01)	0.08	-1.12 (-1.75,-0.50)	<0.001
Change in BMI SDS between 1-6 months	0.02 (-0.02,0.06)	0.35	0.28 (0.08,0.49)	0.007
Life style factors at 6 years of age				
Watching television (0= <2 hours/day, 1 = ≥2 hours/day)	0.11 (-0.01,0.22)	0.07	1.10 (0.47,1.72)	0.001
Playing sports (0=no, 1=yes)	0.01 (-0.05,0.07)	0.73	-0.49 (-0.84,-0.13)	0.007
Having breakfast daily (0=yes, 1=no)	0.31 (0.12,0.50)	0.001	1.76 (0.42,3.10)	0.012

Table is based on imputed dataset. β =effect estimate, CI=confidence interval, BMI=body mass index. Values are derived from linear regression models and represent effect estimates (95% confidence intervals), adjusted for maternal educational level.

Supplement Table 2. Longitudinal associations between maternal educational level, net household income and child's BMI[a]

	Difference in growth rate of BMI SDS			
Maternal educational level	Intercept	P-value[b]	Slope (SDS (95% CI))	P-value[b]
High	0.2339	<0.001	Reference	
Mid-high	-0.0155	0.653	-0.001 (-0.002,0.0001)	0.071
Mid-low	-0.0416	0.233	0.0004 (-0.001,0.001)	0.453
Low	-0.1380	0.001	0.004 (0.003,0.005)	<0.0001
Net household income				
> 2200 euro	0.2171	<0.001	Reference	
1600-2200 euro	-0.0195	0.647	0.0002 (-0.0009,0.0014)	0.685
<1600 euro	-0.1435	0.002	0.003 (0.001,0.004)	<0.0001

[a] Values are based on linear mixed models (based on 28027 measurements for educational level and 23459 measurements for net household income) and reflect the difference in BMI (in SDS) per educational and household income group and compared to the high and > 2200 euro group, which are the reference groups.
[b] P-value reflects the significance level of the estimate.

Supplement Table 3. Multiple linear regression analyses for associations between net household income and child's BMI SDS at 6 years of age (n=3009)

	Net household income			
Models[b]	>2200 euro	1600-2200 euro β (95% CI)	<1600 euro β (95% CI)	Attenuation a[a] (95% CI)
Model 1	Ref	0.04 (-0.06,0.13)	0.12 (0.02,0.21)	
Model 2	Ref	0.01 (-0.08,0.11)	0.13 (0.03,0.22)	8% (-27,79)
Model 3	Ref	-0.00 (-0.09,0.09)	0.10 (-0.01,0.20)	-16% (-107,39)
Model 4	Ref	0.00 (-0.08,0.09)	0.14 (0.04,0.23)	18% (-20,136)
Fully adjusted model	Ref	0.00 (-0.08,0.09)	0.12 (0.02,0.21)	2% (-50,98)

β =effect estimate, CI=confidence interval, BMI=body mass index.
[a] Attenuation a represents the attenuations of effect estimates for net household income <1600 euro relative to model 1 after additional adjustment for selected mediators (100 x ($\beta_{model\ 1} - \beta_{model\ with\ mediators}$) / ($\beta_{model\ 1}$)). Net household income >2200 euro is the reference group. No BMI SDS differences were observed for the 1600-2200 euro subgroup as compared to the >2200 euro subgroup, therefore attenuations in effect estimates for the 1600-2200 euro subgroup are not presented.
[b] Model 1: unadjusted.
Model 2 : model 1+ mother's pre-pregnancy BMI and father's BMI.
Model 3: model 2 + maternal smoking during pregnancy.
Model 4: model 3 + birth weight and gestational age.
Fully adjusted: model 4 + having breakfast daily.

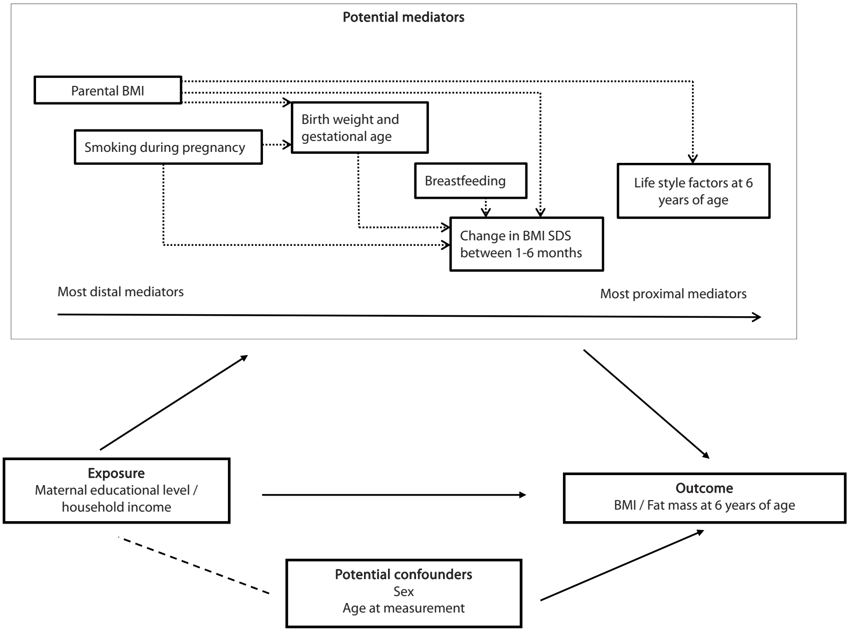
Supplement Table 4. Multiple linear regression analyses for associations between net household income and child's total fat mass (%) at 6 years of age (2928)

	Net household income				
Models[b]	>2200 euro	1600-2200 euro β (95% CI)	Attenuation a[a] (95% CI)	<1600 euro β (95% CI)	Attenuation b[a] (95% CI)
Model 1	Ref	0.74 (0.27,1.22)		1.36 (0.84, 1.89)	
Model 2	Ref	0.62 (0.16,1.09)	-16% (-50,-2)	1.39 (0.86,1.93)	2% (-10,20)
Model 3	Ref	0.50 (0.04,0.96)	-32% (-92,-15)	1.20 (0.64,1.76)	-12% (-32,5)
Model 4	Ref	0.50 (0.04,0.96)	-33% (-97,-15)	1.18 (0.62,1.74)	-14% (-35,4)
Model 5	Ref	0.50 (0.03,0.96)	-43% (-90,-15)	1.13 (0.57,1.70)	-17% (-40,1)
Fully adjusted model	Ref	0.46 (0.00,0.92)	-38% (-109,-19)	0.90 (0.30,1.50)	-34% (-67,-13)

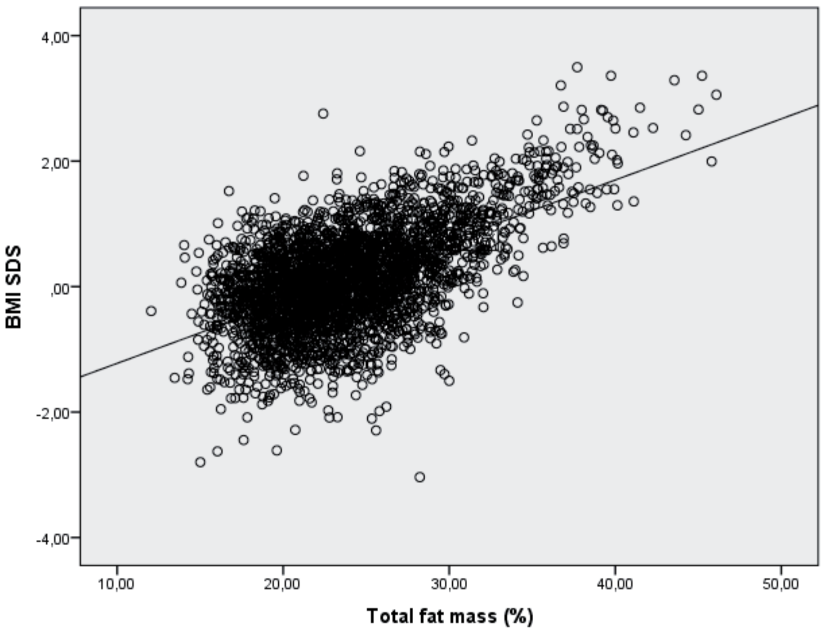
β =effect estimate, CI=confidence interval, BMI=body mass index.

[a] Attenuation a and b represent the attenuations of effect estimates for net household income 1600-2200 euro and <1600 euro relative to model 1 (includes confounders: age, sex and height) after additional adjustment for selected mediators (100 x ($\beta_{\text{model 1}} - \beta_{\text{model with mediators}}$) / ($\beta_{\text{model 1}}$)). Net household income >2200 euro is the reference group.

[b] Model 1: adjusted for confounders age at measurement, sex and height.
Model 2 : model 1+ mother's pre-pregnancy BMI and father's BMI.
Model 3: model 2 + maternal smoking during pregnancy.
Model 4: model 3 + birth weight.
Model 5: model 4 + breastfeeding.
Fully adjusted: model 5 + life style factors at 6 years of age (watching television, playing sports and having breakfast daily.



Supplement Figure 1. Conceptual framework for the association between maternal educational level/ household income and BMI/Fat mass at 6 years of age.



Supplement Figure 2. Correlation between BMI SDS and total fat mass (%).

3

SOCIAL INEQUALITIES IN CHILDREN'S SEDENTARY BEHAVIORS

CHAPTER

3.1

INCREASED RISK OF EXCEEDING ENTERTAINMENT-MEDIA GUIDELINES IN PRESCHOOL CHILDREN FROM LOW SOCIOECONOMIC BACKGROUND: THE GENERATION R STUDY

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Abstract

Objective: To describe and explain the association between maternal educational level and television viewing time among preschool children.

Methods: We analyzed data from 2786 preschoolers enrolled in a birth cohort study in Rotterdam, The Netherlands, between 2002 and 2006. Odds ratios of watching television ≥2 hours/day and ≥1 hour/day were calculated for children of mothers with low, mid-low, and mid-high educational level (reference group: high educational level), before and after adjustment for mediators.

Results: Children of low, mid-low, and mid-high educated mothers were more likely to watch television ≥2 hours/day compared to children of high educated mothers, with children of low educated mothers showing the highest risk (OR: 11.32; 95% CI: 6.58, 19.46). Adjustment for mediators (i.e. maternal body mass index, parental television viewing, presence of a television set in the child's bedroom, and financial difficulties) led to a nearly 50% reduction in odds ratio for the lowest educational group (OR: 6.61; 95% CI: 3.69, 11.84). A similar educational gradient was found for watching television ≥1 hour/day, although effect estimates were smaller.

Conclusion: Maternal education is inversely associated with preschoolers' television viewing time. This association was partly explained by known correlates of children's television viewing.

Introduction

The high prevalence of childhood overweight and concomitant effects on morbidity and mortality constitute a major public health concern [1]. Studies have shown a strong social gradient in childhood overweight, with a higher prevalence of overweight and obesity among children from low socioeconomic strata [2].

There is evidence to suggest that the overweight epidemic among children is (partly) due to increases in levels of children's television viewing [3,4]. Socioeconomic inequalities in television viewing time, which may precede social disparities in overweight, have been observed in school-aged children [5-8] and adolescents [9,10] but less is known about this association in preschoolers [11-14]. Considering the moderate-to-high tracking of television viewing throughout childhood and into adolescence [15,16] it is important to identify high risk groups as early as possible.

Furthermore, the pathways through which low socioeconomic position (SEP) leads to high levels of television viewing are severely understudied [7]. Insight into these underlying mechanisms is crucial for the development of effective interventions designed to reduce the socioeconomic gradient in children's television viewing and ultimately children's health.

The aim of the present study was to examine the association between family SEP and television viewing time in preschool children. This study also investigated whether the association, if present, could be explained by known correlates of children's television viewing.

Methods

Study design

This study was embedded in The Generation R Study, a population-based prospective cohort study from fetal life onwards. The Generation R Study was designed to identify early environmental and genetic determinants of growth, development and health, and has been described previously in detail [17]. The study was conducted in accordance with the guidelines proposed in the World Medical Association Declaration of Helsinki and has been approved by the Medical Ethical Committee at Erasmus MC, University Medical Center Rotterdam. Informed consent was obtained from all participants.

Study population

Invitations to participate in the study were made to all pregnant women with an expected delivery date between April 2002 and January 2006 and who lived in Rotterdam (the Netherlands) at time of delivery. Postnatal consent was given by 7295 mothers.

Because socioeconomic inequalities in television viewing may vary by ethnicity [18], children of Dutch mothers (n=3787) were selected for analyses. Mothers were considered to be Dutch when both of her parents were born in the Netherlands [19]. We excluded participants with missing information on maternal educational level (n=19) and television viewing at age four (n=660). To avoid clustering of data, we furthermore excluded second (n=314) and third children (n=8) of the same mother, leaving a study population of 2786 participants.

Maternal educational level

The highest educational level attained by the mother was assessed by questionnaire at enrollment. The Dutch Standard Classification of Education was used to categorize four levels of education: low (b4 years of high school), mid-low (college), mid-high (Bachelor's degree) and high (Master's degree) [20].

Television viewing time

Two items in a parent-reported questionnaire assessed time spent television viewing when the child was 4 years old: "How many days per week does your child watch TV/ Video/DVD?" (0–7 days)and "How long does your child generally watch TV/Video/DVD per day for?" (b0.5 hour, 0.5–1 hour,1–2 hours,2–3 hours, >3 hours). The middle number of hours of each category (e.g. 1.5 hours for "1-2 hours") was used to estimate the duration of a session. The average television time was estimated by multiplying the number of days by the duration of a session per day, divided by seven [7]. Recommendations of the American Academy of Pediatrics (AAP) state that children's media time should be limited to no more than 1 to 2 hours per day [21]. Recently, Australia and Canada have formulated more stringent guidelines, dictating that children (0–5 years) should spend under one hour per day engaged in screen-based entertainment [22,23]. Therefore, we decided to use a primary outcome variable dichotomized at 2 hours/day and a secondary outcome variable dichotomized at 1 hour/day.

Potential mediators

Variables that were associated with children's television viewing in either one of three systematic reviews were selected as potential mediators for the present study [24-26]. Additionally, we added financial difficulties as a measure of material deprivation in the household. Information on maternal age, single motherhood (single, not single), and maternal body mass index (BMI) (kg/m2) derived from self-reported pre-pregnancy weight and height, was obtained by questionnaire at enrollment. Maternal BMI was recoded into two categories using WHO standards: normal weight (BMI b25), and overweight or obese (BMI ≥25) [27]. Employment status of the mother (no paid job, paid job) was assessed by questionnaire when the child was 2 years. Maternal depression (assessed using the depression subscale of the Brief Symptom Inventory [28]), financial difficulties (yes, no), and presence of a television set in the child's bedroom (yes, no) were assessed by questionnaire when the child was 3 years. Due to a highly skewed distribution, depression was dichotomized in "not depressed" (score of 0) and "depressed" (score >0). Primary caregivers (90 % mothers) were asked to rate their own levels of television viewing in the questionnaire for four-year-olds (very little, not much, neither a lot nor a little, a lot, an awful lot).

Statistical analyses

Descriptive statistics were used to characterize the study population. To handle missing data in the covariates, multiple imputation was applied [29]. Five imputed datasets were generated using a fully conditional specified model, thus taking into account the uncertainty of the imputed values. Pooled estimates from these five imputed datasets were used to report odds ratio's (ORs) and their 95% confidence intervals (CI). Imputations were based on the relationships between all the variables included in this study.

A logistic regression model (basic model) was used to examine the association between maternal educational level and children's television viewing time (reference group: high educational level). The causal step approach proposed by Baron and Kenny [30] was used to assess mediation for each potential mediator separately. First, the association between maternal educational level and the potential mediators was examined using logistic and linear regression models. Next, the association between the potential mediators and children's television viewing time was assessed using logistic regression models, adjusted for maternal educational level. Only those potential mediators that showed significant associations with both maternal educational level and children's television viewing time were considered mediators and selected for the next step. In this step, the mediators were added separately to the basic model. The percentage change in OR after addition of each mediator to the basic model was interpreted as its contribution to the explanation of educational inequalities in children's television viewing time. Percentage change in OR was calculated using the following formula: $(100*[OR_{bm}+mediator-OR_{bm}]/[OR_{bm}-1])$ [31,32]. A full model, in which all mediators were added simultaneously to the basic model, assessed the joint contribution of the mediators. Analyses were conducted with Statistical Package for Social Sciences (SPSS) version 17.0 for Windows (SPSS Inc., Chicago, IL, USA). A significance level of pb0.05 was used to indicate significant associations.

Table 1. Subject characteristics in the total study population and according to level of maternal education in The Generation R Study (Rotterdam, the Netherlands, 2002-2006) (n=2786)[a]

			Level of maternal education				
		Total n=2786	High n=1029 (36.9%)	Mid-high n=808 (29.0%)	Mid-low n=687 (24.7%)	Low n=262 (9.4%)	P-value[b]
Family characteristics							
Age mother (years) ┼		32.1 (4.1)	33.1 (3.2)	32.3 (3.8)	31.0 (4.4)	30.2 (5.3)	<0.001
Single motherhood	single (%)	5.2	3.6	4.4	6.3	10.5	<0.001
Employment status mother	no paid job (%)	14.2	7.9	13.6	19.0	30.4	<0.001
Financial difficulties	yes (%)	12.0	5.4	9.7	19.5	27.9	<0.001
Depression mother	yes (%)	25.8	21.4	25.1	31.3	31.5	<0.001
BMI mother (kg/m^2)	overweight/ obese (%)	21.0	14.5	18.2	28.4	38.5	<0.001
Parental TV viewing time ┼ (1: very little – 5: an awful lot)		2.6 (0.8)	2.5 (0.9)	2.6 (0.8)	2.7 (0.8)	3.0 (0.8)	<0.001
Child characteristics							
Sex	boy (%)	49.9	50.0	49.9	48.2	53.8	0.49
Age (months) ╪		48.2 (47.8-50.2)	48.2 (47.8-49.9)	48.2 (47.8-50.2)	48.2 (47.8-50.2)	48.1 (47.8-51.3)	0.70
TV set in child's bedroom	yes (%)	1.8	0.5	0.9	3.0	6.6	<0.001
TV viewing time	≥ 2 hrs/day (%)	5.6	1.9	3.6	8.6	18.3	<0.001
TV viewing time	≥ 1 hr/day (%)	32.7	22.9	31.1	41.2	54.2	<0.001

Table based on non-imputed dataset. Missings were 0 for age mother, 32 (1.1%) for single motherhood, 423 (15.2%) for employment status mother, 257 (9.2%) for financial difficulties, 239 (8.6%) for depression mother, 627 (22.5%) for BMI mother, 19 (0.7%) for parental TV viewing time, 0 for child's sex, 0 for child's exact age at measurement, and 201 (7.2%) for TV set in child's bedroom.
[a] Values are means (SD) or medians (90% range) for continuous variables, and percentages for categorical variables.
[b] Differences in family and child characteristics for the educational groups were evaluated using one-way analysis of variance (┼) or Kruskal-Wallis test (╪) for continuous variables, and Chi-square test for categorical variables.

Results

In the total study population, 36.9% of mothers were high educated and 9.4% were low educated. Of all children, 5.6% watched television ≥2 hours/day and 32.7% watched television ≥1 hour/day. In comparison to children with high educated mothers, children with low educated mothers more often had a television set in their bedroom and were more likely to exceed entertainment-media guidelines ($p<0.001$) (Table 1).

Compared to children with high educated mothers, those with mid-high, mid-low, and low educated mothers had a significant increased risk of watching television ≥2 hours/day, with the highest risk in the group with the lowest educated mothers (OR: 11.32; 95% CI: 6.58, 19.46) (Table 3).

Of the initial eight potential mediators, four failed Baron and Kenny's criteria of mediation (Tables 2 and 3) [30]. The remaining four mediators, including financial difficulties, maternal BMI, parental television viewing, and presence of a television set in the child's bedroom, were included in subsequent analyses. Separate addition to the basic model attenuated the association between maternal educational level and children's television viewing time for all mediators, with the most marked decreases in OR in the lowest educational group (Table 3). Parental television viewing mediated 24% of the effect of low maternal educational level. Presence of a television set in the child's bedroom contributed least to the explanation of the educational inequalities in children's televi-

Table 2. Associations between potential mediators and children's TV viewing time in The Generation R Study (Rotterdam, the Netherlands, 2002-2006) (n=2786)[a]

		≥ 2 hours per day		≥ 1 hour per day	
		OR (95% CI)	P-value	OR (95% CI)	P-value
Family characteristics					
Age mother (years)		0.97 (0.94,1.01)	0.15	0.98 (0.96,1.00)	<0.05
Single motherhood	not single	1.00 (ref)	0.91	1.00 (ref)	0.37
	single	0.96 (0.49,1.91)		1.18 (0.82,1.68)	
Employment status mother	paid job	1.00 (ref)	0.67	1.00 (ref)	0.23
	no paid job	1.11 (0.70,1.77)		1.15 (0.92,1.45)	
Financial difficulties	no	1.00 (ref)	<0.05	1.00 (ref)	<0.01
	yes	1.68 (1.03,2.75)		1.47 (1.11,1.95)	
Depression mother	no	1.00 (ref)	0.18	1.00 (ref)	<0.05
	yes	1.28 (0.89,1.83)		1.22 (1.00,1.48)	
BMI mother (kg/m^2)	normal weight	1.00 (ref)	<0.05	1.00 (ref)	<0.01
	overweight/ obese	1.67 (1.11,2.52)		1.44 (1.17,1.76)	
Parental TV viewing time (1: very little – 5: an awful lot)		1.83 (1.46,2.29)	<0.001	1.59 (1.43,1.77)	<0.001
Child characteristics					
TV set in child's bedroom	no	1.00 (ref)	<0.01	1.00 (ref)	<0.05
	yes	3.38 (1.65,6.90)		2.34 (1.21,4.51)	

Table based on imputed dataset.
[a] Values are odds ratios (95% confidence intervals), adjusted for maternal educational level.

Table 3. Change in odds ratios for children's TV viewing time ≥ 2 hours per day for levels of maternal education after individual and full adjustment for mediators in The Generation R Study (Rotterdam, the Netherlands, 2002-2006) (n=2786)

Level of maternal education	High (ref) OR	Mid-high OR (95% CI)	Change 1[b] (%)	Mid-low OR (95% CI)	Change 2[b] (%)	Low OR (95% CI)	Change 3[b] (%)
Basic model (includes maternal education)	1.00	1.88 (1.05,3.35)		4.74 (2.83,7.95)		11.32 (6.58,19.46)	
Basic model + financial difficulties	1.00	1.83 (1.03,3.26)	-6	4.35 (2.57,7.36)	-10	10.03 (6.29,16.00)	-13
Basic model + BMI mother	1.00	1.85 (1.04,3.29)	-3	4.38 (2.60,7.38)	-10	9.99 (5.75,17.37)	-13
Basic model + parental TV viewing time	1.00	1.80 (1.01,3.21)	-9	4.33 (2.58,7.28)	-11	8.86 (5.11,15.36)	-24
Basic model + TV set in child's bedroom	1.00	1.86 (1.04,3.32)	-2	4.51 (2.68,7.59)	-6	10.30 (5.95,17.83)	-10
Full model[a]	1.00	1.75 (0.98,3.12)	-15	3.63 (2.13,6.19)	-30	6.61 (3.69,11.84)	-46

Table based on imputed dataset.

[a] Full model= Basic model + all mediators.

[b] Changes 1-3 represent the change in odds ratio relative to the basic model for mid-high, mid-low and low maternal educational level respectively after individual adjustment for mediators (100 * $[OR_{bm + mediator} - OR_{bm}]/[OR_{bm} - 1]$). In case of the full model, changes 1-3 represent the change in odds ratio relative to the basic model for maternal educational levels after full adjustment (100 * $[OR_{bm + all\ mediators} - OR_{bm}]/[OR_{bm} - 1]$).

sion viewing time (10% in the lowest educational group). Full adjustment resulted in an OR reduction of 15% for children with mid-high educated mothers, 30% for children with mid-low educated mothers, and 46% for children with low educated mothers. Fully adjusted ORs remained significant for children of low and mid-low educated mothers ($p<0.001$), indicating that the mediators considered in the present study only partly explained the effect of low maternal educational level on children's television viewing time (Table 3). When stratifying the analyses for boys and girls, results were comparable. Therefore, we do not show stratified analyses.

The results of the analyses for the secondary outcome variable (1 hour/day) were very similar, although effect estimates were smaller. Again, children of low educated mothers displayed the highest risk of exceeding screen recommendations (OR: 3.98; 95% CI: 3.00, 5.28). In addition, maternal age and maternal depression also acted as mediators (Tables 2 and 4).

Table 4. Change in odds ratios for children's TV viewing time ≥ 1 hour per day for levels of maternal education after individual and full adjustment for mediators in The Generation R Study (Rotterdam, the Netherlands, 2002-2006) (n=2786)

Level of maternal education	High (ref) OR	Mid-high OR (95% CI)	Change 1[b] (%)	Mid-low OR (95% CI)	Change 2[b] (%)	Low OR (95% CI)	Change 3[b] (%)
Basic model (includes maternal education)	1.00	1.51 (1.23,1.87)		2.35 (1.91,2.91)		3.98 (3.00,5.28)	
Basic model + age mother	1.00	1.49 (1.21,1.83)	-4	2.25 (1.81,2.79)	-7	3.74 (2.80,4.99)	-8
Basic model + financial difficulties	1.00	1.49 (1.21,1.83)	-4	2.23 (1.80,2.76)	-9	3.67 (2.75,4.91)	-10
Basic model + depression mother	1.00	1.50 (1.22,1.85)	-2	2.31 (1.87,2.85)	-3	3.91 (2.94,5.19)	-2
Basic model + BMI mother	1.00	1.50 (1.22,1.85)	-2	2.24 (1.81,2.77)	-8	3.67 (2.75,4.89)	-10
Basic model + parental TV viewing time	1.00	1.47 (1.19,1.81)	-8	2.20 (1.78,2.72)	-11	3.29 (2.46,4.40)	-23
Basic model + TV set in child's bedroom	1.00	1.51 (1.23,1.86)	0	2.30 (1.86,2.85)	-4	3.80 (2.85,5.06)	-6
Full model[a]	1.00	1.40 (1.13,1.74)	-22	1.86 (1.49,2.33)	-36	2.58 (1.90,3.51)	-47

Table based on imputed dataset.
[a] Full model= Basic model + all mediators.
[b] Changes 1-3 represent the change in odds ratio relative to the basic model for mid-high, mid-low and low maternal educational level respectively after individual adjustment for mediators (100 * [$OR_{bm+ mediator}$– OR_{bm}]/[OR_{bm}- 1]). In case of the full model, changes 1-3 represent the change in odds ratio relative to the basic model for maternal educational levels after full adjustment (100 * [$OR_{bm + all mediators}$– OR_{bm}]/[OR_{bm} - 1]).

Discussion

This study showed that preschool children of low educated mothers had an eleven-fold increased risk of exceeding entertainment-media guidelines proposed by the AAP (<2 hours/day). The effect of low maternal educational level was partly explained by financial difficulties, maternal BMI, parental television viewing, and the presence of a television set in the child's bedroom.

The strong inverse educational gradient in preschoolers' television viewing time found in this study confirms results from studies in both preschool children [11,12,14] and older children [5,7,8]. In contrast, these findings challenge a study among Greek preschoolers (3–5 years) that did not find an effect of maternal educational level on children's television viewing time [13].

The observation that the presence of a television set in the child's bedroom mediated the effect of low educational level on preschooler's television viewing time is in line with a previous study that also found a significant mediating effect for this variable [7]. Furthermore, the mediating effect of parental television viewing is supported by separate studies that reported a negative association between educational attainment and television viewing in adults [33] and a positive association between parental television viewing and children's television viewing [24,26]. Similarly, the results regarding maternal BMI are in line with studies that found women's BMI to be associated with both educational attainment [34] and children's television viewing [26]. One explanation may be that BMI reflects overall lifestyle behaviors of the mother, including physical activity, dietary behaviors, and sedentary behaviors. Thus, this variable may share some of its explanatory pathway with the variable parental television viewing. An alternative explanation could be that overweight and obese mothers may be less inclined to participate in activities that require physical effort and more likely to engage in sedentary activities, such as television viewing, with their children. The finding that financial difficulties had a mediating effect is suggestive of a pathway involving household financial resources. Indeed, previous research has shown that household income is associated with children's television viewing [23]. Further investigation in this area is warranted.

As the association between maternal educational level and preschoolers' television viewing time was not completely eliminated after full adjustment for the mediators used in the present study, we conclude that we have not captured the full range of intermediate variables that are potentially involved in the underlying pathway. Other correlates of children's television viewing that were not available for the current study, e.g. parental rules and perceived neighborhood safety [23], may further mediate the association.

It should be noted that the reviews used to select potential mediators for the present study show inconsistent results. For example, a television set in the child's bedroom shows a positive association with television viewing in the review by Gorely et al. [24], but an unclear association in the review by Hoyos Cillero and Jago [23]. In addition, the review by Hinkley et al. [15] shows that there is still a paucity of literature on correlates of sedentary behaviors in preschool children specifically, and underscores the need for further investigation in this area. The present study adds to the limited research in this age group by demonstrating a strong association between maternal educational level and preschool children's television viewing time.

In this study, we found a stronger educational gradient for television viewing time ≥2 hours/day compared to ≥1 hour/day. This finding indicates that maternal educational level is a stronger predictor of more excessive forms of television viewing. The observation of a smaller number of mediators for television viewing time ≥2 hours/day than ≥1 hour/day may suggest that these behaviors have different correlates. However, based on the similarity in effect estimates for the associations between potential mediators and television viewing time, we hypothesize that this finding is more likely to be a result of insufficient power to detect (significant) associations due to the smaller number of children exceeding the AAP guideline compared to the alternative guideline.

Study strengths and limitations

The main strengths of this study include the size and the diversity of the study population. Furthermore, potential mediators were carefully selected on the basis of existing literature. Several limitations of this study should be considered. Information on children's television time was derived from two items in a parent-reported questionnaire. Other forms of assessment (e.g. diaries and direct observations) are generally considered to be superior to a few items in a questionnaire [35]. Furthermore, as we only captured total weekly television time we were unable to differentiate between weekday television viewing and weekend day television viewing. Stratifying the analyses for weekdays and weekend days may have presented different results. Maternal educational level was used as single indicator of family SEP as this variable has shown to be consistently inversely associated with children's television viewing[24,26]. Nonetheless, analyses were repeated with household income as indicator of SEP. Similar results were found, although effect estimates for income groups were smaller than those observed for maternal educational groups (data not shown). Also, the observational nature of this study does not allow firm conclusions with regard to causality. Finally, our study was conducted in children of Dutch mothers, which limits the generalizability of the results to other study populations.

Conclusion

In light of the many adverse short term [4,21] and long term health effects [36,37] associated with children's television viewing, the present findings indicate a strong need for preventive measures at a young age and provide information on intermediary factors that may be targeted in prevention programs aimed to reduce educational disparities in television viewing. More specifically, raising awareness among low educated parents of the harmful effects of placing television sets in children's bedrooms and of the effects of their own lifestyle behaviors, television viewing in particular, may be a fruitful approach to reduce the educational gradient in television viewing time among preschool children. Further research into additional mechanisms that underlie the association of family SEP with children's television time is warranted.

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CHAPTER

3.2

ETHNIC BACKGROUND AND TELEVISION VIEWING TIME AMONG 4-YEAR-OLD PRESCHOOL CHILDREN: THE GENERATION R STUDY

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Abstract

Objective: Children's television viewing has been associated with an increased risk of overweight and obesity. This study aims to assess the associations of ethnic background and acculturation characteristics with television viewing time in 4-year-old preschool children.

Methods: The authors analyzed data from 3452 preschool children and their parents enrolled in the Generation R Study, a large, multiethnic, prospective birth cohort study in Rotterdam, the Netherlands. Multivariable logistic regression models were used to estimate odds ratios of watching television ≥2 hours/day and ≥1 hour/day for Turkish, Moroccan, and Surinamese children (reference group: native Dutch children), adjusted for family socioeconomic position. Effect modification by family socioeconomic position was also assessed.

Results: After adjustment for family socioeconomic position, Turkish children (adjusted odds ratio [aOR], 2.27; 95% confidence interval [CI], 1.56–3.30), Moroccan children (aOR, 1.68; 95% CI, 1.03–2.76), and Surinamese children (aOR, 3.12; 95% CI, 2.16–4.50) were significantly more likely to watch television ≥2 hours/day compared with native Dutch children. Stratified analyses showed greater disparity between ethnic minority groups and native Dutch children at higher educational levels. There were no significant associations between acculturation characteristics (i.e., generational status, age at immigration, and Dutch language skills) and children's television viewing time.

Conclusion: Children from ethnic minority groups are at an increased risk for high levels of television viewing compared with native Dutch children, independent of family socioeconomic position. Interventions aimed to reduce television viewing time should target all children from ethnic minority groups.

Introduction

Over the past decades, the prevalence of childhood overweight and obesity has reached epidemic proportions. One of the hypothesized contributors to the high prevalence of childhood overweight is children's television viewing. Multiple cross-sectional and longitudinal studies among children have demonstrated a positive association between television viewing and the risk of overweight and obesity [1]. In addition, studies on the long-term effects of television viewing found that television viewing in childhood is a significant predictor of adult body mass index [2,3]. Television viewing may affect the development of overweight in different ways [4]: by decreasing resting metabolic rate during television viewing, by reducing total energy expenditure through displacement of physical activity, or by increasing dietary intake during television viewing or outside viewing hours as a result of exposure to food advertising.

In the Netherlands, regular nationwide growth studies have shown that overweight and obesity prevalences have increased dramatically since 1980 [5]. In addition, the prevalence of overweight and obesity is much higher among ethnic minority groups compared with native Dutch children, in particular among Turkish and Moroccan children [6]. Studies have shown that school-aged children and adolescents from ethnic minority groups spend more time watching television than their native counterparts [7,8]. However, information on the amount of television viewing among specific ethnic groups in the Netherlands is still scarce.

Furthermore, it is not well known to what extent socioeconomic differences explain ethnic differences in television viewing. Children's television viewing has been shown to vary according to socioeconomic position [7,8], and ethnic background and socioeconomic position are strongly related. Level of acculturation of immigrant children and their parents may also be associated with children's television viewing. For instance, a study among immigrant children and adolescents in the United States showed that increased acculturation was associated with an increased risk of excessive television viewing [9].

From a public health perspective, the preschool years constitute a critical period as obesogenic behaviors such as television viewing seem to be established by or during the preschool period [10]. However, little is known about the association between ethnic background and television viewing time in preschoolers [11]. Therefore, the first aim of this study is to describe the associations of ethnic background and acculturation characteristics with television viewing time in preschool children (aged 4 years). The second aim is to assess to what extent the association between ethnic background and television viewing time can be explained by differences in family socioeconomic position. This study uses data from the Generation R Study, a large, multiethnic, prospective birth cohort study in Rotterdam, the Netherlands.

Methods

Study design

This study was embedded in the Generation R Study, a population-based prospective cohort study from fetal life onward. The Generation R Study was designed to identify early environmental and genetic determinants of growth, development, and health and has been described previously in detail [12]. Assessments in pregnancy were planned in early pregnancy, mid-pregnancy, and late pregnancy and included physical examinations, questionnaires, fetal ultrasound examinations, pregnancy complications and outcomes, and biological samples. Data collection for the children included a home visit at the age of 3 months, questionnaires at the ages of 2, 6, 12, 18, 24, 30, 36, and 48 months, and visits to routine child health centers at the ages 2, 3, 4, 6, 11, 14, 18, 24, 36, and 45 months. The study was conducted in accordance with the guidelines proposed in the World Medical Association's Declaration of Helsinki and has been approved by the Medical Ethical Committee at Erasmus Medical Center, University Medical Center Rotterdam. Written informed consent was obtained from all participants.

Study population

Invitations to participate in the study were made to all pregnant women who had an expected delivery date between April 2002 and January 2006 and who lived in the study area (Rotterdam, the Netherlands) at time of delivery. In total, 9778 mothers were enrolled in the study. These mothers gave birth to 9745 known live born children. Following birth, mothers of 7295 children gave consent for postnatal follow-up [12]. For the purpose of this study, we selected children born to mothers with a native Dutch, Turkish, Moroccan, and Surinamese ethnic background (n = 5168). These ethnic groups were chosen because they represent the largest ethnic groups in the Generation R Study as well as in the city of Rotterdam [12]. We excluded participants with missing information on television viewing at age 4 years (n = 1361). To avoid clustering of data, we additionally excluded second (n = 347) and third (n = 8) children of the same mother. The final population for analyses consisted of 3452 subjects: 2800 native Dutch children, 272 Turkish children, 145 Moroccan children, and 235 Surinamese children. About half of the participants were boys (50.5%).

Ethnic background

Children were classified according to the ethnic background of their mothers to take into account the cultural background of the mothers (most often primary caregivers). Maternal ethnic background was based on country of birth of the mother's parents and was assessed by questionnaire at enrollment. In accordance with Statistics Netherlands, a mother was considered nonnative Dutch if one of her parents was born abroad [13].

If both parents were born abroad, country of birth of the mother's mother decided on maternal ethnic background.

Acculturation characteristics

Acculturation characteristics of the mother were assessed by questionnaire at enrollment. Generational status of nonnative Dutch mothers was based on their own country of birth. Foreign-born mothers were classified as "first generation," and mothers born in the Netherlands (with at least one foreign-born parent) were classified as "second generation." First-generation mothers were further categorized according to their age at immigration (0–15 vs ≥16 years). Mothers in the first category were obliged to attend school in the Netherlands, whereas school was not mandatory for mothers who were aged 16 years and older during immigration. Mothers were also asked to rate their Dutch speaking, reading, and writing skills on 3 separate 5-point scales ranging from "not at all" (1) to "very good" (5). These scales were summed to create a new variable indicating general Dutch language skills: "not good" (3–9), "reasonable" (10–14), and "good" (15).

Television viewing time

Two items in a parent-reported questionnaire assessed time spent watching television when the child was 4 years old: "How many days per week does your child watch TV/Video/DVD?" (0–7 d) and "How long does your child generally watch TV/Video/DVD per day?" (<0.5, 0.5–1, 1–2, 2–3, and >3 hours). We took the middle number of hours per category (e.g., 1.5 hours for "1–2 hours") to estimate the duration of a session per day. We estimated the average television viewing time per day by multiplying the number of days by the duration of a session per day, divided by 7 [14]. Recommendations of the American Academy of Pediatrics regarding children's exposure to entertainment- media state that children's media time should be limited to 1 to 2 hours/day [15]. Therefore, we dichotomized television viewing time in ≥2 and <2 hours/day [14]. Based on more recent Australian and Canadian recommendations, which state that children should not spend >1 hour/day engaged in screen-based entertainment [16,17], a second outcome measure of television viewing time (i.e., ≥1 vs <1 hour/day) was created.

Potential confounders

Child's sex and age, and family socioeconomic position were considered potential confounders in the association between ethnic background and children's television viewing time. Socioeconomic position was captured by different indicators, including maternal educational level, maternal employment status, and household income. The highest educational level attained by the mother was assessed by questionnaire at enrollment. The Dutch Standard Classification of Education was used to categorize 3 levels of education: low (no education, primary school, lower vocational training, intermediate general school, or <4 years general secondary school), middle (4 years or more general secondary school or intermediate vocational training), and high (higher vocational training, university, or PhD degree) [18]. Information on maternal employment status was collected by questionnaire when the child was aged 2 years (no paid job, paid job). Net income of the household was assessed by questionnaire when the child was 3 years old and categorized into 3 groups: low (<€2000/ month; i.e., below modal income [19]), middle (€2000–3200/month), and high (>€3200/month).

Statistical analyses

The associations between ethnic background and several child and family characteristics were studied using χ^2 tests or Fisher's exact tests for categorical variables, and Kruskal-Wallis tests for non-normally distributed continuous variables. Series of logistic regression models were used to assess the (independent) association between ethnic background and children's television viewing time. In the univariate model, ethnic background was included as single independent variable using native Dutch children as the reference group. In the multivariable model, we additionally adjusted for confounders. Only those potential confounders that led to a substantial change in effect estimates (i.e., ≥10% change) were included in this model [20]. Effect modification by socioeconomic position was examined by adding interaction terms between ethnic background and each indicator of socioeconomic position to the multivariable model. In case of significant interaction terms, stratified analyses were performed. The associations between acculturation characteristics and children's television viewing time were examined by χ^2 tests within each ethnic group except for the native Dutch group. To handle missing data in the potential confounders, multiple imputation was applied [21]. Five imputed data sets were generated using a fully conditional specified model, thus taking into account the uncertainty of the imputed values. Pooled estimates from these 5 imputed data sets were used to report odds ratios (ORs) and their 95% confidence intervals (CIs). All analyses were conducted in 2012 with Statistical Package for Social Sciences (SPSS) version 20.0 for Windows (SPSS, Inc, Chicago, IL). A significance level of $p < .05$ was used to indicate significant associations.

Nonresponse analyses

Children with missing data on television viewing at age 4 years (n = 1361) were compared with children who did not have missing data on television viewing (n = 3807). Data on television viewing were more often missing for children from ethnic minority groups ($\chi^2 = 595$, df = 3, $p < .001$), children with low-educated mothers ($\chi^2 = 518$, df = 2, $p < .001$), children with mothers without a paid job ($\chi^2 = 73$, df = 1, $p < .001$), and children from low-income households ($\chi^2 = 95$, df = 2, $p < .001$).

Results

Characteristics of the study population

Socio-demographic characteristics and television viewing time of the participants are presented in Table 1. Nearly 20% of participants were children from ethnic minority groups. Indicators of family socioeconomic position varied with ethnic background (all *ps* < .001). A high maternal educational level was most prevalent in the native Dutch

Table 1. Characteristics of the total study population and according to ethnic background (n=3452)*

			Ethnic background				
		Total (n=3452)	Dutch (n=2800) (81.1%)	Turkish (n=272) (7.9%)	Moroccan (n=145) (4.2%)	Surinamese (n=235) (6.8%)	P-value**
Family characteristics							
Maternal educational level (n,%)	low	523 (15.3)	262 (9.4)	135 (51.5)	62 (47.3)	64 (27.7)	<0.001
	middle	940 (27.6)	687 (24.7)	94 (35.9)	48 (36.6)	111 (48.1)	
	high	1947 (57.1)	1837 (65.9)	33 (12.6)	21 (16.0)	56 (24.2)	
Maternal employment status (n,%)	no paid job	486 (17.6)	336 (14.1)	84 (54.2)	31 (39.7)	35 (23.0)	<0.001
	paid job	2275 (82.4)	2040 (85.9)	71 (45.8)	47 (60.3)	117 (77.0)	
Household income (n,%)	<2000	590 (20.0)	306 (12.4)	130 (64.4)	73 (70.9)	81 (46.0)	<0.001
	2000-3200	872 (29.6)	742 (30.1)	55 (27.2)	21 (20.4)	54 (30.7)	
	>3200	1486 (50.4)	1419 (57.5)	17 (8.4)	9 (8.7)	41 (23.3)	
Child characteristics							
Sex (n,%)	boy	1743 (50.5)	1401 (50.0)	147 (54.0)	71 (49.0)	124 (52.8)	0.53
	girl	1709 (49.5)	1399 (50.0)	125 (46.0)	74 (51.0)	111 (47.2)	
Age (months)		48.2 (47.8-50.6)	48.2 (47.8-50.2)	48.4 (47.8-52.8)	48.5 (47.8-51.7)	48.4 (47.8-51.2)	<0.001
TV viewing time (n,%)	≥ 2 hours/day	306 (8.9)	159 (5.7)	63 (23.2)	26 (17.9)	58 (24.7)	<0.001
	< 2 hours/day	3146 (91.1)	2641 (94.3)	209 (76.8)	119 (82.1)	177 (75.3)	
	≥ 1 hour/day	1281 (37.1)	919 (32.8)	148 (54.4)	82 (56.6)	132 (56.2)	<0.001
	< 1 hour/day	2171 (62.9)	1881 (67.2)	124 (45.6)	63 (43.4)	103 (43.8)	
	> 0 hours/day	3378 (97.9)	2742 (97.9)	265 (97.4)	141 (97.2)	230 (97.9)	0.79
	0 hours/day	74 (2.1)	58 (2.1)	7 (2.6)	4 (2.8)	5 (2.1)	
TV set in child's bedroom (n,%)	yes	105 (3.4)	46 (1.8)	26 (12.0)	16 (14.5)	17 (9.1)	<0.001
	no	3005 (96.6)	2552 (98.2)	190 (88.0)	94 (85.5)	169 (90.9)	

Table is based on non-imputed dataset. Missings were 42 (1.2%) for maternal educational level, 691 (20.0%) for maternal employment status, 504 (14.6%) for household income, 0 for child's sex, 0 for child's age, and 342 (9.9%) for television set in child's bedroom.

* Values are medians (90% range) for continuous variables, and frequencies (percentage) for categorical variables.

** Differences in family and child characteristics for the ethnic groups were evaluated using Kruskal-Wallis test for continuous variables, and Chi-squared test or Fisher's exact test for categorical variables.

Table 2. Association between ethnic background and television viewing time (≥ 2 hours per day) in the total study population and according to maternal educational level (n=3452)

Total study population	Ethnic background	Univariate model OR (95% CI)	Multivariable model* OR (95% CI)
	Dutch (Ref)	1.00	1.00
	Turkish	**5.01 (3.62,6.92)**	**2.27 (1.56,3.30)**
	Moroccan	**3.63 (2.31,5.71)**	**1.68 (1.03,2.76)**
	Surinamese	**5.44 (3.89,7.62)**	**3.12 (2.16,4.50)**
Maternal educational level	**Ethnic background**	**Univariate model OR (95% CI)**	**Multivariable model** OR (95% CI)**
High	Dutch (Ref)	1.00	1.00
	Turkish	**10.20 (4.24,24.58)**	**6.23 (2.45,15.85)**
	Moroccan	**7.28 (2.39,22.17)**	**4.98 (1.58,15.72)**
	Surinamese	**7.72 (3.69,16.17)**	**6.41 (2.96,13.86)**
Middle	Dutch (Ref)	1.00	1.00
	Turkish	**3.10 (1.78,5.38)**	**2.83 (1.59,5.02)**
	Moroccan	1.89 (0.84,4.25)	1.71 (0.75,3.93)
	Surinamese	**3.55 (2.15,5.88)**	**3.33 (1.98,5.61)**
Low	Dutch (Ref)	1.00	1.00
	Turkish	1.36 (0.82,2.24)	1.32 (0.77,2.25)
	Moroccan	1.12 (0.57,2.21)	1.09 (0.53,2.22)
	Surinamese	**1.86 (1.01,3.42)**	1.81 (0.95,3.45)

Table is based on imputed dataset. Bold print indicates statistical significance ($p<0.05$).
* Adjusted for maternal educational level and household income.
** Adjusted for household income.

subgroup (65.9%), a middle maternal educational level was most prevalent for Surinamese children (48.1%), and a low maternal educational level was most prevalent for Turkish (51.5%) and Moroccan children (47.3%). Children from all ethnic minority groups were more likely to exceed both guidelines on screen-based entertainment compared with native Dutch children ($p < .001$).

Association between ethnic background and children's television viewing time

In the total study population, ethnic background was significantly associated with television viewing time ($p <.001$) (Table 2). After adjustment for maternal educational level and household income, Turkish children (adjusted odds ratio [aOR], 2.27; 95% CI, 1.56–3.30), Moroccan children (aOR, 1.68; 95% CI, 1.03–2.76), and Surinamese children (aOR, 3.12; 95% CI, 2.16–4.50) were significantly more likely to watch television ≥2 hours/day compared with native Dutch children (Table 2). Child's sex and age, as well as maternal employment status, did not considerably influence the effect estimates (≤5% change) and were left out of the model.

Table 3. Association between ethnic background and television viewing time (≥ 1 hour per day) in the total study population and according to maternal educational level (n=3452)

Total study population	Ethnic background	Univariate model OR (95% CI)	Multivariable model* OR (95% CI)
	Dutch (Ref)	1.00	1.00
	Turkish	**2.44 (1.90,3.14)**	**1.54 (1.16,2.03)**
	Moroccan	**2.66 (1.90,3.73)**	**1.72 (1.20,2.47)**
	Surinamese	**2.62 (2.00,3.43)**	**1.88 (1.41,2.50)**
Maternal educational level	**Ethnic background**	**Univariate model OR (95% CI)**	**Multivariable model** OR (95% CI)**
High	Dutch (Ref)	1.00	1.00
	Turkish	**3.65 (1.85,7.21)**	**3.01 (1.50,6.03)**
	Moroccan	**5.71 (2.25,14.46)**	**4.97 (1.92,12.84)**
	Surinamese	**3.94 (2.29,6.78)**	**3.70 (2.13,6.42)**
Middle	Dutch (Ref)	1.00	1.00
	Turkish	**2.04 (1.32,3.16)**	**1.82 (1.16,2.85)**
	Moroccan	1.62 (0.91,2.86)	1.44 (0.80,2.59)
	Surinamese	**1.86 (1.24,2.79)**	**1.69 (1.12,2.55)**
Low	Dutch (Ref)	1.00	1.00
	Turkish	0.86 (0.57,1.29)	0.86 (0.55,1.35)
	Moroccan	1.04 (0.60,1.78)	1.04 (0.57,1.88)
	Surinamese	0.95 (0.55,1.63)	0.95 (0.53,1.69)

Table is based on imputed dataset. Bold print indicates statistical significance (p<0.05).
* Adjusted for maternal educational level and household income.
** Adjusted for household income.

There was significant effect modification by maternal educational level ($p < .05$). Stratified analyses showed that ethnic disparities increased with increasing maternal educational level (Table 2). Among children from low-educated mothers, Surinamese children only were significantly more likely to watch television ≥2 hours/day compared with native Dutch children (OR, 1.86; 95% CI, 1.01–3.42). Among children with middle-educated mothers, both Turkish children (OR, 3.10; 95% CI, 1.78–5.38) and Surinamese children (OR, 3.55; 95% CI, 2.15–5.88) were significantly more likely to watch television ≥2 hours/day compared with native Dutch children. In the subgroup of children with high-educated mothers, Turkish children (OR, 10.20; 95% CI, 4.24–24.58), Moroccan children (OR, 7.28; 95% CI, 2.39–22.17), and Surinamese children (OR, 7.72; 95% CI, 3.69 16.17) were significantly more likely to watch television ≥2 hours/day compared with native Dutch children (Table 2). Analyses using the second outcome measure (i.e., television viewing time ≥1 hour/day) showed similar results but yielded smaller effect estimates (Table 3).

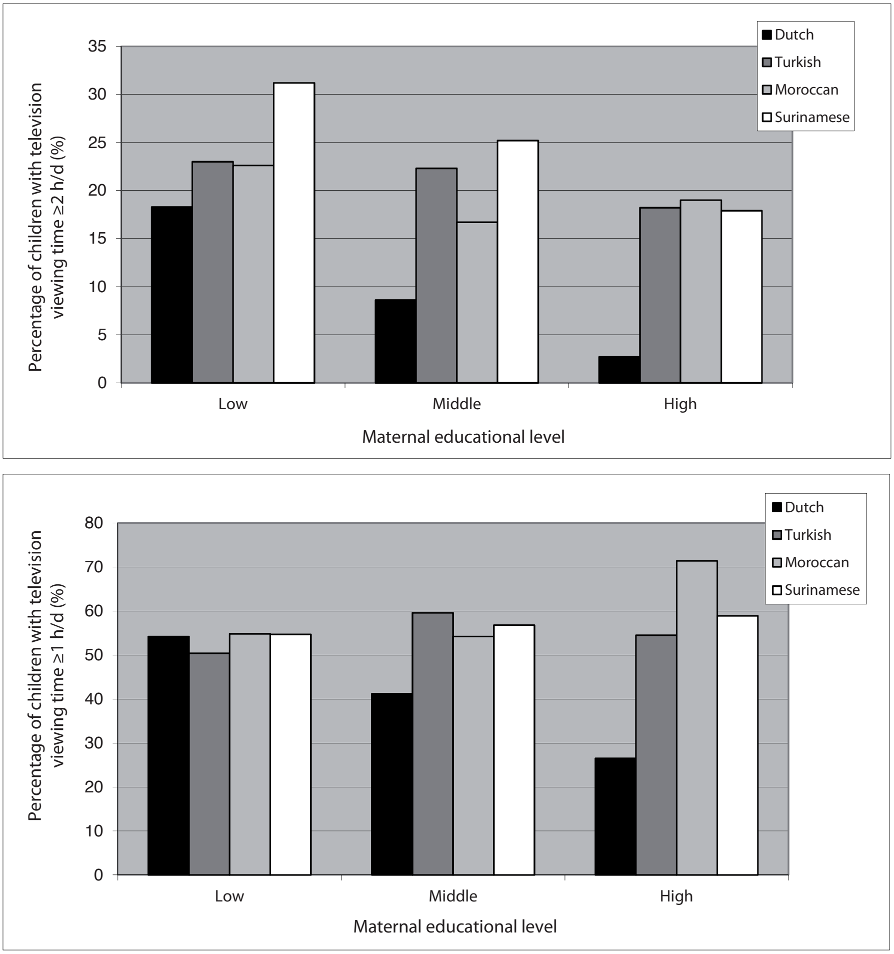

Figure 1. Association between ethnic background and television viewing time (**A**, ≥2 hr/d and **B**, ≥1hr/d) by maternal educational level, based on complete dataset (n = 3410).

Figure 1 shows the percentage of children exceeding both entertainment-media guidelines for the 4 ethnic groups for 3 levels of maternal education. This figure indicates that the native Dutch comparison group demonstrated a steep decline in television viewing time with increasing maternal educational level. However, this pattern was less clear in the ethnic minority groups, Turkish and Moroccan children in particular.

Table 4. Association between maternal immigration characteristics and television viewing time (≥ 2 hour/day) (n=3452)*

	Turkish		Moroccan		Surinamese	
	≥ 2 hrs/day	< 2 hrs/day	≥ 2 hrs/day	< 2 hrs/day	≥ 2 hrs/day	< 2 hrs/day
Generational status						
First generation (n,%)	47 (24.1)	148 (75.9)	24 (20.0)	96 (80.0)	42 (25.9)	120 (74.1)
Second generation (n,%)	16 (21.1)	60 (78.9)	2 (8.3)	22 (91.7)	16 (22.2)	56 (77.8)
*Age at immigration***						
0-15 years (n,%)	12 (20.3)	47 (79.7)	9 (19.6)	37 (80.4)	26 (27.4)	69 (72.6)
≥ 16 years (n,%)	27 (26.2)	76 (73.8)	11 (20.8)	42 (79.2)	11 (23.9)	35 (76.1)
Dutch language skills						
Good (n,%)	16 (23.9)	51 (76.1)	7 (13.5)	45 (86.5)	44 (27.7)	115 (72.3)
Reasonable (n,%)	12 (14.8)	69 (85.2)	8 (26.7)	22 (73.3)	6 (16.7)	30 (83.3)
Not good (n,%)	23 (28.4)	58 (71.6)	8 (21.6)	29 (78.4)	0 (0.0)	1 (100.0)

Table is based on non-imputed dataset. Associations between television viewing time (≥ 2 hour/day) and immigration characteristics were evaluated using Chi-square test or Fisher's exact test. No significant associations were observed.
* Values are frequencies (percentage).
** Only for first generation immigrants.

Chapter 3.2

Association between acculturation characteristics and children's television viewing time

Table 4 shows the associations between acculturation characteristics of nonnative Dutch mothers and children's television viewing time ≥2 hours/day. There were no significant associations of generational status, age at immigration, and Dutch language skills with television viewing time ≥2 hours/day.

Discussion

This study showed that preschool children from Turkish, Moroccan, and Surinamese ethnic backgrounds were significantly more likely to exceed entertainment-media guidelines compared with native Dutch preschoolers. These observed ethnic inequalities were only partly explained by differences in family socioeconomic position (i.e., maternal educational level and household income). This study adds to earlier reports on ethnic inequalities in television viewing time among school-aged children [22] and adolescents [23] by demonstrating that these disparities are already evident in 4-year-old preschool children. Furthermore, they are in line with 2 previous studies conducted among preschool children in Germany [24] and the United States [25]. However, as ethnic minority groups from other countries differ from ethnic minority groups in the

Netherlands with respect to immigration history and culture, pathways underlying the association between ethnic background and television viewing time may be different.
Subsequent stratified analyses showed an increase in ethnic inequalities at higher levels of maternal education as a consequence of a differential educational gradient in television viewing time between native Dutch children and children from ethnic minority groups. That is, while the percentage of children exceeding guidelines showed a marked decrease with increasing maternal educational level for native Dutch children, this decrease was absent or less pronounced in the other ethnic groups. Kimm et al [26], in a study conducted among 9- to 10-year-old black/white schoolgirls in the United States, reported similar interaction effects on television viewing. This study found a significant negative association between parental education and television viewing in white girls but a significantly weaker association in black girls, leading to an increase in ethnic disparities at higher socioeconomic levels.
Additional analyses of data among the subgroup of high-educated mothers showed that mothers from all ethnic minority groups watched more television than native Dutch mothers, although this difference was significant for Moroccan mothers only ($p < .05$). Also, children from all 3 ethnic minority groups more often had a television set in their bedrooms, Suriname children in particular, compared with native Dutch children ($p < .001$, data not shown). Both these variables have been shown to be strongly associated with children's television viewing [7]. These results suggest that in addition to education and income, other (social) environmental factors that may be culturally influenced contribute to ethnic inequalities in children's television viewing time. Also, children who are in day care may spend less time watching television compared with children who are cared for at home because they have fewer available hours. Analyses on day-care attendance at the age of 3 years suggest that day care attendance may be an alternative explanation for our findings because native Dutch children were more often in day care ≥2 d/wk compared with Turkish, Moroccan, and Surinamese children ($p < .05$, data not shown).
This study did not find any associations between acculturation characteristics (i.e., generational status, age at immigration, and Dutch language skills) and television viewing time ≥2 hours/day. When using the second outcome variable (television viewing time ≥1 hour/day) similar results were found (data not shown). A study conducted among children and adolescents in the United States found immigrant children to be less likely to watch television ≥3 hours/day than native children of the same ethnic group, with a narrowing gap with increasing acculturation levels [9]. However, comparison of results is difficult because different definitions of ethnicity and acculturation were used in this study and in the study by Singh et al.[9] In this study, mothers were assigned a Dutch ethnicity when both her parents were born in the Netherlands. When identifying immigrant descent (generational status), this classification goes no further than the second

generation and therefore does not distinguish between Dutch participants and third-generation immigrants. It may be that acculturation processes need to be considered over a longer period of time before their effects become visible. Alternatively, factors that are strongly culturally influenced may be crucial in establishing young children's sedentary behaviors, regardless of the level of acculturation. As the relationships of ethnic background and acculturation with children's sedentary behavior and physical activity in the Netherlands are not well understood, more research in this area is warranted.

Study strengths and limitations

The major strengths of this study include the diversity and size of the study population, and the information available on immigration characteristics and family socioeconomic position. However, some limitations should be taken into account when interpreting the results of this study. The response rate at birth in the Generation R Study was 61%, but there was some selection toward a relatively high-educated and healthier study population [12]. Furthermore, about 25% of participants who were eligible for inclusion in this study based on their ethnic background were excluded from the analyses because of missing data for the outcome variable. Nonresponse analyses showed that data on television viewing were more often missing for children from ethnic minority groups and for children from low socioeconomic position. Selection bias because of selective participation and selective nonresponse could have affected our results when the association between ethnic background and television viewing time differed between participants and nonparticipants. However, we do not think that this is very likely. Furthermore, some variables (e.g., maternal employment status and household income) were measured before the child was aged 4 years. These variables may have changed over time, and therefore (nondifferential) misclassification may have occurred. As the majority of the variables in this study were assessed using parent-reported questionnaires, social desirability (i.e., the tendency for individuals to over report desirable traits and behaviors and underreport undesirable traits and behaviors) may have influenced our results. It is possible that high-educated Dutch mothers are more knowledgeable of guidelines or health effects associated with television viewing time and consequently underreport television viewing by their children. As we have not collected information on the knowledge of the parents, this cannot be ascertained. However, the large inequalities in television viewing time between children of high-educated native Dutch mothers and children of high-educated mothers from ethnic minority groups suggest that differences in knowledge of the mothers are not likely to explain our results. The American Academy of Pediatrics and Australian/ Canadian guidelines used in this study are based on total screen time (i.e. television/DVD viewing and computer use combined) [15-17]. Computer use and gaming have not been assessed in our study. However, studies have shown that media use among preschool children can be mainly attributed to television viewing, as television viewing is far more prevalent than computer use and gaming among children of this age [27]. An important issue in research on ethnic disparities is potential residual confounding by socioeconomic factors [28]. Because it is impossible to take into account all socioeconomic factors, we cannot rule out the possibility that other factors (e.g., wealth) may be partly responsible for the observed ethnic differences [28]. As we controlled our analyses for educational level and income, 2 of the strongest socioeconomic risk factors for television viewing in children [8], we are likely to have captured the most important dimensions of socioeconomic position for this particular outcome. We have repeated the analyses using paternal indicators of socioeconomic position (i.e., paternal educational level and paternal employment status) and found comparable results (data not shown).

In this study, children were classified according to the ethnic background of their mothers. In turn, maternal ethnic background was defined according to the country of birth of their parents. Ethnicity is a complex construct, covering elements of culture, religion, and migration history, among others [29]. It has been suggested that self-designated ethnicity is the most suited indicator of ethnicity to ensure that designation most closely matches an individual's personal and cultural background. Notwithstanding these limitations, we used country of birth because it is the most stable and objective measure of ethnicity [29]. Also, the Surinamese population is very heterogeneous, including (among others) Surinamese-Hindustani originating from India and Surinamese Creoles originating from Africa. As a result of the small numbers in the Surinamese group, we were unable to further specify these subgroups that may differ in socioeconomic and behavioral characteristics.

Finally, this study only considered television viewing time. Although associations between television viewing time and children's health have been studied extensively, other dimensions of television viewing (e.g., watching television with/without parents, age-appropriate programming, and television content) are also important, especially with respect to behavioral and emotional health outcomes in children [30].

Conclusion

This study showed that ethnic differences in television viewing time are already present at preschool age. The increased risk for high levels of television viewing among ethnic minority children was only partly explained by their family socioeconomic position. Furthermore, the gap between native Dutch children and ethnic minority children increased with increasing educational level of the parents. This study did not find an association between level of acculturation and children's television viewing time. These results suggest that interventions aimed to reduce television viewing time should target all children (and their parents) from ethnic minority groups.

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4

SOCIAL INEQUALITIES IN CHILDREN'S PHYSICAL ACTIVITY BEHAVIORS

CHAPTER

4.1

CORRELATES OF PHYSICAL ACTIVITY IN 2-YEAR-OLD TODDLERS: THE GENERATION R STUDY

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Abstract

Objective: To describe and identify correlates of objectively measured physical activity and sedentary behavior in 2-year-old toddlers.

Methods: A total of 347 children participating in a birth cohort study wore a unaxial ActiGraph accelerometer during 1 weekday and 1 weekend day. Information on potential correlates was assessed by parent-reported questionnaires, delivery reports, and regular visits to child health centers. Univariate and multivariable linear regression analyses were conducted to examine the associations between potential correlates and the following physical activity outcomes: percentage of time spent in sedentary behavior, percentage of time spent in moderate-to-vigorous physical activity, and mean counts per minute.

Results: A high percentage of monitored time was spent in sedentary behavior; 85.6% on weekdays and 84.5% on weekend days. Four correlates were significantly associated with at least 1 physical activity outcome in the multivariable regression models: child's sex, child's age, number of siblings, and season of measurement. The associations of gross motor development with moderate-to-vigorous physical activity and mean counts per minute approached significance. Associations of socioeconomic variables and child's body mass index z-score with physical activity outcomes were not significant.

Conclusion: Two-year-old toddlers spend most of their time in sedentary behavior. No modifiable correlates were identified. Further research on physical activity and associated health benefits among very young children is warranted.

Introduction

Physical activity is an important component of a healthy lifestyle and is associated with a number of positive health outcomes in children, including improved cardiovascular health and fitness, muscular strength and endurance, increased academic performance, and reduced depression and anxiety [1-3]. Furthermore, physical activity is positively associated with motor skill development and negatively associated with fat mass [4,5].

Given these important health outcomes, international guidelines regarding the recommended daily amount of children's physical activity have been developed, ranging from 1.5 hours and 2 hours per day for 1- to 3-year-old toddlers and 3- to 5 year-old preschoolers, respectively (guidelines from the National Association for Sport and Physical Education [NASPE], US) to 3 hours per day for 1- to 5-year-old children (Australian guideline) [6,7]. These guidelines are not always met; Hinkley et al reported that only 5% of Australian preschool children achieved the Australian guideline and that 56% of the children met the NASPE guideline [8].

Previous research has provided evidence for moderate tracking of physical activity from childhood into young adulthood [9,10], indicating that physical activity levels during childhood are predictive of physical activity levels later in life. Therefore, in order to intervene before these behaviors have been established, it is important to identify groups of children at risk of low levels of physical activity as early as possible. Furthermore, to develop effective interventions to promote children's physical activity, information on modifiable correlates is necessary.

Studies on physical activity and sedentary behavior among young children, as well as studies on their correlates, are still scarce. Over the recent years, research on correlates of children's physical activity has been extended, but results have been inconsistent [11-17]. These conflicting results may be due to differences in physical activity measurements, including objective measurements (ie, accelerometry) [11-14,16], questionnaires [15], or direct observations [17]. Also, these studies have been conducted in preschool-aged children [11-17], and no studies have focused specifically on younger children (ie, toddlers). Studying physical activity in toddlers is important because children's physical activity increases substantially at this age and, thus, this period may provide a good opportunity to start targeted interventions to promote physical activity. Therefore, the present study aims to describe and identify correlates of objectively measured physical activity and sedentary behavior in 2-year-old toddlers.

Methods

Study design

The present study was embedded in the Generation R Study, a population-based prospective cohort study from early fetal life onwards [18]. The Generation R Study is conducted by the Erasmus Medical Center in close collaboration with the Erasmus University Rotterdam, School of Law and Faculty of Social Sciences, the Municipal Health Service Rotterdam area, Rotterdam, the Rotterdam Homecare Foundation, Rotterdam, and the Stichting Trombosedienst and Artsenlaboratorium Rijnmond, Rotterdam. The study was conducted in accordance with the guidelines proposed in the World Medical Association Declaration of Helsinki and has been approved by the Medical Ethical Committee at Erasmus Medical Center, University Medical Center Rotterdam. Written informed consent was obtained from all participants.

Study population

Invitations to participate in the Generation R Study were made to all pregnant women who had an expected delivery date between April 2002 and January 2006 and who lived in the study area (Rotterdam, The Netherlands) at moment of birth. Among an ethnic (Dutch) homogeneous subgroup of children, more detailed assessments were conducted [18]. These included accelerometer measurements as described below. For this purpose, 500 of the 617 children who were 2 years old and attended the Generation R Study research center between December 2005 and February 2008 were asked to wear an accelerometer. Due to the limited number of accelerometers, not all children were offered an accelerometer. Of these initial 500 children, 30 children did not agree to wear it, 72 children agreed to wear the accelerometer but eventually did not wear it, and data of 51 children were excluded because of losing or malfunctioning of the accelerometer, software problems, or insufficient wear time. The final study population consisted of 347 children (182 boys, 165 girls) with a mean age of 25 (±1) months. Non-response analyses among children who agreed to wear an accelerometer comparing children with usable data (n = 347) to those without usable data (n = 123) showed that children included in the analyses were younger ($F = 12$, $df = 1$, $P < .01$) and more often had a mother with a high educational level ($\chi^2 = 12$, $df = 3$, $P < .01$) compared with children who were not in the analyses.

Measurement of physical activity

Physical activity was assessed with a uniaxial ActiGraph accelerometer (model Am-7164; ActiGraph, Pensacola, Florida). This accelerometer measures normal human movement in the vertical plane. The ActiGraph has shown sufficient feasibility, validity, and reliability in 2 reviews focusing on young children [19,20]. Parents were instructed to place the accelerometer on their child's right hip using an elastic waist belt during waking hours and to remove the accelerometer during bathing or showering. The children were asked to wear the accelerometer during 1 weekday and 1 weekend day.

All accelerometer data were processed using Actisoft 3.2 (ActiGraph) and MAHUffe 1.6.2.6 (Institute of Metabolic Science, Medical Research Council Epidemiology Unit, Cambridge, United Kingdom) software programs. The data were included in analyses when the accelerometer was worn for at least 400 minutes per day [21]. Because of the sporadic and intermittent nature of children's physical activity, short epochs were used. In the present study, movement values (counts per minute [CPM]) were collected every 15 seconds [19]. Substantial periods of zero activity counts (>10 minutes) and sleeping periods were excluded. Data were expressed as mean CPM (averaged over total wear time) and as time spent in activities of different intensity using age-specific count cut points. As there are currently no validated count cut points available for 2-year-old children, Sirard's count cut points for 3-year old children were used. Intervals were categorized as sedentary (≤301 counts/15 s), light (302-614 counts/15 s), moderate (615-1230 counts/15 s), or vigorous (≥1231 counts/15 s) physical activity [22]. In addition to these outcome measures, moderate to-vigorous physical activity (MVPA) was calculated as the sum of time spent in moderate and vigorous activity. Subsequently, we calculated total physical activity as the sum of time spent in light, moderate, and vigorous activity. The majority of children wore the accelerometer during both a weekday and a weekend day (n = 247); 66 children wore the accelerometer only on a weekday, and 34 children only on a weekend day. Therefore, physical activity measurements on weekdays were available for 313 children and physical activity measurements on weekend days were available for 281 children. On average, children wore the accelerometer for 492 (±86) minutes on weekdays, and 484 (±86) minutes on weekend days.

Chapter 4.1

Potential correlates of physical activity

Using a socialecological approach [23], we considered potential correlates from multiple domains including child characteristics, sociodemographic characteristics, and the physical environment. Information on these variables was derived from parent-reported questionnaires during the pre- and postnatal period, delivery reports, and regular visits to child health centers.

Child characteristics

Child characteristics included sex and age of the child, preterm birth (<37 weeks gestation), birth weight, infant temperament at 6 months, gross motor development at 12 months, body mass index (BMI) of the child, and children's television (TV) viewing time. Preterm birth and birth weight of the children were available from delivery reports or by questionnaire at 2 months post-partum. Infant temperament at 6 months was determined using an adapted version of the Infant Behavior Questionnaire Revised [24]. We used the 'activity level' scale, which relates to gross motor activity and squirming. Higher scores on the scale indicate more difficult behavior. The 'gross motor' scale of the Minnesota Infant Development Inventory was used to examine the attainment of motor milestones at the age of 1 year. Examples of items used to assess gross motor development included 'pulls self to standing position' and 'has good balance and coordination' (yes, no). We used the 75% age levels from the original instrument to indicate delay or normal motor development [25]. Body weight and height of the children at 2 years old were measured during a regular visit to the child health center using standard procedure, and converted to BMI (kg/m^2). A BMI z-score was calculated and adjusted for age and sex using a national reference [26]. Children's TV viewing time at the age of 2 years was assessed for weekdays and weekend days separately and dichotomized in <1 hour per day and ≥1 hour per day, according to recent screen time recommendations for young children [27].

Sociodemographic characteristics

Sociodemographic characteristics included maternal age, maternal pre-pregnancy BMI, breastfeeding status at 6 months (yes, no), marital status of the primary caregiver (married, unmarried), number of siblings (0, 1, ≥2), children's exposure to smoking in the household (yes, no), child's daycare attendance (0-1 days, 2-3 days, ≥4 days), parental educational level, parental employment status (paid job, no paid job), and household income. Maternal age, maternal pre-pregnancy height and weight, and parental educational level were assessed in a questionnaire at enrollment and breastfeeding status was assessed in a questionnaire when the child was 6 months old. All other variables were assessed by questionnaire when the child was 2 years old. BMI of the mother was calculated as weight divided by squared height (kg/m^2) and divided into three categories: normal weight (BMI <25), overweight (BMI 25-30), and obese (BMI ≥30). The Dutch Standard Classification of Education was used to categorize 4 levels of parental education: low (<4 years of high school), mid-low (college), mid-high (Bachelor's degree), and high (Master's degree) [28]. Net household income was classified into 3 categories: <€2000 ($2598) per month (below modal income), €2000-3300 ($2598-4287) per month, and >€3300 ($4287) per month [29].

Physical environment

Dates of accelerometer measurement were used to define 4 seasons in The Netherlands: spring (March-May), summer (June-August), fall (September November), and winter (December- February).

Statistical analyses

Descriptive statistics were used to describe the study population and levels of objectively measured physical activity and sedentary behavior in 2-year-old toddlers. We calculated the percentage of children meeting the international guidelines regarding children's daily physical activity using uncorrected total physical activity.6,7 To correct for total wear time, we calculated the percentage of monitored time spent in sedentary behavior, light physical activity, moderate physical activity, MVPA, vigorous physical activity, and total physical activity for weekdays and weekend days separately. Differences in physical activity on weekdays and weekend days were assessed by paired sample t tests for continuous physical activity outcomes and McNemar tests for dichotomous physical activity outcomes (ie, percentage of children meeting guidelines).

To identify correlates of physical activity and sedentary behavior series of linear regression analyses were performed. First, bivariate associations between all potential correlates and percentage of time spent in sedentary behavior, percentage of time spent in MVPA, and mean CPM were assessed using linear regression models. Variables associated with physical activity outcomes with a P value <.20 in the univariate linear regression models were included in multivariable regression models (method: enter) to assess their independent associations with children's physical activity.

Some variables had missing data, ranging from 0.3% missing (child's age) to 17.3% missing (daycare attendance). To reduce potential bias associated with missing data, a multiple imputation procedure was applied to all variables included in this study [30]. Five imputed datasets were generated using a fully conditional specified model, thus taking into account the uncertainty of the imputed values. Pooled estimates from these 5 imputed datasets were used to report effect estimates and their 95% CI. Imputations were based on the relationship between all the variables included in this study. All statistical analyses were performed using SPSS v. 20.0 for Windows (SPSS Inc, Chicago, Illinois). A P value <.05 was considered as statistically significant.

Results

About 10% of children watched TV ≥1 hour per day during a weekday and about 25% of children watched TV ≥1 hour per day during a weekend day. More than one-half of the children had at least 1 sibling (58%). The average maternal age in our study was 32 (4) years, 38.6% of mothers had a high educational level, and 86.3% of mothers had a paid job (Table 1).

Table 1. Descriptive characteristics of the study population (n=347)†

		Total (n=347)	Missing (n, %)
Child characteristics			
Sex	Boy	182 (52.4)	0
	Girl	165 (47.6)	
Age	Months	25.1 (1.1)	1 (0.3)
Preterm birth	Yes	9 (2.6)	0
	No	338 (97.4)	
Birth weight	< 2500 grams	9 (2.6)	0
	≥ 2500 grams	338 (97.4)	
Infant temperament	Activity level	0.7 (0.3)	41 (11.8)
Gross motor development	Delay	89 (27.2)	20 (5.8)
	Normal	238 (72.8)	
BMI z-score		0.1 (1.0)	6 (1.7)
TV time weekday	< 1 hour	299 (89.8)	14 (4.0)
	≥ 1 hour	34 (10.2)	
TV time weekend day	< 1 hour	252 (75.4)	13 (3.7)
	≥ 1 hour	82 (24.6)	
Socio-demographic characteristics			
Age mother	Years	32.0 (3.8)	0
BMI mother (kg/m^2)	<25	209 (72.6)	59 (17.0)
	25-30	59 (20.5)	
	≥30	20 (6.9)	
Breastfeeding status at 6 months	Yes	119 (36.6)	22 (6.3)
	No	206 (63.4)	
Marital status	Married	217 (64.8)	12 (3.5)
	Unmarried	118 (35.2)	
Number of siblings	0	142 (42.0)	9 (2.6)
	1	160 (47.3)	
	≥2	36 (10.7)	
Smoking in household	Yes	35 (10.5)	14 (4.0)
	No	298 (89.5)	
Day care attendance	0-1 days	72 (25.1)	60 (17.3)
	2-3 days	155 (54.0)	
	≥ 4 days	60 (20.9)	
Educational level mother	Low	20 (5.8)	4 (1.2)
	Mid-low	89 (25.9)	
	Mid-high	102 (29.7)	
	High	32 (38.6)	

Table 1. Descriptive characteristics of the study population (n=347)[†] (continued)

Educational level partner	Low	42 (13.4)	33 (9.5)
	Mid-low	66 (21.0)	
	Mid-high	63 (20.1)	
	High	143 (45.5)	
Employment status mother	Paid job	264 (86.3)	41 (11.8)
	No paid job	42 (13.7)	
Employment status partner	Paid job	306 (98.4)	36 (10.4)
	No paid job	5 (1.6)	
Household income	<€2000	31 (9.5)	19 (5.5)
	€2000-3300	137 (41.7)	
	>€3300	160 (48.8)	
Physical environment			
Season	Spring	128 (36.9)	0
	Summer	77 (22.2)	
	Fall	61 (17.6)	
	Winter	81 (23.3)	

[†] Values are means (SD) for normally distributed continuous variables and frequencies (percentage) for categorical variables.

Physical activity in 2-year-old toddlers

Time spent in different intensities is shown in Table 2. On weekdays, a high percentage of monitored time was spent in sedentary behavior (85.6%), 9.6% of time was spent in light physical activity, and 4.8% in MVPA. The percentages for weekend days were slightly different; 84.5% of monitored time was spent in sedentary behavior, 10.3% was spent in light physical activity, and 5.2% was spent in MVPA, respectively. Percentages of time spent in sedentary behavior and different physical activity intensities were significantly different between weekdays and weekend days with children being a little less sedentary and more physically active during weekend days (Table 2). None of the children reached the Australian guideline of 3 hours physical activity per day during a weekday and 1 child reached the guideline on a weekend day. About a quarter (24%) of all children reached the NASPE guideline of 1.5 hours physical activity per day on a weekday and 30% of children reached this guideline on a weekend day (P = .19).

Correlates of physical activity

Outcome measures for the analyses on correlates of physical activity included percentage of time spent in sedentary behavior, percentage time spent in MVPA, and mean CPM on an 'average day' (average of weekday and weekend day). Results from the regression analyses for weekdays and weekend days are presented in Supplement Tables 1 and 2.

Table 2. Physical activity in 2-year-old toddlers during weekdays (n=313) and weekend days (n=281)†

	Weekday (n=313)	Weekend day (n=281)	Δ Weekend-Week (n=247)
Monitored time (min)	492.1 (86.1)	484.0 (86.3)	-14.9 (6.5)*
Australian guideline (%)[a]	0.0	0.4	
NASPE guideline (%)[b]	24.0	30.2	
Sedentary‡	85.6 (5.7)	84.5 (5.9)	-1.2 (0.4)**
Total PA‡	14.4 (5.7)	15.5 (5.9)	1.2 (0.4)**
Light PA‡	9.6 (3.2)	10.3 (3.4)	0.7 (0.2)**
MVPA‡	4.8 (3.0)	5.2 (3.0)	0.5 (0.2)**
Moderate PA‡	3.8 (2.1)	4.2 (2.3)	0.4 (0.1)**
Vigorous PA ‡	1.0 (1.1)	1.0 (0.8)	0.1 (0.1)*
CPM	577.2 (207.9)	610.5 (189.9)	41.8 (11.4)***

† Values are means (SD). ‡ Percentage of monitored time. * p<0.05 **p<0.01 ***p<0.001.
[a] Percentage of children meeting Australian guideline: 3 hrs PA/day for 1-5 year old children.
[b] Percentage of children meeting NASPE (US) guideline:1.5 hrs PA/day for 1-3 year old children.

Correlates of sedentary behavior

Results from the univariate analyses are presented in Table 3. Four correlates remained significant in the multivariable model (Table 4); levels of sedentary behavior were higher among girls compared with boys ($P < .05$) and during winter season compared with spring ($P < .01$). Levels of sedentary behavior were lower among older children ($P < .01$) and children with 2 or more siblings compared with children without siblings ($P < .05$).

Correlates of MVPA

Four correlates were significantly associated with MVPA in the multivariable model (Table 4); levels of MVPA were higher among older children ($P < .05$) and children with 2 or more siblings ($P < .05$). Levels of MVPA were lower among girls ($P < .05$) and during winter season ($P < .05$). The association between gross motor development and MVPA showed a trend toward significance ($P < .1$), indicating that levels of MVPA were lower among children with a delay in gross motor development compared with children with normal motor development.

Correlates of mean CPM

Two correlates were significantly associated with mean CPM in the multivariable model (Table 4); mean CPM were higher among children with 2 or more siblings ($P < .01$) and during winter season ($P < .05$). The associations between child's sex, child's age, and gross motor development with mean CPM approached significance (all $P < .1$).

Table 3. Univariate associations of potential correlates with sedentary behavior, MVPA, and CPM on an average day (n=347)

		Sedentary behavior (% of time) β (95% CI)†	MVPA (% of time) β (95% CI)†	CPM β (95% CI)†
Child characteristics				
Sex	Girl	1.3 (0.4,2.2)*	-0.5 (-1.0,-0.0)*	-31.3 (-63.8,1.1)*
Age		-0.5 (-1.0,-0.1)*	0.2 (0.0,0.4)*	13.3 (-1.4,27.9)*
Preterm birth	Yes	1.4 (-1.6,4.3)	-0.8 (-2.3,0.6)	-63.6 (-167.9,40.7)
Birth weight	<2500 g	2.8 (-0.1,5.7)*	-1.4 (-2.8,0.1)*	-91. 9 (-195.7,11.9)*
Infant temperament		-0.7 (-2.3,0.9)	0.1 (-0.7,0.9)	16.0 (-40.0,72.1)
Gross motor development	Delay	1.2 (0.2,2.3)*	-0.7 (-1.2,-0.1)*	-46.2 (-83.3,-9.2)*
BMI z-score		0.1 (-0.4,0.6)	-0.1 (-0.3,0.2)	-6.6 (-23.8,10.6)
TV time weekday	≥1h	-0.2 (-1.7,1.3)	0.1 (-0.7,0.8)	-3.5 (-56.9,49.9)
TV time weekend day	≥1h	0.3 (-0.8,1.3)	-0.0 (-0.6,0.5)	-14.7 (-53.3,23.9)
Socio-demographic characteristics				
Age mother		0.0 (-0.1,0.2)	-0.0 (-0.1,0.1)	0.8 (-3.6,5.2)
BMI mother (kg/m^2)	<25	(ref)	(ref)	(ref)
	25-30	-1.0 (-2.3,0.3)*	0.3 (-0.3,1.0)	43.6 (-1.6,88.9)*
	≥30	-1.6 (-3.2,-0.0)*	0.4 (-0.5,1.3)	30.3 (-30.9,91.5)
Breastfeeding status	Yes	0.7 (-0.3,1.7)*	-0.3 (-0.8,0.2)*	-25.7 (-60.3,8.9)*
Marital status	Unmarried	-0.0 (-1.0,1.0)	0.1 (-0.4,0.6)	2.8 (-31.9,37.5)
Number of siblings	0	(ref)	(ref)	(ref)
	1	0.0 (-1.0,1.0)	-0.0 (-0.5,0.5)	1.5 (-33.0,36.1)
	≥2	-2.5 (-4.1,-0.9)*	1.1 (0.3,1.9)*	99.5 (44.3,154.8)*
Smoking in household	Yes	-0.1 (-1.7,1.4)	0.1 (-0.7,0.9)	30.7 (-26.3,87.7)
Day care attendance	0-1 d	(ref)	(ref)	(ref)
	2-3 d	1.4 (0.1,2.8)*	-0.3 (-1.0,0.3)	-39.5 (-92.2,13.2)*
	≥4 d	1.5 (0.0,3.0)*	-0.5 (-1.3,0.2)*	-54.1 (-110.3,2.1)*
Educational level mother	Low	-0.8 (-2.8,1.3)	0.3 (-0.8,1.3)	43.8 (-28.3,115.8)
	Mid-low	-0.2 (-1.4,1.0)	-0.1 (-0.7,0.5)	5.4 (-36.2,47.1)
	Mid-high	-0.3 (-1.4,0.9)	-0.1 (-0.6,0.5)	9.8 (-29.8,49.5)
	High	(ref)	(ref)	(ref)
Educational level partner	Low	-0.9 (-2.5,0.6)	0.4 (-0.4,1.1)	23.5 (-29.1,76.0)
	Mid-low	-0.4 (-1.8,1.1)	0.0 (-0.7,0.7)	11.2 (-36.4,58.7)
	Mid-high	-0.5 (-1.7,0.8)	0.1 (-0.5,0.7)	17.2 (-26.6,61.1)
	High	(ref)	(ref)	(ref)
Employment status mother	No paid job	-0.6 (-2.0,0.7)	0.0 (-0.7,0.7)	21.4 (-29.3,72.0)

Table 3. Univariate associations of potential correlates with sedentary behavior, MVPA, and CPM on an average day (n=347) (continued)

Employment status partner	No paid job	-1.0 (-3.1,1.1)	0.6 (-0.6,1.8)	23.0 (-52.8,98.7)
Household income	<€2000	-0.4 (-2.1,1.2)	0.1 (-0.7,0.9)	12.4 (-46.0,70.8)
	€2000-3300	-1.0 (-2.0,-0.0)*	0.4 (-0.1,0.9)*	33.5 (-1.5,68.5)*
	>€3300	(ref)	(ref)	(ref)
Physical environment				
Season	Spring	(ref)	(ref)	(ref)
	Summer	-0.4 (-1.6,0.8)	0.4 (-0.2,1.0)*	19.4 (-23.7,62.5)
	Fall	-0.4 (-1.7,0.9)	0.4 (-0.2,1.1)	20.4 (-26.3,67.1)
	Winter	1.6 (0.4,2.8)*	-0.7 (-1.3,-0.1)*	-54.9 (-97.5,-12.3)*

Table is based on imputed dataset.
† Values are betas and 95% confidence intervals. Betas represent the differences in sedentary behavior, MVPA, and CPM per one unit increase in correlates or relative to reference group.
* p<0.20.

Discussion

Children in this study spent most of the monitored time in sedentary behavior. Our findings are in line with results from previous studies in preschool children, which reported between 76% and 85% of time spent in sedentary behavior, and between 3% and 12% of time spent in MVPA [4,8,31,32]. In contrast, our findings contradict results from a study conducted in the US among 3- to 5-year-olds that found children to spend about 50% of monitored time in sedentary behavior [11].

We found low compliance with international guidelines regarding the recommended daily amount of children's physical activity. Previous studies conducted among Australian and Portuguese preschool children have found higher compliance rates, ranging from 5% for the Australian guideline to 74% for the NASPE guideline [8,32]. In contrast, a study among Belgian preschool children found results similar to ours with 27% of children meeting the NASPE guideline on weekdays and 28% on weekend days [31]. To our knowledge, only 1 previous study has reported physical activity levels in toddlers. In a study among 19-months-old Australian toddlers, Hnatiuk et al found that 91% of children met the Australian guideline [33]. The marked difference in compliance between the study of Hnatiuk et al and this study is likely due to differences in count cut points used to define physical activity intensities, with Hnatiuk et al using significantly lower count cut points. Ideally, guidelines are based on consistent research findings that demonstrate health benefits for specific levels of physical activity among young children. However, there is yet little evidence of a minimum dose required to achieve positive health outcomes [34]. In addition, there is little research on 'normal' development of

physical activity levels during early childhood. Further research on physical activity and its associated health benefits among very young children is warranted.
This study examined correlates of physical activity and sedentary behavior in toddlers. Number of siblings and season of measurement were consistent correlates of sedentary behavior, MVPA, and mean CPM. Other correlates significantly associated with physical activity outcome measures included child's sex and child's age. We found no evidence for modifiable correlates.

Table 4. Multivariable associations of potential correlates with sedentary behavior, MVPA, and CPM on an average day (n=347)

		Sedentary behavior (% of time) β (95% CI)†	MVPA (% of time) β (95% CI)†	CPM β (95% CI)†
Child characteristics				
Sex	Girl	1.1 (0.3,2.0)*	-0.4 (-0.9,-0.0)*	-27.6 (-58.5,3.4)
Age		-0.6 (-1.0,-0.2)**	0.2 (0.0,0.5)*	14.0 (-0.3,28.3)
Birth weight	<2500 g	2.4 (-0.4,5.1)	-1.2 (-2.6,0.2)	-77.7 (-177.6,22.3)
Gross motor development	Delay	0.7 (-0.3,1.8)	-0.5 (-1.0,-0.0)	-31.3 (-68.1,5.6)
Socio-demographic characteristics				
BMI mother (kg/m^2)	<25	(ref)	-	(ref)
	25-30	-0.7 (-1.9,0.5)	-	34.1 (-8.4,76.6)
	≥30	-0.8 (-2.4,0.7)	-	4.4 (-57.0,65.8)
Breastfeeding status	Yes	0.4 (-0.5,1.4)	-0.3 (-0.7,0.2)	-23.3 (-57.6,11.1)
Number of siblings	0	(ref)	(ref)	(ref)
	1	0.1 (-0.9,1.0)	-0.1 (-0.6,0.4)	-0.2(-33.0,32.7)
	≥2	-2.0 (-3.6,-0.5)*	0.9 (0.2,1.7)*	85.6 (31.0,140.2)**
Day care attendance	0-1 d	(ref)	(ref)	(ref)
	2-3 d	0.8 (-0.5,2.0)	-0.1 (-0.7,0.6)	-14.8 (-63.7,34.0)
	≥4 d	0.9 (-0.6,2.4)	-0.3 (-1.0,0.4)	-32.1 (-88.0,23.8)
Household income	<€2000	-0.2 (-1.8,1.4)	0.1 (-0.7,0.9)	7.5 (-49.5,64.6)
	€2000-3300	-0.6 (-1.6,0.4)	0.2 (-0.3,0.7)	20.3 (-14.7,55.4)
	>€3300	(ref)	(ref)	(ref)
Physical environment				
Season	Spring	(ref)	(ref)	(ref)
	Summer	-0.5 (-1.7,0.7)	0.5 (-0.1,1.1)	25.6 (-15.8,67.0)
	Fall	-0.4 (-1.7,0.9)	0.5 (-0.2,1.1)	25.9 (-20.4,72.2)
	Winter	1.6 (0.5,2.8)**	-0.8 (-1.4,-0.2)*	-51.7 (-93.2,-10.2)*

Table is based on imputed dataset.
† Values are betas and 95% confidence intervals. Betas represent the differences in sedentary behavior, MVPA, and CPM per one unit increase in correlates or relative to reference group.
* p<0.05 **p<0.01.

Several studies in preschool-aged children have shown associations of children's sex, children's age, and season of measurement with physical activity or sedentary behavior [11-17]. The association between child's sex and physical activity and sedentary behavior in particular is well established in the scientific literature [11-17,35]. Similarly, we found significant sex differences in levels of sedentary behavior and MVPA. Although a child's sex was not independently associated with mean CPM in this study, we did observe a trend in the expected direction indicating that girls were less physically active compared with boys. Our results are also in line with a previous study conducted among toddlers that found higher levels of MVPA in boys than girls [33]. Few studies have examined the influence of siblings; however 1 recent study did not find an effect of number of siblings on sedentary behavior in US preschool children [11]. Our findings with respect to the (near significant) negative associations between a delay in gross motor development and children's MVPA and mean CPM is supported by previous studies that found physical activity to be positively associated with movement skills and parent perception of athletic coordination and athletic competence in preschool children [4,11,16].

In contrast to this study, previous studies have also reported associations of physical activity and sedentary behavior with child's BMI, household income, and preterm birth [11-17]. Contrary to our expectation, we did not find associations between BMI z-score and physical activity or sedentary behavior. One explanation concerns the cross-sectional measurement of BMI and physical activity outcomes. Alternatively, this study may have lacked power to detect associations due to relatively little variation in BMI. Future studies using longitudinal study designs and more heterogeneous study populations may provide more information about the nature and direction of the associations between BMI and objectively measured physical activity and sedentary behavior. No modifiable correlates were identified in the present study. Nevertheless, our findings that number of siblings and season of measurement were related to children's sedentary behavior and physical activity suggest a number of opportunities to increase physical activity levels in toddlers. Parents should provide plenty of opportunities for active play indoors when weather conditions during winter make it difficult for children to reach their recommended daily amount of physical activity by outdoor play. In addition, being around other children may stimulate children to become more active.

Study strengths and limitations

The strengths of this study include the use of objective measurements of physical activity, the inclusion of different physical activity outcome measures (ie, sedentary behavior, light-, moderate-, vigorous physical activity, and mean CPM), the consideration of a large number of potential correlates, and the unique young age of children participating in the study. Limitations of this study must also be acknowledged.

First, children's physical activity was measured on 2 days, including 1 week day and 1 weekend day. Although it has been suggested that 2 to 3 days of monitoring may provide accurate estimates of habitual physical activity in children under the age of 3 years [19], including more days of monitoring will increase the accuracy of the measurements. However, we expected little variance in physical activity in these young children. This is supported by our observation of the relatively small differences between physical activity on weekdays and weekend days.

Second, most of the information on potential correlates was collected by parent reported questionnaires. Although anonymity was assured, participants may have given socially acceptable answers leading to misclassification. This may be especially true for lifestyle characteristics such as TV viewing and maternal BMI. Also, we had information on general daycare attendance only; information on whether the accelerometer was actually worn at daycare or at home was not collected. Furthermore, neighborhood characteristics were not included as potential correlates because there was little variability in neighborhoods of the participants. Further investigation in this area is warranted. Many of the (potential) correlates studied in the present study were measured cross-sectionally. Therefore, inferences about the causal nature of the observed associations should be made with caution. However, as reverse causality is unlikely to explain our results (eg, in the case of number of siblings and season of measurement), we believe that these variables are likely to be antecedents of children's physical activity.

Third, non-response analyses showed that children participating in this study were younger and more often had mothers with a high educational level compared with non-participants. This selective participation may have affected our results if physical activity levels and associations between (potential) correlates and children's physical activity differ between participants and non-participants. However, this is difficult to ascertain.

Fourth, this study used Sirard's count cut point for 3-yearold children to establish time spent in physical activity of different intensities. Several other cut points for 3- to 5-year-olds have been developed [36,37]. Applying different count cut points can lead to vastly different results with respect to time spent in varying physical activity intensities [38]. Also, application of 3-year-old count cut points in a population of 2 year-old toddlers may have led to biased results by putting children in sedentary behavior while they may actually be engaged in (light) activity. To date, no specific cut points have been developed for toddlers. Recently, an attempt has been made to identify and validate count cut point for toddlers under the age of 3 years [39]. Results from this study indicate that current count cut points for 3-year-olds may be too high for toddlers, leading to an overestimation of time spent in sedentary behavior and an underestimation of time spent in (light) physical activity [39]. More research on developing and validating accelerometer count cut points for very young children under the age of 3 years is needed.

Finally, because this study was conducted in a sample of native Dutch children, results may not be generalized to other study populations.

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Supplement Table 1. Univariate associations of potential correlates with sedentary behavior, MVPA, and CPM on a weekday and weekend day separately (n=347)

		Sedentary behavior (% of time)		MVPA (% of time)		CPM	
		Weekday β (95% CI)†	Weekend day β (95% CI)†	Weekday β (95% CI)†	Weekend day β (95% CI)†	Weekday β (95% CI)†	Weekend day β (95% CI)†
Child characteristics							
Sex	Girl	1.0 (-0.2,2.1)*	1.7 (0.5,2.8)*	-0.4 (-1.0,0.2)*	-0.6 (-1.2,0.0)*	-25.5 (-67.9,17.0)	-37.2 (-75.0,0.6)*
Age		-0.7 (-1.2,-0.2)*	-0.4 (-0.9,0.1)*	0.3 (0.0,0.5)*	0.2 (-0.1,0.4)*	13.4 (-5.7,32.6)*	3.1 (-3.7,29.9)*
Preterm birth	Yes	2.4 (-1.2,6.0)*	0.5 (-3.1,4.0)	-1.2 (-3.1,0.6)*	-0.5 (-2.3,1.3)	-105.5 (-238.5,27.6)*	-21.7 (-139.3,95.9)
Birth weight	<2500 g	4.1 (0.5,7.7)*	1.7 (-1.8,5.2)	-1.6 (-3.4,0.3)*	-1.2 (-3.0,0.6)*	-129.2 (-260.5,2.0)*	-54.6 (-176.6,67.5)
Infant temperament		-0.4 (-2.4,1.6)	-1.0 (-2.9,0.9)	0.2 (-0.9,1.2)	0.1 (-1.0,1.1)	13.5 (-55.9,82.9)	18.6 (-54.4,91.5)
Gross motor development	Delay	1.3 (-0.1,2.6)*	1.2 (-0.0,2.5)*	-0.7 (-1.3,0.0)*	-0.7 (-1.3,-0.0)*	-54.0 (-102.4,-5.7)*	-38.5 (-80.3,3.4)*
BMI z-score		0.1 (-0.5,0.7)	0.1 (-0.5,0.7)	-0.1 (-0.4,0.2)	-0.0 (-0.4,0.3)	-8.7 (-30.8,13.4)	-4.5 (-23.8,14.8)
TV time weekday	≥1h	0.0 (-1.9,2.0)	-0.3 (-2.1,1.5)	-0.4 (-1.4,0.7)	0.4 (-0.5,1.4)	-9.5 (-79.0,59.9)	2.6 (-57.2,62.5)
TV time weekend day	≥1h	0.7 (-0.6,2.1)	-0.0 (-1.3,1.3)	-0.5 (-1.2,0.2)*	0.4 (-0.3,1.0)	-30.8 (-80.8,19.1)	1.4 (-41.4,44.3)
Socio-demographic characteristics							
Age mother		0.0 (-0.1,0.2)	0.0 (-0.1,0.2)	-0.0 (-0.1,0.1)	-0.0 (-0.1,0.1)	1.0 (-4.6,6.6)	0.6 (-4.6,5.7)
BMI mother (kg/m^2)	<25	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
	25-30	-1.1 (-2.7,0.5)*	-1.0 (-2.5,0.5)*	0.4 (-0.5,1.2)	0.4 (-0.4,1.2)	50.8 (-9.2,110.9)*	36.4 (-14.4,87.3)*
	≥30	-1.4 (-3.5,0.7)*	-1.8 (-3.8,0.1)*	0.4 (-0.8,1.5)	0.4 (-0.7,1.6)	21.4 (-63.4,106.2)	39.2 (-26.6,105.0)
Breastfeeding status	Yes	0.9 (-0.3,2.1)*	0.6 (-0.7,1.8)	-0.5 (-1.1,0.1)*	-0.2 (-0.8,0.4)	-31.7 (-75.9,12.5)*	-19.6 (-59.3,20.1)
Marital status	Unmarried	0.4 (-0.8,1.6)	-0.4 (-1.6,0.7)	-0.1 (-0.7,0.6)	0.3 (-0.3,0.9)	-7.8 (-52.6,37.1)	13.4 (-25.4,52.2)
Number of siblings	0	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
	1	-0.0 (-1.2,1.2)	0.0 (-1.2,1.2)	-0.0 (-0.6,0.6)	-0.0 (-0.7,0.6)	6.0 (-38.1,50.0)	-2.9 (-42.3,36.6)
	≥2	-3.3 (-5.2,-1.3)*	-2.0 (-3.9,-0.1)*	1.5 (0.4,2.5)*	1.0 (0.0,2.0)*	127.5 (54.1,200.9)*	71.5 (9.2,133.9)*

Smoking in household	Yes	-1.0 (-3.0,1.0)	0.5 (-1.3,2.3)	0.4 (-0.6,1.4)	-0.1 (-1.0,0.9)	58.4 (-18.4,135.2)*	3.1 (-59.3,65.5)
Day care attendance	0-1 d	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
	2-3 d	1.3 (-0.7,3.3)*	1.6 (0.1,3.2)*	-0.2 (-1.3,0.9)	-0.6 (-1.4,0.2)*	-29.9 (-108.9,49.0)	-49.1 (-102.0,3.9)*
	≥4 d	0.5 (-1.3,2.3)	2.6 (0.8,4.4)*	0.0 (-0.9,1.0)	-1.2 (-2.0,-0.3)*	-23.2 (-96.0,49.5)	-84.9 (-145.2,-24.6)*
Educational level mother	Low	-0.5 (-3.0,2.1)	-1.2 (-3.6,1.3)	0.0 (-1.3,1.3)	0.6 (-0.7,1.9)	22.3 (-70.7,115.2)	65.2 (-16.4,146.9)*
	Mid-low	-0.1 (-1.6,1.4)	-0.4 (-1.8,1.1)	-0.3 (-1.0,0.5)	0.1 (-0.6,0.8)	8.7 (-45.5,62.9)	2.2 (-45.1,49.4)
	Mid-high	-0.2 (-1.6,1.2)	-0.5 (-1.8,0.9)	-0.2 (-0.9,0.5)	0.1 (-0.6,0.8)	9.9 (-41.3,61.1)	9.8 (-35.0,54.5)
	High	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Educational level partner	Low	-1.0 (-3.0,1.0)	-0.9 (-2.7,0.9)	0.5 (-0.6,1.5)	0.3 (-0.6,1.2)	30.0 (-39.6,99.5)	17.0 (-42.6,76.5)
	Mid-low	-0.2 (-1.9,1.6)	-0.6 (-2.2,1.0)	0.1 (-0.8,0.9)	-0.0 (-0.9,0.8)	17.1 (-45.0,79.1)	5.3 (-44.8,55.4)
	Mid-high	-0.6 (-2.1,1.0)	-0.4 (-1.9,1.2)	0.3 (-0.5,1.1)	-0.1 (-0.9,0.7)	25.7 (-30.6,81.9)	8.8 (-41.6,59.1)
	High	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Employment status mother	No paid job	-1.1 (-2.7,0.6)	-0.3 (-2.0,1.4)	0.2 (-0.7,1.1)	-0.0 (-0.9,0.9)	44.8 (-14.6,104.1)*	-2.0 (-66.2,62.2)
Employment status partner	No paid job	-1.5 (-4.6,1.6)	-0.3 (-3.4,2.8)	0.8 (-1.2,2.9)	0.3 (-1.2,1.7)	43.8 (-62.1,149.8)	2.1 (-97.6,101.8)
Household income	<€2000	1.0 (-1.0,3.0)	-1.9 (-3.9,0.1)*	-0.5 (-1.5,0.6)	0.7 (-0.3,1.7)*	-20.4 (-93.9,53.0)	45.2 (-23.7,114.1)*
	€2000-3300	-0.8 (-2.0,0.5)	-1.3 (-2.5,-0.1)*	0.3 (-0.3,0.9)	0.5 (-0.2,1.1)*	30.7 (-13.6,75.0)*	36.3 (-3.9,76.5)*
	>€3300	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
Physical environment							
Season	Spring	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
	Summer	-0.8 (-2.3,0.7)	-0.1(-1.6,1.4)	0.6 (-0.2,1.4)*	0.3 (-0.5,1.0)	34.4 (-21.6,90.4)	4.3 (-45.0,53.7)
	Fall	-1.9 (-3.6,-0.3)*	1.0 (-0.6,2.6)	1.3 (0.5,2.2)*	-0.4 (-1.2,0.4)	78.3 (18.3,138.4)*	-37.5 (-90.8,15.9)*
	Winter	1.0 (-0.5,2.5)*	2.2 (0.8,3.7)*	-0.5 (-1.3,0.3)	-1.0 (-1.7,-0.2)*	-38.3 (-93.2,16.6)*	-71.5 (-120.6,-22.4)*

Table is based on imputed dataset.
† Values are betas and 95% confidence intervals. Betas represent the differences in sedentary behavior, MVPA, and CPM per one unit increase in correlates or relative to reference group.
* $p<0.20$.

Supplement Table 2. Multivariable associations of potential correlates with sedentary behavior, MVPA, and CPM on a weekday and weekend day separately (n=347)

		Sedentary behavior (% of time)		MVPA (% of time)		CPM	
		Weekday β (95% CI)†	Weekend day β (95% CI)†	Weekday β (95% CI)†	Weekend day β (95% CI)†	Weekday β (95% CI)†	Weekend day β (95% CI)†
Child characteristics							
Sex	Girl	0.8 (-0.3,1.9)	1.4 (0.4,2.5)**	-0.4 (-1.0,0.2)	-0.5 (-1.1,0.0)	-	-30.4 (-66.9,6.2)
Age		-0.7 (-1.2,-0.2)**	-0.5 (-1.0,-0.0)*	0.3 (-0.0,0.5)	0.2 (-0.0,0.5)	11.6 (-7.0,30.2)	17.0 (0.2,33.7)*
Preterm birth	Yes	0.3 (-3.5,4.1)	-	-0.3 (-2.3,1.7)	-	-23.1 (-164.8,118.5)	-
Birth weight	<2500 g	3.8 (-0.0,7.5)	-	-1.4 (-3.4,0.5)	-1.0 (-2.8,0.8)	-95.8 (-235.0,43.3)	-
Gross motor development	Delay	0.8 (-0.5,2.1)	0.7 (-0.6,2.0)	-0.5 (-1.2,0.1)	-0.5 (-1.1,0.2)	-39.0 (-85.7,7.8)	-23.7 (-66.5,19.1)
TV time weekend day	≥1h	-	-	-0.5 (-1.1,0.2)	-	-	-
Socio-demographic characteristics							
BMI mother (kg/m^2)	<25	(ref)	(ref)	-	-	(ref)	(ref)
	25-30	-0.8 (-2.2,0.6)	0.0 (-1.1,1.2)	-	-	41.8 (-17.1,100.6)	27.1 (-22.0,76.1)
	≥30	-0.4 (-2.5,1.7)	-1.4 (-3.3,0.4)	-	-	-8.6 (-93.1,75.9)	23.2 (-42.3,88.8)
Breastfeeding status	Yes	0.8 (-0.4,2.0)	-	-0.5 (-1.1,0.1)	-	-32.9 (-77.1,11.2)	-
Number of siblings	0	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
	1	0.1 (-1.1,1.3)	0.0 (-1.1,1.2)	-0.1 (-0.7,0.5)	-0.1 (-0.7,0.5)	1.0 (-42.2,44.2)	-2.8 (-40.6,35.0)
	≥2	-2.8 (-4.8,-0.9)**	-1.4 (-3.3,0.4)	1.3 (0.3,2.3)**	0.7 (-0.3,1.6)	116.3 (37.8,194.9)**	50.5 (-11.2,112.3)
Smoking in household	Yes	-	-	-	-	40.5 (-31.5,112.5)	-
Day care attendance	0-1 d	(ref)	(ref)	-	(ref)	-	(ref)
	2-3 d	0.8 (-1.2,2.8)	0.8 (-0.7,2.3)	-	-0.3 (-1.0,0.5)	-	-28.7 (-81.0,23.7)
	≥4 d	0.3 (-1.5,2.1)	1.6 (-0.3,3.6)	-	-0.8 (-1.8,0.1)	-	-60.6 (-125.4,4.3)

Supplement Table 2. Multivariable associations of potential correlates with sedentary behavior, MVPA, and CPM on a weekday and weekend day separately (n=347) (continued)

Educational level mother	Low	-	-	-	-	-	19.2 (-65.7,104.1)
	Mid-low	-	-	-	-	-	-24.7 (-74.8,25.4)
	Mid-high	-	-	-	-	-	-8.3 (-53.5,36.8)
	High	-	-	-	-	-	(ref)
Employment status mother	No paid job	-	-	-	-	-2.0 (-67.3,63.4)	-
Household income	<€2000	-	-1.4 (-3.4,0.6)	-	0.5 (-0.5,1.5)	-13.3 (-87.9,61.2)	36.0 (-32.3,104.2)
	€2000-3300	-	-0.8 (-2.1,0.5)	-	0.2 (-0.4,0.8)	21.6 (-21.4,64.5)	26.4 (-16.6,69.4)
	>€3300	-	(ref)	-	(ref)	(ref)	(ref)
Physical environment							
Season	Spring	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
	Summer	-0.9 (-2.4,0.5)	-0.2 (-1.6,1.3)	0.6 (-0.1,1.4)	0.3 (-0.4,1.0)	43.7 (-11.3,98.7)	10.5 (-37.8,58.8)
	Fall	-2.0 (-3.6,-0.4)*	0.9 (-0.6,2.5)	1.3 (0.5,2.2)**	-0.3 (-1.1,0.5)	84.3 (25.0,143.5)**	-30.5 (-84.4,23.3)
	Winter	1.1 (-0.4,2.5)	2.3 (0.9,3.7)**	-0.5 (-1.2,0.3)	-1.0 (-1.8,-0.3)**	-32.0 (-86.0,21.9)	-71.4 (-119.8,-23.0)**

Table is based on imputed dataset.

† Values are betas and 95% confidence intervals. Betas represent the differences in sedentary behavior, MVPA, and CPM per one unit increase in correlates or relative to reference group.

* p<0.05 **p<0.01.

CHAPTER

4.2

SOCIAL INEQUALITIES IN YOUNG CHILDREN'S SPORTS PARTICIPATION AND OUTDOOR PLAY

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Abstract

Objective: Research on social inequalities in sports participation and unstructured physical activity among young children is scarce. This study aimed to assess the associations of family socioeconomic position (SEP) and ethnic background with children's sports participation and outdoor play.

Methods: We analyzed data from 4726 ethnically diverse 6-year-old children participating in the Generation R Study. Variables were assessed by parent-reported questionnaires when the child was 6 years old. Low level of outdoor play was defined as outdoor play <1 hour per day. Series of multiple logistic regression analyses were performed to assess associations of family SEP and ethnic background with children's sports participation and outdoor play.

Results: Socioeconomic inequalities in children's sports participation were found when using maternal educational level ($p<0.05$), paternal educational level ($p<0.05$), maternal employment status ($p<0.05$), and household income ($p<0.05$) as family SEP indicator (less sports participation among low SEP children). Socioeconomic inequalities in children's outdoor play were found when using household income only ($p<0.05$) (more often outdoor play <1 hour per day among children from low income household). All ethnic minority children were significantly more likely to not to participate in sports and play outdoor <1 hour per day compared with native Dutch children. Adjustment for family SEP attenuated associations considerably, especially with respect to sports participation.

Conclusion: Low SEP children and ethnic minority children are more likely not to participate in sports and more likely to display low levels of outdoor play compared with high SEP children and native Dutch children, respectively. In order to design effective interventions, further research, including qualitative studies, is needed to explore more in detail the pathways relating family SEP and ethnic background to children's sports participation and outdoor play.

Introduction

Regular engagement in physical activity in childhood is associated with multiple physical and psychosocial health benefits, including improved academic performance, improved cardiorespiratory fitness, skeletal health, muscle strength, and motor skills, and a decreased risk of childhood overweight and obesity [1-5]. In addition to making an important contribution to overall physical activity, specific physical activity behaviors such as sports participation (team sports in particular) and unstructured play (outdoor play in particular) are assumed to bring about additional health benefits including increased social integration, teamwork and social skills, emotional control, confidence, discipline, empathy, and emotional well-being [6-8].

Studies on sports participation consistently show that children from families with a low socioeconomic position (SEP) [9-16] and ethnic minority children [9,12,17] participate less often in organized sports compared with high SEP children and ethnic majority children. Research on the associations of family SEP [13,18-20] and ethnic background [17,19] with children's outdoor play is more scarce and conflicting, possible due to the use of different indicators of SEP [13,18-20]. Furthermore, previous research on the associations of ethnic background with children's sports participation and outdoor play have either been conducted in the US [12,19], which hampers generalization to ethnic minority groups in Europe, or in Europe comparing heterogeneous groups of ethnic minority children (native versus non-native children [9,17]), which hampers effect evaluation for specific ethnic minority groups. As migration histories and cultural backgrounds differ substantially between children from different ethnic minority groups, these children may display very different physical activity behaviors.

In the present study, we aimed to assess the associations of family SEP, as indicated by parental educational level, parental employment status, and household income, and ethnic background with sports participation and outdoor play among 6-year-old ethnically diverse children. Data were used from the Generation R Study, a multi-ethnic prospective birth cohort in Rotterdam, the Netherlands.

Methods

Study design

This cross-sectional study was embedded in the Generation R Study, a population-based prospective cohort study from fetal life onwards. The Generation R Study was designed to identify early environmental and genetic determinants of growth, development and health, and has been described previously in detail [21]. The study was conducted in accordance with the guidelines proposed in the World Medical Association Declaration of Helsinki and has been approved by the Medical Ethical Committee at Erasmus MC, University Medical Center Rotterdam. Written informed consent was obtained from all participants [21].

Study population

Invitations to participate in the study were sent out to all pregnant women who had an expected delivery date between April 2002 and January 2006 and who lived in the study area (Rotterdam, the Netherlands) at time of delivery. In total, 8305 children from the original 9749 known live born children of the Generation R cohort participate in the school aged period from 5 years onwards [21]. For the purpose of this study, we selected children born to mothers with a native Dutch, Surinamese-Creole, Surinamese-Hindustani, Dutch Antillean, Cape Verdean, Turkish, or Moroccan ethnic background (n=6447). These ethnic groups were chosen because they represent the largest ethnic groups in the Generation R Study, as well as in the city of Rotterdam [21]. We excluded children with missing data on both sports participation and outdoor play (n=1322). To avoid clustering of data, we furthermore excluded second (n=392) and third children (n=7) of the same mother, leaving a study population of 4726 participants. Of those, 4685 participants had information on sports participation and 3903 participants had information on outdoor play.

Family socioeconomic position and ethnic background

Family SEP and ethnic background were assessed by parent-reported questionnaires when the child was 6 years old. Indicators of family SEP included maternal and paternal educational level (highest level attained), maternal and paternal employment status (no paid job, paid job), and net household income (<€2000/month [i.e. below modal income [22]], €2000-€3200/month, >€3200/month). The Dutch Standard Classification of Education was used to categorize four levels of education: low (no education, primary school, lower vocational training, intermediate general school, or three years or less general secondary school), mid-low (more than three years general secondary school, intermediate vocational training, or first year of higher vocational training), mid-high (higher vocational training) and high (university or PhD degree) [23]. Children's ethnic background was based on the ethnic background of their mothers to take into account the cultural background of the mothers (most often primary caregivers). In accordance with Statistics Netherlands, a mother was considered nonnative Dutch if one of her parents was born abroad. If both parents were born abroad, country of birth of the mother's mother decided on maternal ethnic background [24].

Sports participation and outdoor play

Children's sports participation (yes, no) and outdoor play were assessed by parent-reported questionnaire when the child was 6 years old (Supplement Table 1). School-based organized activities such as physical educational lessons and swimming lessons were assessed separately and thus not included in the question on sports participation. For outdoor play, frequency (i.e. number of days) and duration (never, less than 30 minutes, 30-60 minutes, 1-2 hours, 2-3 hours, 3-4 hours) were asked for weekdays and weekend days separately. The middle number of hours of each category (e.g. 2.5 hours for 2-3 hours) was used to estimate the duration of a session. These variables were combined to estimate daily outdoor play by using the following formula: daily use= ([(days per week) * (hours on a weekday)] + [(days per weekend) * (hours on a weekend day)]) / 7. Due to a skewed distribution, this variable was then dichotomized into <1 hour per day (i.e. low level of outdoor play) versus ≥1 hour per day.

Potential confounders

Child's sex, child's age, and season at measurement (summer, fall, winter, spring) were considered potential confounders in the associations of family SEP and ethnic background with children's outdoor play and sports participation. When assessing the association between family SEP and children's physical activity behaviors, ethnic background was considered a potential confounder, and vice versa. The hypothesized interrelationships between all variables are presented in Figure 1.

Statistical analyses

Descriptive statistics were used to characterize the study population. Sports participation and outdoor play according to family SEP and ethnic background were evaluated by Chi-square tests. The associations of family SEP with children's sports participation and outdoor play were assessed using series of multiple logistic regression models. The first set of models included each indicator of family SEP separately (i.e. crude models). The second set of models were adjusted for confounders, including ethnic background, age of the child, and season of measurement (i.e. basic models). Finally, the independent effects of SEP indicators were assessed by model adjusted for all SEP indicators (i.e. full model). Similar series of multiple logistic regression models were carried out to investigate the associations of ethnic background with both physical activity behaviors. A crude model contained ethnic background only. A basic model was adjusted for confounders, including age of the child and season at measurement. Finally, the full model additionally adjusted for all indicators of family SEP. This stepwise adjustment was used to gain insight into the separate confounding effects of SEP, a construct highly related with ethnic background [25-27]. Child's sex did not affect the effect estimates; therefore, this variable was left out of the analyses [28]. Collinearity between maternal educational level, paternal educational level, and income were assessed by pair-wise Spearman's rho correlation coefficients (r>0.8). Size of the correlation coefficients did not indicate collinearity (0.54-0.60) and therefore these variables were included in the full models simultaneously. To handle missing data in the data, multiple imputation was applied [29]. Five imputed datasets were generated using a fully conditional specified model, thus taking into account the uncertainty of the imputed values. Pooled estimates from these five imputed datasets were used to report effect estimates and their 95% confidence intervals (CIs). Imputations were based on the relationships between all the variables included in this study. All analyses were conducted in 2014 with Statistical Package for Social Sciences (SPSS) version 21.0 for Windows (SPSS Inc., Chicago, IL, USA). A significance level of $p<0.05$ was used to indicate significant associations.

Nonresponse analyses

Children with missing data on both sports participation and outdoor play (n=1322) were compared with children without missing data (n=5125) using Chi-square tests. Data were more often missing for children with a low maternal educational level ($\chi 2=26$, df=3, $p<0.001$), children with a low paternal educational level ($\chi 2=17$, df=3, $p<0.001$), children from a low household income ($\chi 2=23$, df=2, $p<0.001$), children with a mother

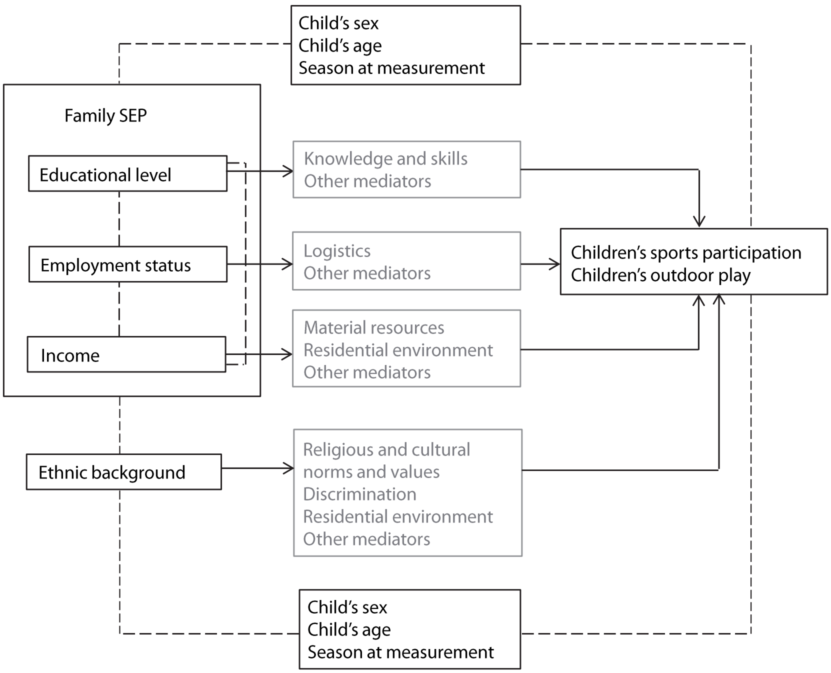

Figure 1. Hypothesized interrelationships between variables included in the study. Arrows represent hypothesized causal associations. Dotted lines represent hypothesized (non-causal) associations.

without a paid job ($\chi2=4$, df=1, $p<0.05$), children with a father without a paid job ($\chi2=6$, df=1, $p<0.05$), and ethnic minority children ($\chi2=470$, df=6, $p<0.001$).

Results

Table 1 shows characteristics of the study population. One third of the children were non-native Dutch (29.4%). Nearly half of children had a mother with a low or mid-low educational level (45.7%). A quarter of children belonged to a household with a net income of less than 2000 euro per month (24.1%). A little over half of the children did not participate in sports (56.1%) and a third of children played outdoors <1 hour per day (33.7%). The prevalence of sports participation was lower, and the prevalence of outdoor play <1 hour per day higher, among low SEP children and ethnic minority children (Table 2).
Children of mid-high, mid-low, and low educated mothers were more likely not to participate in sports compared with children of high educated mothers, with children of low educated mothers showing the highest odds (OR: 2.73; 95% CI: 2.18,3.42) (basic model, Table 3). Similar results were found for paternal educational level. Children from low income households (OR: 2.18; 95% CI: 1.82,2.61) and middle income households (OR: 1.97; 95% CI: 1.70,2.29) were more likely not to participate in sports compared with children living in high income households. Finally, children of mothers without a paid job were more likely not to participate in sports compared with children of mothers with a paid job (OR: 1.23; 95% CI: 1.06,1.44). Children from low income households had increased odds of outdoor play <1 hour per day compared with children from high income households (OR: 1.32; 95% CI: 1.07,1.64). Independent SEP associations with children's participation in sports and outdoor play were found for maternal educational level (sports participation and outdoor play), paternal educational level (sports participation), and household income (sports participation and outdoor play) (full model, Table 3).
All ethnic minority children were more likely not to participate in sports compared with native Dutch children, with the highest odds for Turkish children (OR: 3.16; 95% CI: 2.51,3.98) (basic model, Table 4). Additional analyses showed that Turkish children did not significantly differ from Moroccan children and Dutch Antillean children (data not shown). Adjustment for family SEP attenuated the associations considerably for all ethnic minority groups, rendering some associations non-significant (i.e. for Surinamese-Creole, Surinamese-Hindustani, and Cape Verdean children) (full model, Table 4). All ethnic minority children were more likely to play outdoors <1 hour per day compared with native Dutch children, with Turkish children displaying the highest odds (OR: 3.56; 95% CI: 2.76,4.58). Turkish children did not significantly differ from Moroccan children and Cape Verdean children (data not shown). Adjustment for SEP attenuated the associations slightly.

Table 1. Characteristics of the study population (n=4726)

		Total n (%)	Missing n (%)
Family characteristics			
Maternal educational level	High	124 (26.7)	64 (1.4)
	Mid-high	1285 (27.6)	
	Mid-low	1489 (31.9)	
	Low	643 (13.8)	
Paternal educational level	High	1393 (32.9)	493 (10.4)
	Mid-high	970 (22.9)	
	Mid-low	1138 (26.9)	
	Low	732 (17.3)	
Maternal employment status	Paid job	3342 (75.6)	305 (6.5)
	No paid job	1079 (24.4)	
Paternal employment status	Paid job	3914 (94.2)	569 (12.0)
	No paid job	243 (5.8)	
Household income	> €3200/month	2174 (49.7)	348 (7.4)
	€2000-€3200/month	1148 (26.2)	
	<€ 2000/month	1056 (24.1)	
Ethnic background	Dutch	3338 (70.6)	0
	Surinamese-Creole	163 (3.4)	
	Surinamese-Hindustani	170 (3.6)	
	Dutch Antillean	126 (2.7)	
	Cape Verdean	195 (4.1)	
	Turkish	453 (9.6)	
	Moroccan	281 (6.0)	
Child characteristics			
Sex	Girl	2338 (49.5)	0
	Boy	2388 (50.5)	
Age	Months (mean, SD)	73.0 (5.9)	0
Sports participation	Yes	2057 (43.9)	41 (0.9)
	No	2628 (56.1)	
Outdoor play	≥1 hour/day	2587 (66.3)	823 (17.4)
	<1 hour/day	1316 (33.7)	

Table is based on non-imputed dataset. Values are means (SD) for normally distributed continuous variables and frequencies (percentage) for categorical variables.

Table 2. Physical activity behaviors according to family socioeconomic position and ethnic background (n=4726)

		Sports participation (n=4685)			Outdoor play (n=3903)		
		Yes n (%)	No n (%)	P-value*	≥1 hour/day n (%)	<1 hour/day n (%)	P-value*
Maternal educational level	High	695 (56.0)	545 (44.0)	<0.001	737 (67.4)	356 (32.6)	0.06
	Mid-high	607 (47.6)	667 (52.4)		748 (68.8)	339 (31.2)	
	Mid-low	549 (37.3)	921 (62.7)		791 (64.8)	429 (35.2)	
	Low	184 (28.9)	453 (71.1)		286 (62.7)	170 (37.3)	
Paternal educational level	High	779 (56.4)	602 (43.6)	<0.001	809 (67.5)	390 (32.5)	<0.05
	Mid-high	445 (46.3)	516 (53.7)		586 (70.6)	244 (29.4)	
	Mid-low	409 (36.1)	723 (63.9)		643 (67.5)	310 (32.5)	
	Low	239 (32.9)	487 (67.1)		343 (61.9)	211 (38.1)	
Maternal employment status	Paid job	1548 (46.6)	1773 (53.4)	<0.001	1925 (67.6)	924 (32.4)	<0.01
	No paid job	389 (36.6)	674 (63.4)		514 (62.2)	313 (37.8)	
Paternal employment status	Paid job	1755 (45.2)	2129 (54.8)	<0.001	2229 (67.8)	1061 (32.2)	0.36
	No paid job	79 (32.8)	162 (67.2)		116 (64.4)	64 (35.6)	
Household income	>€3200	1169 (54.2)	988 (45.8)	<0.001	1317 (69.4)	581 (30.6)	<0.001
	€2000-<€3200	410 (36.0)	730 (64.0)		663 (68.3)	308 (31.7)	
	<€2000	329 (31.5)	715 (68.5)		417 (54.2)	352 (45.8)	
Ethnic background	native Dutch	1623 (48.9)	1693 (51.1)	<0.001	2062 (70.9)	846 (29.1)	<0.001
	Surinamese-Creole	64 (39.5)	98 (60.5)		77 (61.1)	48 (38.4)	
	Surinamese-Hindustani	62 (36.9)	106 (63.1)		78 (60.0)	52 (40.0)	
	Dutch Antillean	42 (34.1)	81 (65.9)		59 (63.4)	34 (36.6)	
	Cape Verdean	72 (36.9)	123 (63.1)		74 (51.7)	69 (48.3)	
	Turkish	114 (25.8)	328 (74.2)		143 (45.3)	173 (54.7)	
	Moroccan	80 (28.7)	199 (71.3)		94 (50.0)	94 (50.0)	

Table is based on non-imputed dataset.
*P-Values assessed by Chi-square tests.

Table 3. Associations of family SEP indicators with sports participation (no) (n=4685) and outdoor play (<1 hour/day) (n=3903)

	Sports participation (no)			Outdoor play (<1 hour/day)		
	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)
Maternal educational level						
High (ref)	1.00	1.00	1.00	1.00	1.00	1.00
Mid-high	**1.40 (1.20,1.64)**	**1.33 (1.13,1.55)**	1.07 (0.90,1.27)	0.94 (0.78,1.12)	0.85 (0.70,1.03)	0.85 (0.69,1.04)
Mid-low	**2.14 (1.84,2.50)**	**1.95 (1.65,2.29)**	**1.28 (1.05,1.55)**	1.13 (0.95,1.35)	0.88 (0.72,1.07)	0.82 (0.64,1.04)
Low	**3.17 (2.58,3.89)**	**2.73 (2.18,3.42)**	**1.65 (1.26,2.17)**	1.25 (1.00,1.57)	0.78 (0.60,1.02)	**0.67 (0.49,0.92)**
Paternal educational level						
High (ref)	1.00	1.00	1.00	1.00	1.00	1.00
Mid-high	**1.49 (1.26,1.77)**	**1.45 (1.22,1.72)**	**1.25 (1.05,1.50)**	0.88 (0.72,1.08)	0.84 (0.68,1.04)	0.86 (0.68,1.08)
Mid-low	**2.31 (1.97,2.72)**	**2.20 (1.85,2.61)**	**1.59 (1.29,1.95)**	1.04 (0.87,1.24)	0.93 (0.76,1.14)	0.97 (0.76,1.23)
Low	**2.63 (2.19,3.14)**	**2.26 (1.85,2.76)**	**1.46 (1.16,1.83)**	**1.39 (1.13,1.70)**	1.02 (0.80,1.29)	1.05 (0.79,1.40)
Maternal employment status						
Paid job (ref)	1.00	1.00	1.00	1.00	1.00	1.00
No paid job	**1.49 (1.30,1.71)**	**1.23 (1.06,1.44)**	1.01 (0.85,1.20)	**1.25 (1.06,1.47)**	0.93 (0.77,1.12)	0.87 (0.70,1.08)
Paternal employment status						
Paid job (ref)	1.00	1.00	1.00	1.00	1.00	1.00
No paid job	**1.61 (1.26,2.07)**	1.29 (1.00,1.67)	1.08 (0.82,1.43)	1.29 (0.91,1.82)	0.96 (0.63,1.45)	0.84 (0.54,1.31)
Household income						
> €3200/month (ref)	1.00	1.00	1.00	1.00	1.00	1.00
€2000-€3200/ month	**2.08 (1.80,2.40)**	**1.97 (1.70,2.29)**	**1.52 (1.28,1.79)**	1.05 (0.88,1.24)	0.97 (0.80,1.16)	1.06 (0.86,1.31)
<€ 2000/month	**2.49 (2.14,2.90)**	**2.18 (1.82,2.61)**	**1.57 (1.27,1.94)**	**1.84 (1.56,2.18)**	**1.32 (1.07,1.64)**	**1.57 (1.21,2.04)**

Table is based on imputed dataset. Bold print indicates statistical significance. Values represent odds ratios and 95% confidence intervals derived from (multiple) logistic regression analyses. SEP=socioeconomic position.

* Adjusted for confounders (i.e. ethnic background, child's age, and season at measurement).

** Additional adjusted for other SEP indicators.

Table 4. Associations of ethnic background with sports participation (no) (n=4685) and outdoor play (<1 hour/day) (n=3903)

	Sports participation (no)			Outdoor play (<1 hour/day)		
	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)
Ethnic background						
Dutch (ref)	1.00	1.00	1.00	1.00	1.00	1.00
Surinamese-Creole	**1.47 (1.06,2.03)**	**1.66 (1.19,2.30)**	1.10 (0.78,1.55)	**1.52 (1.05,2.20)**	**1.61 (1.08,2.39)**	1.48 (0.98,2.24)
Surinamese-Hindustani	**1.64 (1.19,2.26)**	**1.82 (1.31,2.52)**	1.22 (0.87,1.72)	**1.63 (1.13,2.33)**	**1.83 (1.25,2.68)**	**1.73 (1.17,2.57)**
Dutch Antillean	**1.85 (1.27,2.70)**	**2.26 (1.53,3.33)**	**1.51 (1.01,2.26)**	1.41 (0.91,2.16)	**1.87 (1.18,2.95)**	**1.73 (1.08,2.76)**
Cape Verdean	**1.64 (1.22,2.21)**	**1.84 (1.35,2.49)**	1.08 (0.78,1.49)	**2.27 (1.62,3.19)**	**2.45 (1.71,3.50)**	**2.16 (1.47,3.17)**
Turkish	**2.76 (2.21,3.45)**	**3.16 (2.51,3.98)**	**1.92 (1.49,2.47)**	**2.95 (2.33,3.72)**	**3.56 (2.76,4.58)**	**3.55 (2.68,4.69)**
Moroccan	**2.39 (1.82,3.12)**	**2.82 (2.14,3.71)**	**1.70 (1.26,2.30)**	**2.44 (1.81,3.28)**	**2.72 (1.98,3.75)**	**2.59 (1.83,3.66)**

Table is based on imputed dataset. Bold print indicates statistical significance. Values represent odds ratios and 95% confidence intervals derived from (multiple) logistic regression analyses. SEP=socioeconomic position.
* Adjusted for basic confounders (i.e. child's age, and season at measurement).
** Additionally adjusted for all SEP indicators.

Discussion

In this study, we aimed to assess the associations of family SEP, as indicated by parental educational level, parental employment status, and household income, and ethnic background with children's sports participation and outdoor play. Low SEP children and ethnic minority children were more likely not to participate in sports and more likely to display low levels of outdoor play compared with high SEP children and native Dutch children, respectively. Associations of family SEP with children's sports participation and outdoor play differed according to SEP indicator, especially regarding outdoor play.

Socioeconomic inequalities in sports participation and outdoor play

Our finding of an association between family SEP and children's sports participation is in line with earlier research that showed low SEP children to participate in organized sports less often compared with high SEP children [9-16]. Congruent with our results, this association was consistently found irrespective of indicator of SEP (e.g. parental educational level, parental occupation, income, or a composite measures of SEP) [9-16]. In contrast, we found that the association between family SEP and children's outdoor play differed according to SEP indicator, with (only) a low household income predicting low levels of outdoor play. Such inconsistencies between SEP indicators have been observed previously [19], and may account for the discrepant results in previous studies on socioeconomic inequalities in children's outdoor play [13,18-20]. The results of this study therefore highlight the need for the use of different SEP indicators when investigating socioeconomic inequalities in young children's physical activity behaviors, outdoor play in particular [30-32].

Reduction of socioeconomic inequalities in children's sports participation and outdoor play requires knowledge on the underlying pathways [33]. Previous research on the perceived barriers and challenges of engaging in physical activity has shown that low SEP children and their parents experience multiple barriers from different domains, including, but not limited to, time management and scheduling demands, financial barriers, family obligations, lack of adult involvement, lack of control, and environmental barriers (e.g. lack of sports facilities and playgrounds and safety issues) [34-37]. By assessing the independent associations of different SEP indicators with children's sports participation and outdoor play, the current study may provide some preliminary insights into these different pathways [30-32,38,39].

Independent associations with children's sports participation were found for parental educational level and household income. A high household income is likely to represent necessary resources for participation in organized sports [32]. In the Netherlands, participation in organized sports involves multiple expenses, including membership fees, costs of sports gear and attributes, and costs associated with transportation [40-42]. Indeed, financial barriers are often mentioned as a major factor restricting sports participation among children from low-income families [35,40-42]. Furthermore, a high income may represent a more favorable residential environment with (quality) sports facilities in the nearby neighborhood [36,37]. With respect to a high parental educational level, we hypothesize that knowledge (e.g. with respect to the health benefits of children's sports participation), attitudes, and skills (e.g. favorable parenting practices) may represent some of the contributing mechanisms [13,30-32,38]. Low educated parents may also lack the awareness of existent funding opportunities [43], which may help explain why financial barriers remain an important obstacle even in the presence of such funding [35,40-42].

Independent associations with children's outdoor play were found for maternal educational level and household income. A high income household may indicate the ability to purchase play material (e.g. bicycles and jumping ropes) or may represent a residential environment suitable for children's outdoor play [32]. Previous studies have shown that favorable attributes of the physical environment, such as access to recreational facilities, presence of sidewalks, controlled intersections, low crime rates, and area affluence positively influence children's physical activity [44]. With respect to maternal educational level, we hypothesize that low educated mothers may have more free time (e.g. due to unemployment) that enables them to supervise outdoor play of their children [19]. Although maternal employment is often used to capture these work related components of SEP [31,32], the current operationalization (paid job, no paid job) may not have been sufficiently sensitive. We have conducted sensitivity analyses using a more elaborate variable for employment (i.e. no paid job, paid job part-time [<36 hours/week], and paid job full-time [≥ 36 hours/week]), and found highly similar results (data not shown).

In sum, the finding of independent associations of parental educational level and household income with children's sports participation and outdoor play indicate different potential pathways relating family SEP to these behaviors. Further research, including both quantitative studies performing formal mediation analyses and qualitative studies, are warranted to provide a deeper understanding of the mechanisms driving the associations of family SEP with children's participation in sports and outdoor play.

Ethnic inequalities in sports participation and outdoor play

In accordance with previous research [9,12,17,19], results of the current study showed that ethnic minority children were more likely not to participate in sports and display low levels of outdoor play compared with native Dutch children. Our results disagree with the results of an Australian study that failed to find an association between ethnic background (indigenous versus non-indigenous) and children's sports participation [15], although this study did find a positive association between main language spoken in home (English) and sports participation. Furthermore, a Danish study found that 6- to 7-year-old non-native Danish children more often played outdoors than Danish children [17]. However, this study did not take into account time spent playing outdoors [17]. In addition to extending the limited evidence base on ethnic inequalities in children's sports participation and outdoor play, the current study adds by showing that the effects of ethnic background are not uniform across all ethnic minority groups.

Family SEP contributed substantially to the observed ethnic inequalities in sports participation and to a lesser extent to the observed inequalities in outdoor play. These results are in accordance with our finding of more consistent (and more substantial) socioeconomic influences on sports participation than outdoor play. Even though adjustment for family SEP rendered some associations non-significant, we postulate that this may be a consequence of power problems due to low numbers of participants in these groups, rather than full explanation by family SEP.

Over and beyond potential mechanisms related to family SEP, the observed ethnic inequalities may further be explained by variables specifically associated with ethnic minority background, including (amongst others) acculturation characteristics (e.g. language, generational status, length of stay in host country, stressful experiences related to migration and resettlement), religion based norms and values, cultural based norms and values, and discrimination processes [45-47]. For example, parental participation in club-organized sports, as an indicator of experience with and knowledge about the participation in sports, has been shown to be an important mediator in the association between ethnic background and sports participation among children [17]. Also, ethnic minority children more often live in disadvantaged neighborhoods with high crime rates compared with ethnic majority children, which may negatively affect outdoor play due to parental safety concerns or lack of (safe and attractive) physical activity opportunities [48-50].

Previous research in older school-aged children and adolescents has shown that ethnic background may interact with child's sex in influencing children's physical activity, sports participation in particular [51,52]. We explored this issue using multiple logistic regression models including interaction terms between ethnic background and child's sex. Contrary to these previous studies, we did not find significant interaction effects between ethnic background and child's sex (both $p>0.05$, data not shown), suggesting that sex differences in the associations of ethnic background with sports participation and outdoor play are not yet present at such a young age.

Study strengths and limitations

A major strength of this study is the large sample of children of different socioeconomic and ethnic backgrounds. Several limitations should be considered when interpreting the findings. First, nonresponse analyses showed that low SEP children and ethnic minority children more often had missing data on both physical activity behaviors. Selection bias may have occurred if the associations of family SEP and ethnic background with children's physical activity behaviors are different for participants and non-participants; however, this is difficult to ascertain.

Second, information bias in the outcome variables may have occurred due to a number of reasons. Because parent-reported questionnaires were used to assess children's sports participation and outdoor play, social desirable answering (i.e. the over reporting of favorable behaviors) cannot be excluded. Moreover, outdoor play is likely to also occur in settings other than the home environment (e.g. school and after-school care), and therefore parents' report of outdoor play may have been an underestimation of total outdoor play. Furthermore, data on outdoor play were dichotomized based on the distribution of these data. Existent guidelines for physical activity among youth (5-17 years) specify a recommended amount of at least 1 hour per day of moderate-to-vigorous physical activity [53-56]. As there are no guidelines on outdoor play specifically, we used this cut-off point. However, it should be acknowledged that only parts of outdoor play are spent in moderate-to-vigorous physical activity [57]. Also, the use of a dichotomized variable may have potentially led to a loss of information and statistical power to detect associations. Sensitivity analyses using dichotomized data with a different cut-off point (i.e. 2 hours per day) and continuous data yielded highly similar results (Supplement Table 2).

Third, SEP is a complex, multidimensional construct that can be described and measured in numerous ways [30-32]. In order to assess the association between family SEP and children's sports participation and outdoor play, we used the commonest individual-level indicators, i.e. educational level, income, and occupation (employment). Inclusion of other individual-level (e.g. housing characteristics) or even area-level indicators (e.g. neighborhood SEP) may have provided further insights into potential mechanisms underlying the observed associations; however, information on these variables was not available for the current study. A related argument concerns the adjustment for family SEP when assessing ethnic inequalities in health and health behaviors. As suggested by other scholars, adjustment for SEP should ideally capture all dimensions of SEP and failure to do so may lead to residual confounding [25-27]. Also, SEP indicators may mediate the effects of other SEP indicators [38]. For example, educational level may influence employment which may in turn influence income. In this case, the latter two indicators would be considered mediators.

Fourth, the results presented in this study were based on a multiple imputed dataset. In addition to preventing loss of information, multiple imputation also deals with potential bias associated with missing data [29]. Sensitivity analyses using complete data showed similar results to the imputed data (Supplement Tables 3 and 4).

Finally, given that the current results are context specific (e.g. due to the organization of sports and distribution of resources across social groups), caution should be taken when generalizing the current results to other populations.

Conclusion

Low SEP children and ethnic minority groups are more likely not to participate in sports and more likely to display low levels of outdoor play compared with high SEP children and native Dutch children, respectively. These results indicate that low SEP children and ethnic minority children represent important target groups for interventions designed to promote young children's physical activity. In order to design effective interventions, further research, including qualitative studies, is needed to explore more in detail the pathways relating family SEP and ethnic background to children's sports participation and outdoor play.

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Supplement Table 1. Assessment of sports participation and outdoor play

Questions	Answer categories
"Does your child take part in sports (for example. football, judo, gymnastics, jazz ballet, tennis, etc)?"	Yes
	No
"On average, how many weekdays per week does your child play outside?"	Never on weekdays
	1 day per week
	2 days per week
	3 days per week
	4 days per week
	Every weekday
"On average, how many weekend days per week does your child play outside?"	Never in the weekend
	1 day in the weekend
	2 days in the weekend
"On the days that your child plays outside, how long, on average, does your child play outside? Differentiate between weekdays and weekend days and answer according to the present season."	Never
(Answer categories for weekdays and weekend days separately)	Less than 30 minutes
(Answer categories for mornings, afternoons and evenings after dinner separately)	30-60 minutes
	1-2 hours
	2-3 hours
	3-4 hours

Supplement Table 2. Associations of family SEP indicators and ethnic background with outdoor play (n=3903)

	Outdoor play (<2 hours/day)			Outdoor play (hours per day)		
	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)	Crude model β (95% CI)	Basic model* β (95% CI)	Full model** β (95% CI)
Maternal educational level						
High (ref)	1.00	1.00	1.00	0.00	0.00	0.00
Mid-high	0.84 (0.69,1.01)	**0.76 (0.63,0.93)**	**0.75 (0.61,0.93)**	**0.11 (0.01,0.21)**	**0.16 (0.07,0.25)**	**0.15 (0.05,0.25)**
Mid-low	**0.68 (0.57,0.81)**	**0.55 (0.45,0.68)**	**0.55 (0.43,0.70)**	**0.23 (0.13,0.33)**	**0.35 (0.26,0.45)**	**0.33 (0.22,0.44)**
Low	**0.68 (0.54,0.87)**	**0.48 (0.37,0.63)**	**0.49 (0.36,0.68)**	**0.20 (0.07,0.33)**	**0.42 (0.30,0.55)**	**0.40 (0.25,0.55)**
Paternal educational level						
High (ref)	1.00	1.00	1.00	0.00	0.00	0.00
Mid-high	0.95 (0.78,1.16)	0.95 (0.77,1.18)	1.05 (0.84,1.33)	0.06 (-0.05,0.17)	**0.25 (0.13,0.37)**	0.01 (-0.09,0.12)
Mid-low	**0.77 (0.65,0.92)**	**0.73 (0.60,0.89)**	0.91 (0.72,1.15)	**0.19 (0.09,0.30)**	**0.24 (0.14,0.33)**	**0.12 (0.01,0.23)**
Low	0.89 (0.71,1.11)	**0.72 (0.56,0.92)**	0.96 (0.72,1.28)	0.09 (-0.03,0.21)	0.06 (-0.04,0.17)	0.11 (-0.03,0.24)
Maternal employment status						
Paid job (ref)	1.00	1.00	1.00	0.00	0.00	0.00
No paid job	0.89 (0.75,1.05)	**0.72 (0.59,0.87)**	**0.76 (0.62,0.94)**	0.01 (-0.08,0.10)	**0.13 (0.04,0.23)**	**0.10 (0.01,0.20)**
Paternal employment status						
Paid job (ref)	1.00	1.00	1.00	0.00	0.00	0.00
No paid job	1.01 (0.72,1.40)	0.86 (0.58,1.27)	0.86 (0.57,1.29)	-0.03 (-0.21,0.16)	0.14 (-0.04,0.31)	0.15 (-0.03,0.33)
Household income						
> €3200/month (ref)	1.00	1.00	1.00	0.00	0.00	0.00
€2000-€3200/ month	0.88 (0.74,1.04)	0.85 (0.71,1.01)	1.12 (0.91,1.37)	**0.10 (0.00,0.19)**	**0.12 (0.03,0.21)**	-0.05 (-0.15,0.05)
<€ 2000/month	1.13 (0.95,1.36)	0.87 (0.70,1.08)	**1.31 (1.01,1.70)**	**-0.14 (-0.24,-0.04)**	0.05 (-0.06,0.15)	**-0.21 (-0.34,-0.08)**

Supplement Table 2. Associations of family SEP indicators and ethnic background with outdoor play (n=3903) (continued)

Ethnic background	Crude model OR (95% CI)	Basic model*** OR (95% CI)	Full model**** OR (95% CI)	Crude model β (95% CI)	Basic model*** β (95% CI)	Full model**** β (95% CI)
Dutch (ref)	1.00	1.00	1.00	0.00	0.00	0.00
Surinamese-Creole	1.21 (0.81,1.79)	1.30 (0.85,1.97)	1.49 (0.97,2.30)	-0.19 (-0.40,0.03)	**-0.22 (-0.42,-0.02)**	**-0.32 (-0.52,-0.11)**
Surinamese-Hindustani	1.44 (0.96,2.15)	**1.61 (1.05,2.45)**	**1.86 (1.21,2.87)**	**-0.30 (-0.51,-0.09)**	**-0.35 (-0.54,-0.15)**	**-0.45 (-0.65,-0.25)**
Dutch Antillean	1.13 (0.72,1.78)	1.54 (0.96,2.46)	**1.85 (1.13,3.02)**	-0.07 (-0.31,0.18)	**-0.24 (-0.47,-0.01)**	**-0.34 (-0.57,-0.10)**
Cape Verdean	**1.76 (1.18,2.65)**	**1.91 (1.25,2.92)**	**2.32 (1.48,3.62)**	**-0.40 (-0.60,-0.20)**	**-0.40 (-0.59,-0.22)**	**-0.52 (-0.71,-0.32)**
Turkish	**1.63 (1.24,2.14)**	**1.87 (1.40,2.49)**	**2.50 (1.83,3.42)**	**-0.40 (-0.54,-0.26)**	**-0.45 (-0.58,-0.32)**	**-0.60 (-0.74,-0.46)**
Moroccan	**2.38 (1.61,2.51)**	**2.78 (1.85,4.17)**	**3.67 (2.38,5.66)**	**-0.51 (-0.68,-0.33)**	**-0.54 (-0.71,-0.38)**	**-0.69 (-0.87,-0.52)**

Table is based on imputed dataset. Bold print indicates statistical significance. Values represent odds ratios (95% confidence intervals) derived from (multiple) logistic regression analyses and betas (95% confidence intervals) derived from (multiple) linear regression analyses. SEP=socioeconomic position.
* Adjusted for confounders (i.e. child's age, and season at measurement, and ethnic background).
** Additionally adjusted for all SEP indicators.
*** Adjusted for confounders (i.e. child's age and season at measurement).
**** Additionally adjusted for al SEP indicators.

Supplement Table 3. Associations of family SEP indicators with sports participation (no) (n=4685) and outdoor play (<1 hour/day) (n=3903)

	Sports participation (no)			Outdoor play (<1 hour/day)		
	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)
Maternal educational level	n=4621	n=4621	n=3583	n=3856	n=3856	n=3064
High	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Mid-high	**1.40 (1.20,1.64)**	**1.32 (1.13,1.55)**	1.14 (0.95,1.37)	0.94 (0.78,1.12)	0.85 (0.70,1.03)	0.83 (0.67,1.04)
Mid-low	**2.14 (1.83,2.50)**	**1.94 (1.65,2.29)**	**1.25 (1.01,1.56)**	1.12 (0.95,1.33)	0.88 (0.73,1.08)	0.83 (0.64,1.07)
Low	**3.14 (2.56,3.85)**	**2.71 (2.16,3.39)**	**1.91 (1.37,2.65)**	1.23 (0.78,1.12)	0.78 (0.60,1.02)	0.74 (0.51,1.08)
Paternal educational level	n=4200	n=4200	n=3583	n=3536	n=3536	n=3064
High	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Mid-high	**1.50 (1.27,1.77)**	**1.46 (1.24,1.73)**	**1.21 (1.00,1.47)**	0.86 (0.71,1.05)	0.84 (0.68,1.03)	0.82 (0.65,1.03)
Mid-low	**2.29 (1.95,2.69)**	**2.21 (1.87,2.62)**	**1.52 (1.23,1.87)**	1.00 (0.83,1.20)	0.95 (0.77,1.16)	0.93 (0.72,1.20)
Low	**2.64 (2.19,3.18)**	**2.32 (1.89,2.85)**	**1.44 (1.10,1.87)**	**1.28 (1.04,1.57)**	1.02 (0.80,1.30)	1.04 (0.76,1.42)
Maternal employment status	n=4384	n=4384	n=3583	n=3676	n=3676	n=3064
Paid job	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
No paid job	**1.51 (1.31,1.74)**	**1.27 (1.09,1.48)**	0.97 (0.80,1.18)	**1.27 (1.08,1.49)**	0.94 (0.78,1.13)	0.94 (0.75,1.18)
Paternal employment status	n=4125	n=4125	n=3583	n=3470	n=3470	n=3064
Paid job	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
No paid job	**1.69 (1.28,2.23)**	**1.36 (1.01,1.82)**	1.13 (0.80,1.60)	1.16 (0.85,1.59)	0.91 (0.64,1.29)	1.00 (0.68,1.49)
Household income	n=4341	n=4341	n=3583	n=3638	n=3638	n=3064
> €3200/month	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
€2000-€3200/ month	**2.11 (1.82,2.44)**	**1.99 (1.71,2.32)**	**1.62 (1.35,1.94)**	1.05 (0.89,1.24)	0.96 (0.80,1.16)	1.01 (0.81,1.26)
<€ 2000/month	**2.57 (2.20,3.00)**	**2.28 (1.89,2.74)**	**2.20 (1.69,2.88)**	**1.91 (1.61,2.27)**	**1.36 (1.10,1.69)**	**1.48 (1.09,2.01)**

Table is based on non-imputed dataset. Bold print indicates statistical significance. Values represent odds ratios and 95% confidence intervals derived from (multiple) logistic regression analyses. SEP=socioeconomic position.

* Adjusted for confounders (i.e. ethnic background, child's age, and season at measurement).

** Additional adjusted for other SEP indicators.

Supplement Table 4. Associations of ethnic background with sports participation (no) (n=4685) and outdoor play (<1 hour/day) (n=3903)

	Sports participation (no)			Outdoor play (<1 hour/day)		
	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)
Ethnic background	n=4685	n=4685	n=3583	n=3903	n=3903	n=3064
Dutch	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Surinamese-Creole	**1.47 (1.06,2.03)**	**1.66 (1.19,2.30)**	0.95 (0.59,1.53)	**1.52 (1.05,2.20)**	**1.61 (1.08,2.39)**	1.58 (0.90,2.76)
Surinamese-Hindustani	**1.64 (1.19,2.26)**	**1.82 (1.31,2.52)**	1.36 (0.90,2.05)	**1.63 (1.13,2.33)**	**1.83 (1.25,2.68)**	1.33 (0.83,2.14)
Dutch Antillean	**1.85 (1.27,2.70)**	**2.26 (1.53,3.33)**	1.23 (0.69,2.21)	1.41 (0.91,2.16)	**1.87 (1.18,2.95)**	1.09 (0.54,2.21)
Cape Verdean	**1.64 (1.22,2.21)**	**1.84 (1.35,2.49)**	0.81 (0.52,1.27)	**2.27 (1.62,3.19)**	**2.45 (1.71,3.50)**	**1.88 (1.11,3.18)**
Turkish	**2.76 (1.21,3.45)**	**3.16 (2.51,3.98)**	**1.69 (1.25,2.29)**	**2.95 (2.33,3.73)**	**3.56 (2.76,4.58)**	**3.84 (2.75,5.36)**
Moroccan	**2.39 (1.82,3.12)**	**2.82 (2.14,3.71)**	1.33 (0.92,1.92)	**2.44 (1.81,3.28)**	**2.72 (1.98,3.75)**	**2.37 (1.55,3.63)**

Table is based on non-imputed dataset. Bold print indicates statistical significance. Values represent odds ratios and 95% confidence intervals derived from (multiple) logistic regression analyses. SEP=socioeconomic position.

* Adjusted for basic confounders (i.e. child's age, and season at measurement).

** Additionally adjusted for all SEP indicators.

INEQUALITIES

LIFESTYLE

AND

BEHAVIORS

CHILDHOOD

OVERWEIGHT

5

SOCIAL INEQUALITIES IN CHILDREN'S DIETARY BEHAVIORS

YOUNG

SOCIAL

CHILDREN'S

IN

CHAPTER

5.1

MATERNAL EDUCATIONAL LEVEL AND PRESCHOOL CHILDREN'S CONSUMPTION OF HIGH-CALORIE SNACKS AND SUGAR-CONTAINING BEVERAGES: MEDIATION BY THE FAMILY FOOD ENVIRONMENT

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Abstract

Objective: To examine the associations between maternal educational level and preschoolers' consumption of high-calorie snacks and sugar-containing beverages, and to assess the mediating effects of variables relating to the family food environment.

Methods: We analyzed data from 2814 native Dutch preschoolers enrolled in a birth cohort study in Rotterdam (the Netherlands), between 2002 and 2006. Logistic regression models were used to calculate odds ratios of snacking ≥2 times/day and consuming sugar-containing beverages ≥3 glasses/day for children of mothers with low, mid-low, and mid-high educational levels (reference group: high educational level), before and after adjustment for mediators.

Results: Children of low and mid-low educated mothers were significantly more likely to consume excessive amounts of high-calorie snacks and sugar-containing beverages compared with children of high educated mothers, with the highest odds in children of low educated mothers (OR: 2.44; 95% CI: 1.84, 3.23 and OR: 2.46; 95% CI: 1.87, 3.24, respectively). Parental feeding practices, parental consumption of sugar-containing beverages, and children's television time partly explained these associations.

Conclusion: Maternal educational level is inversely related to preschoolers' consumption of high-calorie snacks and sugar-containing beverages. Targeting the family food environment may be an effective way of reducing educational inequalities in children's unhealthy dietary behaviors.

Introduction

Over the past decades, the prevalence of overweight and obesity among children has increased dramatically worldwide [1]. Coinciding with this rise in childhood overweight and obesity has been an increase in the frequency and mean intake of soft drinks and snacks among children [2,3]. These parallel developments suggest that unhealthy dietary behaviors may partly drive the current childhood overweight epidemic. This hypothesis is supported by research that showed positive associations of consumption of soft drinks and sweet snacks with body mass index and the prevalence of overweight [4-6].

Because dietary behaviors track throughout childhood and into adolescence [7], it is important to identify high risk groups as early as possible. Studies in preschool children have shown that soft drink consumption is more common among children from low socioeconomic families [8-10]. However, less is known about the association between socioeconomic position and children's consumption of high-calorie snacks. Furthermore, only few studies have investigated intermediary factors that underlie the association between family socioeconomic position and preschool children's consumption of snacks and soft drinks [8,10]. Insight into these underlying mechanisms is crucial for the identification of modifiable determinants that may be targeted in intervention programs.

The family food environment is likely to play an important role in shaping (young) children's dietary behaviors. Studies among young children have shown that snacking and soft drink consumption are associated with parental feeding practices (e.g., parental permissiveness) and parental consumption of these foods [10-12]. Furthermore, children who watch a lot of television are more likely to consume snacks and sugar sweetened beverages [11,13]. Therefore, the first aim of this study was to examine associations between maternal educational level, as indicator of family socioeconomic position (SEP), and consumption of high-calorie snacks and sugar containing beverages in 4-year-old preschool children. Second, we aimed to assess to what extent parental feeding practices, parental consumption, and children's television viewing time mediate these associations.

Methods

Study design

This study was embedded in the Generation R Study, a population-based prospective cohort study from fetal life onwards. The Generation R Study was designed to identify early environmental and genetic determinants of growth, development and health, and has been described previously in detail [14]. The study was conducted in accordance with the guidelines proposed in the World Medical Association Declaration of Helsinki and has been approved by the Medical Ethical Committee at Erasmus MC, University Medical Center Rotterdam. Informed consent was obtained from all participants.

Study population

Invitations to participate in the study were made to all pregnant women who had an expected delivery date between April 2002 and January 2006 and who lived in the study area (Rotterdam, the Netherlands) at time of delivery. Postnatal consent was obtained for 7295 children of the original 9745 live born children of the Generation R cohort [14]. As socioeconomic inequalities in dietary behaviors may vary according to ethnic background [15], children of Dutch mothers were selected for analyses (n = 3787). We excluded participants with missing information on maternal educational level (n = 19) and with missing information on both snacking and consumption of sugar-containing beverages (n = 627). To avoid clustering of data, we also excluded second (n = 319) and third children (n = 8) of the same mother, leaving a study population of 2814 participants. Of these, 2759 participants had information on snacking and 2778 participants had information on sugar-containing beverage consumption.

Family socioeconomic position

We used maternal educational level as indicator of family socioeconomic position. The highest educational level attained by the mother was assessed by questionnaire at enrolment. The Dutch Standard Classification of Education was used to categorize four levels of education: low (<4 years high school), mid-low (college), mid-high (Bachelor's degree) and high (Master's degree) [16].

Children's dietary behaviors

Consumption of high-calorie snacks and sugar-containing beverages was assessed in a parent-reported questionnaire (90% mothers) when the child was four years old. For snack consumption the following question was used: 'How often does your child eat a high-calorie snack each day on average (something that is eaten in between the three main meals, for example sweets, potato chips, chocolate bars, ice cream)?'. Answer categories for this question included: 'never', 'once per day', '2–3 times per day', '4–6 times per day', and 'more than 6 per day'. Consumption of sugar-containing beverages was assessed using the question: 'How often does your child have sugar-containing drinks?' Sugar-containing beverages were defined as those beverages containing a lot of (added) sugar, including soft drinks, fruit juices, lemonade, and sweetened milk products (e.g. chocolate milk). Answer categories ranged from 'less than one glass per day' to 'more than 4 glasses per day' (6 categories in total). Due to skewed distributions, snack consumption was dichotomized into '≥2 times/day' and '≤1 time/day' and consumption of sugar-containing beverages was dichotomized into '≥3 glasses/day' and '≤2 glasses/day'. Cut-points for both variables were based on the distribution of the data and previous research on unhealthy dietary behaviors in young children [17].

Family food environment

Potential mediators relating to the family food environment were assessed in a questionnaire when the child was four years old. Three subscales of the Child Feeding Questionnaire (CFQ) by Birch et al. [18] were used to assess parental feeding practices, including monitoring (3 items), restriction (8 items), and pressure to eat (4 items). These three subscales of the CFQ have been validated in various populations [19-21], and are widely used to assess parental control over feeding [22-25]. Internal consistency of the administered scales was moderate-to-large in our study population ($\alpha = 0.90$ for monitoring; $\alpha = 0.71$ for restriction; $\alpha = 0.64$ for pressure to eat). Consumption of sugar-containing beverages by the primary caregiver was assessed on a 5-point Likert scale ranging from 'No, hardly any' (1) to 'Yes, an awful lot' (5). The same variable was used as a proxy variable for parental consumption of high-calorie snacks in the analyses on children's snack consumption, as information on snacking by the parents was not available for the present study. Frequency (0–7 days) and duration of television viewing (<0.5 h, 0.5–1 h, 1–2 h, 2–3 h, >3 h) by the children were obtained and converted into average daily television viewing time by multiplying the number of days by the duration of the session per day (middle number of hours), divided by seven [26]. This estimate was dichotomized in ≥2 h/day and <2 h/day according to recommendations of the American Academy of Pediatrics [27].

Statistical analyses

Associations between maternal educational level and several child and parent characteristics were studied using $\chi 2$-tests for categorical variables and Kruskal–Wallis tests or ANOVA for continuous variables. The mediating effects of family food environment variables in the association between maternal educational level and children's consumption of high-calorie snacks and sugar-containing beverages were tested using Baron and Kenny's step approach [28] (Figure 1). First, the associations between maternal educational level and children consumption of snacks and beverages were examined using logistic regression models (basic models). Adjustment for child's sex and age did not influence the size or precision of the effect estimates and were therefore left out of the models. Second, the associations between maternal educational level and the potential mediators were assessed using logistic and linear regression models. Third, the associations between the potential mediators and children's snack and beverage consumption were assessed using logistic regression models, adjusted for maternal educational level. Potential mediators that were significantly associated with both maternal educational level and consumption of snacks and beverages were added separately to the basic models. To assess the size of mediated effects, we calculated the percentage change in odds ratios (ORs) for maternal educational level using the following formula: (100 * $[OR_{bm + mediator} – OR_{bm}] / [OR_{bm} – 1]$) [29]. A full model containing maternal educational level and all mediators assessed the joint effects of the mediators. To handle missing data in the covariates, multiple imputation was applied [30]. Five imputed datasets were generated using a fully conditional specified model, thus taking into account the uncertainty of the imputed values. Pooled estimates from these five imputed datasets were used to report ORs and their 95% confidence intervals (CIs). Imputations were based on the relationships between all the variables included in this study. All analyses were conducted with Statistical Package for Social Sciences (SPSS) version 20.0 for Windows (2011, SPSS Inc., Chicago, IL, USA). A significance level of p b 0.05 was used to indicate significant associations.

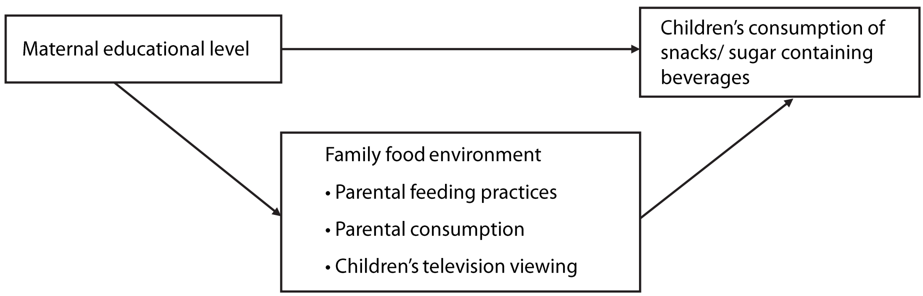

Figure 1. Hypthesized model of the mediating effects of the family food environment on the associations between maternal educational level and children's consumption of high-calorie snacks and sugar containing beverages.

Results

Table 1 shows characteristics of the study population. Nearly 10% of mothers had a low educational level. In the total population, about 32% of children consumed high-calorie snacks ≥2 times/day and about 35% of children consumed sugar-containing beverages ≥3 glasses/day. These prevalences varied according to the level of maternal education (both $p < 0.001$); prevalence of the consumption of high-calorie snacks was 1.8 times larger and prevalence of the consumption of sugar-containing beverages was 1.7 times larger in children of low educated mothers compared with children of high educated mothers. Parental monitoring and restriction were positively associated ($p < 0.01$) and pressure to eat was negatively associated with maternal educational level ($p < 0.001$).
Maternal educational level was significantly inversely associated with both dietary behaviors ($p < 0.001$); compared to children of high educated mothers, children of low and mid-low educated mothers had significantly increased odds of consuming high-calorie snacks ≥2 times/day and sugar-containing beverages ≥3 glasses/day, with the highest odds in children of low educated mothers (OR: 2.44; 95% CI: 1.84, 3.23 and OR: 2.46; 95% CI: 1.87, 3.24 respectively) (Tables 2 and 3).
Regarding children's snack consumption, all five potential mediators met Baron and Kenny's criteria of mediation (Tables 2 and 4). The strongest mediators included parental consumption of sugar-containing beverages (percentage change:–21%) and children's television viewing time (percentage change: –25%). Inclusion of parental restriction increased the association between maternal educational level and children's snacking, thus acting as a suppressor in this relationship (Table 2). Regarding children's sugar-containing beverage consumption, three out of five potential mediators fulfilled Baron and Kenny's criteria of mediation (Tables 3 and 4). Again, parental consumption of sugar-containing beverages (percentage change: –29%) and children's television viewing time (percentage change: –18%) were the two strongest mediators.
For consumption of both high-calorie snacks and sugar-containing beverages, fully adjusted ORs remained significant for children of mid-low(OR: 1.66; 95% CI: 1.34, 2.07 and OR 1.46; 95% CI: 1.19, 1.81, respectively) and low educated mothers (OR: 1.79; 95% CI: 1.32, 2.42 and OR: 1.79; 95% CI: 1.34, 2.40, respectively), indicating that the mediators considered in the present study did not fully explain the associations between low maternal educational level and children's consumption of high-calorie snacks and sugar-containing beverages.

Table 1. Subject characteristics in the total study population and according to level of maternal education in the Generation R Study (Rotterdam, The Netherlands, 2002-2006) (n=2814)

			Level of maternal education				
		Total (n=2814)	High[a] (n=1039) (36.9%)	Mid-high[a] (n=811) (28.8%)	Mid-low[a] (n=696) (24.8%)	Low[a] (n=268) (9.5%)	P-value[c]
Parent characteristics							
CFQ Monitoring[b]	Median (90% range)	15.0 (11.0-15.0)	15.0 (11.0-15.0)	15.0 (12.0-15.0)	15.0 (10.0-15.0)	14.0 (9.0-15.0)	<0.01
CFQ Restriction[b]	Mean (SD)	23.4 (5.9)	23.9 (5.7)	23.3 (5.8)	23.2 (6.2)	22.4 (6.4)	<0.01
CFQ Pressure to eat[b]	Mean (SD)	12.0 (3.8)	11.6 (3.8)	12.0 (3.8)	12.5 (3.7)	12.7 (3.8)	<0.001
Parental consumption of sugar-containing beverages	Mean (SD)	2.1 (0.9)	2.0 (0.9)	2.1 (0.9)	2.2 (0.9)	2.4 (1.0)	<0.001
Child characteristics							
Sex	Boy (%)	49.9	50.0	49.8	48.1	54.5	0.37
Age (months)	Median (90% range)	48.2 (47.8-50.2)	48.2 (47.8-49.9)	48.2 (47.8-50.2)	48.2 (47.8-50.3)	48.1 (47.8-51.0)	0.75
Consumption of sugar-containing beverages	≥ 3 glasses/day (%)	35.2	29.1	33.2	40.9	50.2	<0.001
Consumption of high-calorie snacks	≥ 2 times/day (%)	32.2	24.9	31.9	38.6	44.7	<0.001
Television viewing time	≥ 2 hours/day (%)	5.6	1.9	3.6	8.6	18.4	<0.001

Table is based on non-imputed dataset. Missings were 27 (1.0%) for CFQ monitoring, 32 (1.1%) for CFQ restriction, 22 (0.8%) for CFQ pressure to eat, 3 (0.1%) for parental consumption of sugar-containing beverages, 0 for child's sex, 0 for child's exact age at measurement, 36 (1.3%) for children's consumption of sugar-containing beverages, 55 (2.0%) for children's consumption of high-calorie snacks, 34 (1.2%) and for children's television viewing time.

[a] High: Master's degree; mid-high: Bachelor's degree; mid-low: college; low: < 4 years of high school.

[b] CFQ= Child Feeding Questionnaire.

[c] Differences in parent and child characteristics for the educational groups were evaluated using ANOVA for continuous normally distributed variables, Kruskal-Wallis tests for non-normally distributed continuous variables, and Chi-square tests for categorical variables.

Table 2. Mediating effects of family food environment variables in the association between maternal educational level and children's consumption of high-calorie snacks ≥ 2 times/day in the Generation R Study (Rotterdam, The Netherlands, 2002-2006) (n=2759)[a]

Level of maternal education	High (ref) OR	Mid-high[a] OR (95% CI)	Change 1[c] (%)	Mid-low[a] OR (95% CI)	Change 2[c] (%)	Low[a] OR (95% CI)	Change 3[c] (%)
Basic model (includes maternal education)	1.00	1.41 (1.15,1.74)		1.90 (1.54,2.34)		2.44 (1.84,3.23)	
Basic model + CFQ monitoring[b]	1.00	1.43 (1.16,1.76)	+5	1.85 (1.50,2.29)	-6	2.25 (1.69,3.00)	-13
Basic model + CFQ restriction[b]	1.00	1.43 (1.17,1.76)	+5	1.93 (1.57,2.38)	+3	2.53 (1.90,3.36)	+6
Basic model + CFQ pressure to eat[b]	1.00	1.39 (1.13,1.70)	-5	1.85 (1.50,2.28)	-6	2.34 (1.78,3.08)	-7
Basic model + parental consumption of sugar-containing beverages	1.00	1.37 (1.12,1.68)	-10	1.80 (1.46,2.22)	-11	2.14 (1.62,2.85)	-21
Basic model + children's television viewing time	1.00	1.39 (1.13,1.71)	-5	1.79 (1.44,2.21)	-12	2.08 (1.56,2.78)	-25
Full model[d]	1.00	1.38 (1.12,1.70)	-7	1.66 (1.34,2.07)	-27	1.79 (1.32,2.42)	-45

Table is based on imputed dataset.
[a] High: Master's degree; mid-high: Bachelor's degree; mid-low: college; low: < 4 years of high school.
[b] CFQ= Child Feeding Questionnaire.
[c] Changes 1-3 represent the percentage change in odds ratio relative to the basic model for mid-high, mid-low and low maternal educational level respectively after individual adjustment for mediators (100 * $[OR_{bm + mediator} - OR_{bm}]/[OR_{bm} - 1]$). In case of the full model, changes 1-3 represent the percentage change in odds ratio relative to the basic model for maternal educational levels after full adjustment (100 * $[OR_{bm + all\ mediators} - OR_{bm}]/[OR_{bm} - 1]$).
[d] Full model = basic model + all mediators.

Discussion

This study showed that maternal educational level was significantly inversely associated with preschool children's consumption of high-calorie snacks ≥2 times/day and sugar-containing beverages ≥3 glasses/day. These associations were partly explained by parental feeding practices, parental consumption of sugar-containing beverages, and children's television viewing time.

The inverse association between maternal educational level and preschoolers' consumption of sugar-containing beverages is in line with earlier studies who found a similar

Table 3. Mediating effects of family food environment variables in the association between maternal educational level and children's consumption of sugar-containing beverages ≥ 3 glasses/day in the Generation R Study (Rotterdam, The Netherlands, 2002-2006) (n=2778)

Level of maternal education	High (ref) OR	Mid-high[a] OR (95% CI)	Change 1[c] (%)	Mid-low[a] OR (95% CI)	Change 2[c] (%)	Low[a] OR (95% CI)	Change 3[c] (%)
Basic model (includes maternal education)	1.00	1.21 (1.00,1.48)		1.69 (1.38,2.07)		2.46 (1.87,3.24)	
Basic model + CFQ monitoring[b]	1.00	1.22 (1.00,1.48)	+5	1.66 (1.36,2.03)	-4	2.37 (1.79,3.12)	-6
Basic model + parental consumption of sugar-containing beverages	1.00	1.16 (0.95,1.42)	-24	1.54 (1.26,1.90)	-22	2.03 (1.53,2.69)	-29
Basic model + children's television viewing time	1.00	1.20 (0.99,1.45)	-5	1.61 (1.31,1.98)	-12	2.19 (1.65,2.91)	-18
Full model[d]	1.00	1.15 (0.94,1.40)	-29	1.46 (1.19,1.81)	-33	1.79 (1.34,2.40)	-46

Table is based on imputed dataset.
[a] High: Master's degree; mid-high: Bachelor's degree; mid-low: college; low: < 4 years of high school.
[b] CFQ= Child Feeding Questionnaire.
[c] Changes 1-3 represent the percentage change in odds ratio relative to the basic model for mid-high, mid-low and low maternal educational level respectively after individual adjustment for mediators (100 * [$OR_{bm + mediator}$– OR_{bm}]/[OR_{bm} - 1]). In case of the full model, changes 1-3 represent the percentage change in odds ratio relative to the basic model for maternal educational levels after full adjustment (100 * [$OR_{bm + all mediators}$– OR_{bm}]/[OR_{bm} – 1]).
[d] Full model = basic model + all mediators.

relationship [8-10]. However, our finding for snack consumption contrasts with a study by Vereecken et al. that did not find an association between maternal educational level and sweets (candy and chocolates) [10]. One explanation may be that our definition of high-calorie snacks comprised a wider range of food items including savory snack items (e.g. potato chips), the intake of which has shown a large increase over the past decades [3].

Similar to our findings, previous research found maternal intake and parental feeding practices to mediate the relationship between low maternal education and increased soft drink consumption in young Flemish children (2–7 years) [8,10]. The present study adds to existing research by showing that children's television viewing time was an additional mediator. This finding is supported by separate studies that showed an inverse relationship between parental educational level and children's television viewing time

Table 4. Associations between potential mediators and children's consumption of high-calorie snacks (n=2759) and sugar-containing beverages (n=2778) in the Generation R Study (Rotterdam, The Netherlands, 2002-2006)[a]

		High-calorie snacks (≥ 2 times/day)	Sugar-containing beverages (≥ 3 glasses/day)
		OR (95% CI)	OR (95% CI)
Parent characteristics			
CFQ Monitoring[b]		0.85 (0.82,0.89)	0.93 (0.89,0.97)
CFQ Restriction[b]		1.02 (1.01,1.04)	1.00 (0.99,1.02)
CFQ Pressure to eat[b]		1.04 (1.01,1.06)	1.01 (0.99,1.04)
Parental consumption of sugar-containing beverages		1.34 (1.22,1.46)	1.64 (1.50,1.79)
Child characteristics			
Television viewing time	< 2 hours/day	1.00 (ref)	1.00 (ref)
	≥ 2 hours/day	2.60 (1.85,3.64)	2.13 (1.50,3.01)

Table is based on imputed dataset.
[a] Values are odds ratios (95% confidence intervals), adjusted for maternal educational level.
[b] CFQ= Child Feeding Questionnaire.

[26,31,32], and a positive relationship between children's television viewing time and children's consumption of sweet beverages [33-36].

Studies on the associations between parental feeding practices and children's dietary behaviors are still limited and results are conflicting [10-12].Our finding that more restriction was related to more snacking is seemingly contradictory and adds to the ongoing debate about the directionality of the relationship between parental feeding practices and children's dietary intake and weight status [37]. More research to unravel this relationship is warranted.

Television viewing may affect children's dietary behaviors through exposure to food advertisements. Taras et al. showed that children's television viewing was positively associated with the number of food items requested, as well as increased purchase of these foods by the parents [38]. Also, brief exposure to food commercials has shown to increase children's preference for advertised foods [39]. Alternatively, television may influence children's consumption of high-calorie snacks and sugar-containing beverages by providing a context that encourages frequent consumption of these food items [40].

The substantial influence of parental consumption of sugar-containing beverages on children's dietary behaviors may have different explanations. First, parents are likely to act as a role model for their children [10,41]. Second, consumption of unhealthy food items by the parents may result in high availability and accessibility of these products in the home, providing a physical food environment that facilitates the consumption of these food items by their children [10].

Study strengths and limitations

The main strengths of this study are the sample size and the inclusion of participants with varying educational backgrounds. Also, the measures used to assess parental feeding practices are extensively validated in different populations [19-21]. Some limitations must also be considered. First, the educational gradients in children's consumption of high-calorie snacks and sugar-containing beverages were not fully explained by the mediators considered in the present study. This study lacked information on potentially relevant variables relating to the family food environment that have been found to be associated with young children's consumption of snacks and sweetened beverages and maternal educational level, including availability and accessibility of food items in the home [8], and parental nutritional knowledge and health attitudes [42]. Also, we did not have information on parental consumption of high-calorie snacks. Even though previous research has shown that consumption of snacks and sweetened beverages cluster [43], using parental consumption of sugar-containing beverages as a proxy for parental snacking may have led to misclassification. Second, this study used parent-reported questionnaire data only and therefore social desirability cannot be excluded. This may be especially true with respect to the reporting of dietary behaviors and parenting practices. Third, firm conclusions about the causal nature of the associations cannot be inferred since mediating variables and the outcome were measured at one point in time (child age 4 years). For example, the associations between children's television viewing time and dietary behaviors may be explained by the clustering of lifestyle behaviors, rather than causal associations through food advertising and snacking during television viewing. Fourth, we used maternal education as single indicator for socioeconomic position of the family. Socioeconomic position is a complex, multidimensional construct, whose commonest indicators are educational level, income, and occupation [44]. Educational level was chosen because this variable is relevant to people regardless of age and occupational status. Furthermore, general and health-related knowledge and skills attained through education may make a person more receptive to health education messages [44]. Educational level of the mother was chosen because women are most often primary caregivers of the child. We have conducted sensitivity analyses using other socioeconomic indicators (i.e., paternal educational level and household income) and found similar results, although effects estimates were smaller (data not shown). Finally, because this study was based on children from Dutch mothers only, results may not be generalized to other study populations.

Conclusion

The present study adds to the limited research on dietary behaviors in preschool children by showing clear inverse educational gradients in young children's consumption of high-calorie snacks and sugar-containing beverages. Findings of the present study indicate that interventions aimed to reduce educational inequalities in these unhealthy dietary behaviors should target parental feeding practices, parental consumption of sugar-containing beverages and high-calorie snacks, and children's television viewing time. More specific, low educated parents should be encouraged to limit their children's and their own intake of high-calorie snacks and sugar-containing beverages, monitor their children's diet, and restrict children's television viewing time.

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CHAPTER 5.2

SOCIAL INEQUALITIES IN YOUNG CHILDREN'S MEAL SKIPPING BEHAVIORS: THE GENERATION R STUDY

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Abstract

Objective: Regular meal consumption is considered as an important aspect of a healthy diet. While ample evidence shows social inequalities in breakfast skipping among adolescents, little is known about social inequalities in breakfast skipping and skipping of other meals among young school-aged children. Such information is crucial in targeting interventions aimed to promote a healthy diet in children.

Methods: We examined data from 4704 ethnically diverse children participating in The Generation R Study, a population-based prospective cohort study in Rotterdam, the Netherlands. Information on family socioeconomic position (SEP), ethnic background, and meal skipping behaviors was assessed by parent-reported questionnaire when the child was 6 years old. Multiple logistic regression analyses were performed to assess the associations of family SEP and ethnic background with meal skipping behaviors.

Results: Meal skipping prevalence ranged from 3% (dinner skipping) to 11% (lunch skipping). The prevalence of meal skipping was higher among children from low family SEP and ethnic minority children. Independent SEP associations were found for maternal educational level (breakfast skipping) ($p<0.05$), paternal educational level (lunch and dinner skipping) (both $p<0.05$), and household income (breakfast and dinner skipping) (both $p<0.05$). Adjustment for family SEP attenuated the associations of ethnic minority background with meal skipping behaviors considerably, especially with respect to breakfast skipping.

Conclusion: Family SEP and ethnic background were consistently associated with all meal skipping behaviors, with children from low family SEP and ethnic minority children having a higher prevalence of meal skipping. Given these inequalities, interventions aimed to promote regular meal consumption, breakfast consumption in particular, should target children from low socioeconomic groups and ethnic minority children. More qualitative research is warranted to investigate the pathways underlying social inequalities in children's meal skipping behaviors.

Introduction

Healthy dietary behaviors are important determinants of children's development and health outcomes [1-3]. One element of a healthy diet is regular meal consumption [4], of which breakfast consumption has been studied most extensively [2,3,5]. Regular breakfast consumption has been associated with overall diet quality (e.g., more servings of fruits, vegetables, grain and dairy products, and less frequent consumption of unhealthy snacks and soft drinks), lower body mass index (BMI), and increased cognitive function and academic performance [3,5-9]. Consequentially, daily consumption of a nutrient-dense breakfast has been included in the dietary guidelines for Americans as published by the US departments of Agriculture and Health and Human Services (HHS) [10].
Identification and characterization of children at high risk of breakfast skipping is crucial when designing interventions. Previous research has shown that adolescents with an ethnic minority background and adolescents from low family socioeconomic position (SEP) are more likely to skip breakfast compared with their counterparts [11-15]. Furthermore, breakfast skipping has been consistently associated with family composition, with adolescents from single parent families being more likely to skip breakfast than adolescents from two-parent families [16-18]. However, studies on the associations of family SEP and ethnic background with breakfast skipping in young school-aged children are scarce [8,19]. Given that dietary behaviors track through childhood and into adolescence [20,21], identification of risk groups at an early age is warranted. Furthermore, despite ample evidence on the associations between breakfast skipping and diet quality, little is known on the extent to which breakfast skipping is associated with skipping of other main meals.
To address these gaps in previous research, we aimed to assess the prevalence and mutual associations of breakfast skipping, lunch skipping, and dinner skipping in 6-year-old children. Furthermore, we aimed to assess the associations of family SEP (parental educational level, parental employment status, household income, and family composition) and ethnic background with these meal skipping behaviors. The present study used data from The Generation R Study, a large multi-ethnic birth cohort study in Rotterdam, the Netherlands.

Methods

Study design

This study was embedded in the Generation R Study, a population-based prospective cohort study from fetal life onwards. The Generation R Study was designed to identify early environmental and genetic determinants of growth, development, and health, and has been described previously in detail [22]. The study was conducted in accordance with the guidelines proposed in the World Medical Association Declaration of Helsinki and has been approved by the Medical Ethical Committee at Erasmus MC, University Medical Center Rotterdam. Written informed consent was obtained from all parents.

Study population

Invitations to participate in the study were made to all pregnant women who had an expected delivery date between April 2002 and January 2006 and who lived in the study area (Rotterdam, the Netherlands) at time of delivery. From the original 9749 known live born children of the Generation R cohort, 8305 children still participate in the school aged period (5 years onward) [22]. For this study, we selected children born to mothers with a native Dutch, Surinamese-Creole, Surinamese-Hindustani, Dutch Antillean, Cape Verdean, Turkish, or Moroccan ethnic background (n=6447). These ethnic groups were chosen because they represent the largest ethnic groups in the Generation R Study, as well as in the city of Rotterdam [22]. Children with missing data on all three meal skipping behaviors were excluded (n=1347). To avoid clustering of data, we furthermore excluded second (n=389) and third children (n=7) of the same mother, leaving a study population of 4704 participants. Of these participants, 4687 had information on breakfast skipping, 4593 had information on lunch skipping, and 4537 had information on dinner skipping.

Meal skipping behaviors

Meal skipping behaviors were assessed in parent-reported questionnaires at child age 6 years. Number of days on which children consumed breakfast, lunch, and dinner was assessed for weekdays (6 answer options ranging from 0 to 5 days) and weekend days separately (3 answer options ranging from 0 to 2 days), and these were added to calculate weekly consumption (8 answer options ranging from 0 to 7 days). Skipping a meal was defined as consumption less than 7 days per week (Supplement Table 1).

Family socioeconomic position and ethnic background

Information on family SEP and ethnic background was assessed by parent-reported questionnaire when the child was 6 years old. Indicators of family SEP included maternal and paternal educational level (highest level attained), maternal and paternal employment status (no paid job, paid job), and net household income (<€2000/month [i.e. below modal income [23]], €2000-€3200/month, >€3200/month). The Dutch Standard Classification of Education was used to categorize four levels of education: low (no education, primary school, lower vocational training, intermediate general school, or three years or less general secondary school), mid-low (more than three years general secondary school, intermediate vocational training, or first year of higher vocational training), mid-high (higher vocational training), and high (university or PhD degree) [24]. Albeit not a traditional SEP indicator (i.e. education, income, occupation [25]), we also included family composition (single parent, two parents) as indicator of family SEP as it has been used as a proxy indicator of SEP in previous research and has been consistently associated with breakfast skipping [16-18,26]. Children's ethnic background was based on the ethnic background of their mothers to take into account the cultural background of the mothers (most often primary caregivers). Maternal ethnic background was based on country of birth of the mother's parents. In accordance with Statistics Netherlands, a mother was considered nonnative Dutch if one of her parents was born abroad. If both parents were born abroad, country of birth of the mother's mother decided on maternal ethnic background [27].

Potential confounders

Child's sex and age were considered potential confounders in the associations of family SEP and ethnic background with children's meal skipping behaviors. When assessing the associations of family SEP with children's meal skipping behaviors, ethnic background was considered a potential confounder, and vice versa.

Statistical analyses

Descriptive statistics were used to characterize the study population. Meal skipping behaviors according to family SEP and ethnic background were assessed using Chi-square tests. Spearman's rho correlation coefficients were calculated to assess the correlation between children's relative rank positions in number of days of breakfast, lunch, and dinner skipping (0-7 days, Supplement Table 1). Furthermore, cross-tabulations of the dichotomized meal skipping variables (yes, no) were used to assess the proportion of lunch and dinner skippers among breakfast skippers and the proportion of lunch and dinner consumers among breakfast consumers.

Associations of family SEP with meal skipping behaviors at age 6 years were assessed using series of multiple logistic regression analyses. First, we created crude models (i.e., unadjusted models) and basic models adjusted for confounders (i.e., child's sex, age at measurement, and ethnic background). To assess the independent effects of each of the SEP indicators, full models additionally contained all SEP indicators simultaneously. For ethnic background, similar logistic regression models were built. First, crude models and basic models adjusted for basic confounders (i.e., child's sex and age at measurement) were built. To adjust for confounding effects by family SEP, full models were additionally adjusted for all indicators of family SEP. Additional analyses with respect to social inequalities in weekly consumption of meals (0-21) were also performed (Supplement Tables 2-3). Collinearity analysis using Spearman's rho coefficients yielded acceptable collinearity ($r<0.8$) between maternal educational level, paternal educational level, and household income; therefore, these variables were included simultaneously in the full models.

Table 1. Characteristics of the study population (n=4704)

		Total n (%)	Missing n (%)
Maternal educational level	High	1240 (26.8)	67 (1.4)
	Mid-high	1280 (27.6)	
	Mid-low	1480 (31.9)	
	Low	637 (13.7)	
Paternal educational level	High	1387 (32.9)	489 (10.4)
	Mid-high	964 (22.9)	
	Mid-low	1134 (26.9)	
	Low	730 (17.3)	
Maternal employment status	Paid job	3324 (75.6)	308 (6.5)
	No paid job	1072 (24.4)	
Paternal employment status	Paid job	3894 (94.1)	566 (12.0)
	No paid job	244 (5.9)	
Household income	>€3200	2169 (49.6)	336 (7.1)
	€2000-<€3200	1144 (26.2)	
	<€2000	1055 (24.2)	
Family composition	Two parents	4002 (85.8)	37 (0.8)
	Single parent	665 (14.2)	
Ethnic background	native Dutch	3324 (70.7)	0
	Surinamese-Creole	161 (3.4)	
	Surinamese-Hindustani	168 (3.6)	
	Dutch Antillean	124 (2.6)	
	Cape Verdean	193 (4.1)	
	Turkish	458 (9.7)	
	Moroccan	276 (5.9)	
Child's sex	Boy	2380 (50.6)	0
	Girls	2324 (49.4)	
Child's age	Median (90% range)	6.0 (5.7-7.1)	0
Breakfast skipping	No	4389 (93.6)	17 (0.4)
	Yes	298 (6.4)	
Lunch skipping	No	4107 (89.4)	111 (2.4)
	Yes	486 (10.6)	
Dinner skipping	No	4395 (96.9)	
	Yes	142 (3.1)	167 (3.6)

Table is based on non-imputed dataset.

A multiple imputation procedure was applied to handle missing data in the family SEP variables [28]. Five imputed datasets were generated using a fully conditional specified model, thus taking into account the uncertainty of the imputed values. Pooled estimates from these five imputed datasets were used to report beta's, odds ratios (ORs) and their 95% confidence intervals (CIs). Imputations were based on the relationships between all the variables included in this study. All analyses were conducted with Statistical Package for Social Sciences (SPSS) version 21.0 for Windows (SPSS Inc., Chicago, IL, USA). A significance level of $p<0.05$ was used to indicate significant associations.

Results

Table 1 shows characteristics of the study population. The majority of children had a Dutch ethnic background (70.7%). Approximately half of the children had a mother with a (mid-)low educational level (54.6%). The prevalence of meal skipping in the total study population was 6.4%, 10.6%, and 3.1% for breakfast, lunch, and dinner skipping, respectively. Meal skipping behaviors were more prevalent among children with an ethnic minority background and children from low SEP families, irrespective of SEP indicator (Table 2). Spearman's rho correlation coefficients were 0.26 for breakfast and lunch skipping, 0.36 for breakfast and dinner skipping, and 0.31 for lunch and dinner skipping, respectively (all $p<0.001$). Of those children who skipped breakfast, 41% also skipped lunch, and 28% also skipped dinner. Of those children who consumed breakfast, 92% also consumed lunch, and 99% also consumed dinner.

Tables 3-5 show the associations of family SEP and ethnic background with children's meal skipping behaviors. Children of mothers with a mid-high, mid-low, and low educational level were more likely to skip breakfast compared with children of mothers with a high educational level, with the highest odds for children of mothers with a low educational level (OR: 3.28; 95% CI: 2.01,5.35) (basic model, Table 3). Similarly, children with a low paternal educational level were more likely to skip breakfast than children with a high paternal educational level (OR: 1.89; 95% CI: 1.23,2.91). Children from middle income households (OR 2.26; 95% CI: 1.55,3.29) and children from low income households (OR: 3.02; 95% CI: 2.03,4.48) had increased odds of skipping breakfast compared with children from high income households. Finally, children from a single parent family were more likely to skip breakfast than children from a two-parent family (OR: 1.57; 95% CI: 1.14,2.14). Independent SEP associations were found for maternal educational level and household income (full model, Table 3). Similar associations were found for the associations between family SEP and lunch skipping (basic model, Table 4). Results were slightly different for dinner skipping, where associations were also found for paternal employment status and mid-high paternal educational level (OR: 0.47; 95% CI: 0.25,0.89). Independent SEP associations were found for paternal educational level (lunch and dinner skipping) and household income (dinner skipping).

Table 2. Meal skipping behaviors according to family SEP and ethnic background (n=4704)

		Breakfast skipping (n=4687)		P-value*	Lunch skipping (n=4593)		P-value*	Dinner skipping (n=4537)		P-value*
		No (n,%)	Yes (n,%)		No (n,%)	Yes (n,%)		No (n,%)	Yes (n,%)	
Maternal educational level	High	1214 (97.9)	26 (2.1)	<0.001	1128 (92.8)	88 (7.2)	<0.001	1185 (98.2)	22 (1.8)	<0.01
	Mid-high	1222 (95.5)	57 (4.5)		1139 (90.8)	115 (9.2)		1205 (97.2)	35 (2.8)	
	Mid-low	1363 (92.6)	109 (7.4)		1277 (88.6)	165 (11.4)		1376 (96.8)	46 (3.2)	
	Low	537 (85.1)	94 (14.9)		512 (82.8)	106 (17.2)		576 (94.7)	32 (5.3)	
Paternal educational level	High	1344 (96.9)	43 (3.1)	<0.001	1259 (92.8)	98 (7.2)	<0.001	1311 (97.5)	34 (2.5)	<0.01
	Mid-high	928 (96.6)	33 (3.4)		882 (92.5)	72 (7.5)		929 (98.6)	13 (1.4)	
	Mid-low	1052 (93.2)	77 (6.8)		965 (87.8)	134 (12.2)		1054 (96.8)	35 (3.2)	
	Low	637 (88.0)	87 (12.0)		598 (84.6)	109 (15.4)		665 (95.3)	33 (4.7)	
Maternal employment status	Paid job	3158 (95.2)	159 (4.8)	<0.001	2948 (90.6)	306 (9.4)	<0.001	3136 (97.4)	84 (2.6)	<0.01
	No paid job	964 (90.3)	103 (9.7)		902 (86.8)	137 (13.2)		980 (95.8)	43 (4.2)	
Paternal employment status	Paid job	3684 (94.9)	200 (5.1)	<0.001	3447 (90.5)	363 (9.5)	<0.05	3672 (97.5)	95 (2.5)	<0.001
	No paid job	204 (84.6)	37 (15.4)		201 (85.9)	33 (14.1)		218 (92.4)	18 (17.6)	
Household income	>€3200	2118 (97.7)	50 (2.3)	<0.001	1966 (92.2)	166 (7.8)	<0.001	2074 (98.3)	36 (1.7)	<0.001
	€2000-<€3200	1062 (92.9)	81 (7.1)		993 (88.8)	125 (11.2)		1070 (96.7)	36 (3.3)	
	<€2000	902 (86.4)	142 (13.6)		850 (83.7)	165 (16.3)		940 (94.2)	58 (5.8)	
Family composition	Two parents	3767 (94.3)	226 (5.7)	<0.001	3528 (90.1)	388 (9.9)	<0.001	3763 (97.2)	110 (2.8)	<0.01
	Single parent	586 (89.2)	71 (10.8)		548 (85.4)	94 (14.6)		598 (95.2)	30 (4.8)	

Table 2. Meal skipping behaviors according to family SEP and ethnic background (n=4704) (continued)

Ethnic background	native Dutch	3324 (97.1)	95 (2.9)	<0.001	2988 (91.7)	272 (8.3)	<0.001	3159 (98.0)	64 (2.0)	<0.001
	Surinamese-Creole	139 (86.3)	22 (13.7)		133 (85.8)	22 (14.2)		142 (92.8)	11 (7.2)	
	Surinamese-Hindustani	147 (88.0)	20 (12.0)		153 (92.7)	12 (7.3)		153 (95.0)	8 (5.0)	
	Dutch Antillean	108 (87.8)	15 (12.2)		106 (86.9)	16 (13.1)		117 (95.1)	6 (4.9)	
	Cape Verdean	173 (90.6)	18 (9.4)		156 (83.9)	30 (16.1)		171 (93.4)	12 (6.6)	
	Turkish	372 (82.3)	80 (17.7)		338 (77.9)	96 (13.1)		409 (94.7)	23 (5.3)	
	Moroccan	226 (82.5)	48 (17.5)		233 (86.0)	38 (14.0)		244 (93.1)	18 (6.9)	

Table is based on non-imputed dataset. SEP= socioeconomic position.

* P-values assessed by Chi-square tests.

Chapter 5.2

Table 3. Associations of family SEP and ethnic background with breakfast skipping at age 6 years (n=4687)

	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)
Maternal educational level			
High (ref)	1.00	1.00	1.00
Mid-high	**2.21 (1.38,3.54)**	**1.70 (1.05,2.74)**	1.46 (0.88,2.43)
Mid-low	**3.82 (2.48,5.88)**	**1.97 (1.24,3.13)**	1.43 (0.85,2.42)
Low	**8.25 (5.28,12.90)**	**3.28 (2.01,5.35)**	**2.21 (1.24,3.94)**
Paternal educational level			
High (ref)	1.00	1.00	1.00
Mid-high	1.16 (0.73,1.85)	0.91 (0.57,1.45)	0.68 (0.42,1.11)
Mid-low	**2.50 (1.64,3.77)**	1.43 (0.93,2.19)	0.88 (0.54,1.42)
Low	**4.38 (2.96,6.47)**	**1.89 (1.23,2.91)**	1.02 (0.62,1.67)
Maternal employment status			
Paid job (ref)	1.00	1.00	1.00
No paid job	**2.14 (1.65,2.75)**	1.11 (0.82,1.50)	0.77 (0.55,1.09)
Paternal employment status			
Paid job (ref)	1.00	1.00	1.00
No paid job	**2.76 (1.81,4.19)**	1.45 (0.92,2.28)	1.17 (0.74,1.86)
Household income			
>€3200 (ref)	1.00	1.00	1.00
€2000-<€3200	**3.26 (2.29,4.64)**	**2.26 (1.55,3.29)**	**1.96 (1.27,3.04)**
<€2000	**6.70 (4.77,9.39)**	**3.02 (2.03,4.48)**	**2.43 (1.40,4.22)**
Family composition			
Two parents (ref)	1.00	1.00	1.00
Single parent	**1.99 (1.50,2.63)**	**1.57 (1.14,2.14)**	1.09 (0.76,1.57)
	Crude model OR (95% CI)	Basic model*** OR (95% CI)	Full model**** OR (95% CI)
Ethnic background			
Dutch (ref)	1.00	1.00	1.00
Surinamese-Creole	**5.37 (3.28,8.80)**	**5.29 (3.22,8.69)**	**3.36 (1.98,5.72)**
Surinamese-Hindustani	**4.62 (2.77,7.69)**	**4.55 (2.73,7.58)**	**2.95 (1.72,5.04)**
Dutch Antillean	**4.71 (2.65,8.40)**	**4.44 (2.48,7.97)**	**2.79 (1.50,5.17)**
Cape Verdean	**3.53 (2.09,5.98)**	**3.39 (2.00,5.76)**	**1.78 (1.01,3.14)**
Turkish	**7.30 (5.32,10.01)**	**7.27 (5.27,10.01)**	**4.27 (2.94,6.22)**
Moroccan	**7.21 (4.97,10.46)**	**7.10 (4.87,10.36)**	**4.03 (2.59,6.28)**

Table is based on imputed dataset. Bold print indicates statistical significance. Values represent odds ratios and 95% confidence intervals derived from (multiple) logistic regression analyses. SEP= socioeconomic position.

* Adjusted for confounders: child's sex, child's age, and ethnic background.

** Additionally adjusted for all SEP indicators.

*** Adjusted for confounders: child's sex and child's age.

**** Additionally adjusted for all SEP indicators.

Table 4. Associations of family SEP and ethnic background with lunch skipping at age 6 years (n=4593)

	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)
Maternal educational level			
High (ref)	1.00	1.00	1.00
Mid-high	1.29 (0.97,1.73)	1.20 (0.90,1.61)	1.08 (0.79,1.48)
Mid-low	**1.67 (1.28,2.19)**	1.31 (0.98,1.75)	1.02 (0.72,1.44)
Low	**2.72 (2.01,3.67)**	**1.80 (1.29,2.51)**	1.28 (0.84,1.95)
Paternal educational level			
High (ref)	1.00	1.00	1.00
Mid-high	1.08 (0.79,1.47)	1.00 (0.73,1.37)	0.96 (0.68,1.34)
Mid-low	**1.84 (1.37,2.47)**	**1.56 (1.15,2.12)**	1.42 (0.99,2.03)
Low	**2.43 (1.84,3.20)**	**1.80 (1.33,2.44)**	**1.53 (1.06,2.20)**
Maternal employment status			
Paid job (ref)	1.00	1.00	1.00
No paid job	**1.52 (1.23,1.89)**	0.90 (0.71,1.15)	0.97 (0.73,1.28)
Paternal employment status			
Paid job (ref)	1.00	1.00	1.00
No paid job	1.50 (0.98,2.28)	0.92 (0.59,1.46)	0.93 (0.57,1.51)
Household income			
>€3200 (ref)	1.00	1.00	1.00
€2000-<€3200	**1.47 (1.14,1.90)**	1.28 (0.98,1.67)	1.06 (0.79,1.42)
<€2000	**2.31 (1.84,2.90)**	**1.64 (1.24,2.15)**	1.23 (0.84,1.79)
Family composition			
Two parents (ref)	1.00	1.00	1.00
Single parent	**1.57 (1.23,2.00)**	**1.42 (1.09,1.84)**	1.17 (0.85,1.61)
	Crude model OR (95% CI)	Basic model*** OR (95% CI)	Full model**** OR (95% CI)
Ethnic background			
Dutch (ref)	1.00	1.00	1.00
Surinamese-Creole	**1.82 (1.14,2.90)**	**1.73 (1.08,2.77)**	1.29 (0.79,2.11)
Surinamese-Hindustani	0.82 (0.47,1.57)	0.83 (0.46,1.52)	0.65 (0.35,1.21)
Dutch Antillean	1.66 (0.97,2.85)	1.51 (0.88,2.61)	1.11 (0.63,1.96)
Cape Verdean	**2.11 (1.40,3.18)**	**2.02 (1.34,3.05)**	1.37 (0.88,2.14)
Turkish	**3.12 (2.41,4.04)**	**2.98 (2.30,3.87)**	**2.27 (1.67,3.08)**
Moroccan	**1.79 (1.24,2.58)**	**1.68 (1.16,2.42)**	1.24 (0.82,1.88)

Table is based on imputed dataset. Bold print indicates statistical significance. Values represent odds ratios and 95% confidence intervals derived from (multiple) logistic regression analyses. SEP= socioeconomic position.
* Adjusted for confounders: child's sex, child's age, and ethnic background.
** Additionally adjusted for all SEP indicators.
*** Adjusted for confounders: child's sex and child's age.
**** Additionally adjusted for all SEP indicators.

Following adjustment for confounders (i.e. child's sex and age), children from all ethnic minority backgrounds were more likely to skip breakfast than native Dutch children, with Turkish children showing the highest risks (OR: 7.27; 95% CI: 5.27,10.01) (basic model, Table 3). Additional analyses showed that Turkish children were not significantly different from other ethnic minority children, except for Cape Verdean children (data not shown). Following further adjustment for family SEP, all associations remained significant (full model, Table 3). Children from all ethnic minority groups, except for Surinamese-Hindustani and Dutch Antillean children, were more likely to skip lunch compared with native Dutch children (basic model, Table 4). Turkish children were significantly different from other ethnic minority children, except for Cape Verdean children (data not shown). Following adjustment for family SEP, only Turkish children were significantly more likely to skip lunch compared with native Dutch children. Children from all ethnic minority backgrounds were more likely to skip dinner than native Dutch children (basic model, Table 5) Additional analyses showed that Surinamese-Creole children did not differ significantly from other ethnic minority children (data not shown). After further adjustment for family SEP, the odds for skipping dinner remained increased for Surinamese-Creole, Cape Verdean, and Moroccan children (full model, Table 5). The analyses on weekly consumption of meals showed similar socioeconomic and ethnic inequalities (Supplement Tables 2-3).

Discussion

This study aimed to assess the prevalence and mutual associations of breakfast, lunch, and dinner skipping among young school-aged children. Furthermore, the associations of family SEP and ethnic background with these meal skipping behaviors were investigated. The prevalence of meal skipping ranged from 3% (dinner skipping) to 11% (lunch skipping), and these meal skipping behaviors were moderately correlated. Meal skipping was more prevalent among children from low SEP families and children with ethnic minority backgrounds.

Meal skipping behaviors

The prevalence of breakfast skipping is similar to that found in previous studies among 4-7 year-old children [6,19,29,30]. Conversely, two Dutch studies among children aged 4-6 years and 7-10 years reported prevalences of breakfast skipping ranging from 0% to 4% [31,32]. As these studies were performed in the '90s and increased rates of breakfast skipping have been observed [33], time of measurement may be an explanation for this discrepancy. An alternative explanation would relate to the ethnic composition of the study population, with the current study encompassing more ethnic minority children

Table 5. Associations of family SEP and ethnic background with dinner skipping at age 6 years (n=4537)

	Crude model OR (95% CI)	Basic model* OR (95% CI)	Full model** OR (95% CI)
Maternal educational level			
High (ref)	1.00	1.00	1.00
Mid-high	1.58 (0.92,2.71)	1.27 (0.73,2.21)	1.26 (0.70,2.27)
Mid-low	**1.87 (1.12,3.13)**	1.18 (0.68,2.05)	0.98 (0.51,1.89)
Low	**3.26 (1.90,5.61)**	**1.86 (1.02,3.40)**	1.31 (0.63,2.71)
Paternal educational level			
High (ref)	1.00	1.00	1.00
Mid-high	0.54 (0.29,1.03)	**0.47 (0.25,0.89)**	**0.39 (0.20,0.76)**
Mid-low	1.42 (0.88,2.27)	0.96 (0.59,1.58)	0.72 (0.41,1.59)
Low	**2.19 (1.34,3.56)**	1.25 (0.72,2.17)	0.81 (0.42,1.59)
Maternal employment status			
Paid job (ref)	1.00	1.00	1.00
No paid job	**1.82 (1.28,2.60)**	0.74 (0.50,1.10)	1.01 (0.65,1.57)
Paternal employment status			
Paid job (ref)	1.00	1.00	1.00
No paid job	**3.12 (1.78,5.45)**	**2.09 (1.14,3.84)**	1.67 (0.86,3.24)
Household income			
>€3200 (ref)	1.00	1.00	1.00
€2000-<€3200	**1.89 (1.16,3.06)**	1.57 (0.95,2.59)	1.70 (0.95,3.04)
<€2000	**3.75 (2.48,5.68)**	**2.42 (1.48,3.96)**	**2.44 (1.22,4.91)**
Family composition			
Two parents (ref)	1.00	1.00	1.00
Single parent	**1.79 (1.16,2.61)**	1.26 (0.81,1.98)	0.79 (0.47,1.33)
	Crude model OR (95% CI)	Basic model*** OR (95% CI)	Full model**** OR (95% CI)
Ethnic background			
Dutch (ref)	1.00	1.00	1.00
Surinamese-Creole	**3.82 (1.97,7.41)**	**3.85 (1.98,7.49)**	**2.91 (1.42,5.97)**
Surinamese-Hindustani	**2.58 (1.22,5.48)**	**2.59 (1.22,5.52)**	1.98 (0.90,4.37)
Dutch Antillean	**2.53 (1.07,5.96)**	**2.62 (1.10,6.21)**	1.90 (0.76,4.75)
Cape Verdean	**3.46 (1.84,6.54)**	**3.57 (1.88,6.77)**	**2.30 (1.13,4.68)**
Turkish	**2.78 (1.71,4.52)**	**2.76 (1.69,4.52)**	1.65 (0.93,2.94)
Moroccan	**3.64 (2.12,6.24)**	**3.63 (2.11,6.27)**	**1.93 (1.02,3.66)**

Table is based on imputed dataset. Bold print indicates statistical significance. Values represent odds ratios and 95% confidence intervals derived from (multiple) logistic regression analyses. SEP= socioeconomic position.

* Adjusted for confounders: child's sex, child's age, and ethnic background.

** Additionally adjusted for all SEP indicators.

*** Adjusted for confounders: child's sex and child's age.

**** Additionally adjusted for all SEP indicators.

(with higher rates of breakfast skipping) than these earlier studies. Research on lunch skipping and dinner skipping in young children is scarce; however, studies among older (7-13 year-old) children show a higher prevalence of lunch skipping and dinner skipping [34-36]. Since meal skipping is known to increase with age throughout childhood and adolescence [32,37], the age difference between studies may explain why we found a lower prevalence of lunch and dinner skipping.

Studies on the co-occurrence of meal skipping behaviors are scarce; therefore, comparison of the moderate correlation coefficients found in the current study are precluded. However, consistent with our findings, a study among 9-11 year-old Finnish children found that of those children who ate breakfast regularly, 90% also ate school lunch and dinner regularly [34]. If the determinants of these meal skipping behaviors largely overlap, larger correlation coefficients and a more similar prevalence may have been expected. Based on the observation that breakfast consumption was more strongly associated with family SEP and ethnic background, we speculate that the factors underlying breakfast skipping may be more structural than those underlying lunch and dinner skipping. Further research on the correlates of meal skipping, lunch and dinner skipping especially, in young children is merited.

Socioeconomic inequalities in meal skipping behaviors

Our findings of socioeconomic inequalities in children's meal skipping behaviors correspond to earlier studies showing higher levels of breakfast skipping among preschool children [19], school aged children [8], and adolescents [12-15] from low SEP families. Our study adds to the limited evidence base on socioeconomic inequalities in lunch and dinner skipping behaviors by showing socioeconomic inequalities in both meal skipping behaviors. In a European-wide study among 10-12 year-old children, similar socioeconomic inequalities were found for dinner skipping but not for lunch skipping [15]. However, when analyses were presented for each country separately, results did show an (non-significant) increased risk of lunch skipping among low SEP children in the Netherlands. More research in this area is warranted.

The current study furthermore found independent associations between different SEP indicators and meal skipping behaviors. These independent associations are likely to represent different pathways connecting family SEP with meal skipping [25,38,39]. For example, in accordance with earlier studies, we found maternal educational level and household income to be independently associated with breakfast skipping [19,39]. Maternal educational level may exert its effects on meal skipping via knowledge and skills (e.g. parenting practices) acquired through education whereas household income is likely to represent financial resources available for food purchasing [25,39]. Family composition has been consistently found to be associated with breakfast skipping [12,16-18]. In the present study, the association between family composition and breakfast skipping attenuated after adjustment for other SEP indicators. These results suggest that the effects of family composition may not represent a separate pathway in the line of household organization or routines [17], but rather may be due to other socioeconomic characteristics of single parent families. The finding of an independent association between paternal educational level and dinner skipping, with children from mid-high educated fathers being less likely to skip dinner compared with children of high educated fathers, was an unexpected finding for which we have no explanation.

Ethnic inequalities in meal skipping behaviors

The findings of ethnic inequalities in children's breakfast skipping are in line with previous research, most of which has been conducted in adolescent populations [8,11-15,19]. Moreover, two earlier Dutch studies among children aged 4-10 years also showed increased risks of breakfast skipping among Turkish and Moroccan children compared with native Dutch children [31,32]. Ethnic differences were also found for lunch and dinner skipping. Contrary to these results, a European-wide study failed to find any ethnic disparities in lunch and dinner skipping when analyzing the total study population [15]. Due to pooling of data, existent ethnic inequalities within one country may have been obscured. Furthermore, for most of the countries, including the Netherlands, data on ethnic inequalities in lunch and dinner skipping were unavailable and therefore direct comparison of results is precluded.

Adjustment for family SEP attenuated results considerable for all meal skipping behaviors, indicating that the elevated risks of meal skipping among ethnic minority children are partly explained by adverse socioeconomic circumstances of the family. However, family SEP did not completely explain the associations of ethnic minority background and meal skipping behaviors, especially with respect to breakfast skipping. SEP independent effects of ethnic background on breakfast skipping have been reported by previous studies in both preschool children [19] and adolescents [11]. These findings indicate that, in addition to family SEP, cultural/social norms and values specific to these ethnic minority groups may further explain the increased risk of meal skipping among ethnic minority children. Barriers to improving healthiness of children's diet among ethnic minority groups may include (amongst others) language barriers, lack of control over feeding practices and food intake, lack of time to prepare food, dealing with child's taste and preferences, and alternative priorities regarding a healthy development of children (e.g. children's behavioral issues and concerns over safety and security) [40-42].

Study strengths and limitations

The strengths of this study consist of the large and ethnically diverse study population and the availability of multiple indicators of family SEP. Several limitations should be considered when interpreting the results. First, potential information bias may have been introduced by parents' assessment on children's meal skipping behaviors. The use of parent-reported questionnaires may have led to social desirable answers, i.e. the over reporting of favorable behaviors and underreporting of unfavorable behaviors. If meal skipping was underreported by parents of low SEP and ethnic minority children, observed associations underestimate true associations; however, this is difficult to ascertain. Moreover, at the age of 6 years, children in the Netherlands attend primary schools [43] and some children consume lunch at school. As a consequence, parents will be able to report on lunch being taken to school, but less so on lunch being actually consumed by their children. Second, we did not have information on type of foods consumed during breakfast, lunch, and dinner and social inequalities in children's consumption of food items during meals have been reported previously [1,44]. Third, fully adjusted models were constructed to assess the independent effects of different SEP indicators and the SEP independent effects of ethnic background. Family SEP is a multidimensional construct and therefore difficult to completely capture [25,26,45]. Indeed, although we were able to control for a wide array of socioeconomic indicators, residual confounding by SEP (e.g., due to unmeasured SEP indicators such as wealth and neighborhood SEP) in the assessment of ethnic inequalities cannot be ruled out [25,26,45]. Furthermore, family SEP may partly be on the causal pathway linking ethnic minority background with increased levels of meal skipping behaviors as impaired language proficiency and work floor discrimination may lead to lower levels of education, lesser job opportunities, and lower salaries for ethnic minority groups [46]. From this viewpoint, family SEP indicators may partly act as a mediators rather than confounders. In a similar vein, parts of the effects of socioeconomic indicators may be mediated through other socioeconomic indicators [47]. For example, the effects of educational level may be partly mediated through income as higher educated parents will be more likely to have a higher income. As a consequence, associations of ethnic background and indicators of family SEP, maternal educational level in particular, with meal skipping behaviors may have been underestimated when adjusting for (other) SEP variables.

Conclusion

The prevalence of breakfast skipping, meal skipping, and dinner skipping among young ethnically diverse children ranged between 3% and 11%. Breakfast skipping was moderately associated with lunch skipping and dinner skipping. Family SEP and ethnic background were consistently associated with all meal skipping behaviors, with children from low family SEP and ethnic minority children having a higher prevalence of meal skipping. Given these inequalities, interventions aimed to promote regular meal consumption, breakfast consumption in particular, should target children from low socioeconomic groups and ethnic minority children. More qualitative research is warranted to investigate the pathways underlying social inequalities in children's meal skipping behaviors.

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Supplement Table 1. Meal skipping behaviors at age 6 years

Number of weekdays days on which meal is consumed	Breakfast (n=4687) n (%)	Lunch (n=4593) n (%)	Dinner (n=4573) n (%)
0	39 (0.8)	24 (0.5)	6 (0.1)
1	12 (0.3)	16 (0.3)	8 (0.2)
2	44 (0.9)	26 (0.6)	15 (0.3)
3	70 (1.5)	26 (0.6)	19 (0.4)
4	88 (1.9)	71 (1.5)	71 (1.6)
5	4434 (94.6)	4430 (96.5)	4418 (97.4)
Number of weekend days on which meal is consumed			
0	7 (0.1)	43 (0.9)	6 (0.2)
1	73 (1.6)	330 (7.2)	43 (0.9)
2	4607 (98.3)	4220 (91.9)	4488 (98.9)
Number of days on which meal is consumed (weekly consumption)			
0*	6 (0.1)	8 (0.2)	4 (0.1)
1*	2 (0.0)	7 (0.2)	1 (0.0)
2*	35 (0.7)	17 (0.4)	4 (0.1)
3*	14 (0.3)	14 (0.3)	9 (0.2)
4*	49 (1.0)	31 (0.7)	18 (0.4)
5*	66 (1.4)	60 (1.3)	21 (0.5)
6*	126 (2.7)	349 (7.6)	85 (1.9)
7	4389 (93.6)	4107 (89.4)	4395 (96.9)

Table is based on non-imputed dataset.

* Children with consumption < 7 days were considered breakfast, lunch, or dinner skippers.

Supplement Table 2. Number of meals consumed in total population and according to family SEP and ethnic background (n=4500)

		Median	90% range	P-value*
Total population		21	19-21	-
Maternal educational level	High	21	20-21	<0.001
	Mid-high	21	20-21	
	Mid-low	21	18-21	
	Low	21	16-21	
Paternal educational level	High	21	20-21	<0.001
	Mid-high	21	20-21	
	Mid-low	21	18-21	
	Low	21	17-21	
Maternal employment status	Paid job	21	19-21	<0.001
	No paid job	21	17-21	
Paternal employment status	Paid job	21	19-21	<0.001
	No paid job	21	16-21	
Household income	>€3200	21	20-21	<0.001
	€2000-<€3200	21	18-21	
	<€2000	21	16-21	
Family composition	Two parents	21	19-21	<0.001
	Single parent	21	17-21	
Ethnic background	native Dutch	21	20-21	<0.001
	Surinamese-Creole	21	17-21	
	Surinamese-Hindustani	21	18-21	
	Dutch Antillean	21	16-21	
	Cape Verdean	21	16-21	
	Turkish	21	16-21	
	Moroccan	21	16-21	

Table is based on non-imputed dataset. SEP= socioeconomic position.
* P-values assessed by Kruskal-Wallis tests.

Supplement Table 3. Associations of family SEP and ethnic background with number of meals consumed at age 6 years (n=4500)

	Crude model β (95% CI)	Basic model* β (95% CI)	Full model** β (95% CI)
Maternal educational level			
High (ref)	0.00	0.00	0.00
Mid-high	**-0.10 (-0.20,-0.00)**	-0.04 (-0.14,0.06)	-0.02 (-0.12,0.08)
Mid-low	**-0.26 (-0.25,-0.16)**	-0.08 (-0.17,0.02)	0.00 (-0.11,0.12)
Low	**-0.71 (-0.83,-0.59)**	**-0.41 (-0.54,-0.28)**	**-0.28 (-0.44,-0.13)**
Paternal educational level			
High (ref)	0.00		0.00
Mid-high	0.00 -0.10,0.11)	0.06 (-0.04,0.16)	0.09 (-0.02,0.20)
Mid-low	**-0.26 (-0.38,-0.15)**	**-0.11 (-0.23,-0.00)**	-0.03 (-0.15,0.09)
Low	**-0.49 (-0.63,-0.35)**	**-0.23 (-0.37,-0.09)**	-0.07 (-0.23,0.09)
Maternal employment status			
Paid job (ref)	0.00	0.00	0.00
No paid job	**-0.30 (-0.39,-0.21)**	-0.09 (-0.18,0.01)	0.03 (-0.08,0.13)
Paternal employment status			
Paid job (ref)	0.00	0.00	0.00
No paid job	**-0.40 (-0.62,-0.18)**	-0.15 (-0.37,0.08)	-0.04 (-0.27,0.18)
Household income			
>€3200 (ref)	0.00	0.00	0.00
€2000-<€3200	**-0.21 (-0.30,-0.13)**	**-0.12 (-0.20,-0.03)**	-0.07 (-0.17,0.03)
<€2000	**-0.59 (-0.68,-0.50)**	**-0.32 (-0.43,-0.22)**	**-0.22 (-0.37,-0.06)**
Family composition			
Two parents (ref)	0.00	0.00	0.00
Single parent	**-0.29 (-0.40,-0.19)**	**-0.18 (-0.29,-0.07)**	-0.02 (-0.15,0.11)
	Crude model β (95% CI)	Basic model*** β (95% CI)	Full model**** β (95% CI)
Ethnic background			
Dutch (ref)	0.00	0.00	0.00
Surinamese-Creole	**-0.43 (-0.63,-0.23)**	**-0.41 (-0.61,-0.21)**	**-0.29 (-0.49,-0.08)**
Surinamese-Hindustani	**-0.32 (-0.51,-0.13)**	**-0.30 (-0.49,-0.11)**	-0.19 (-0.38,0.01)
Dutch Antillean	**-0.57 (-0.79,-0.35)**	**-0.53 (-0.75,-0.30)**	**-0.38 (-0.61,-0.15)**
Cape Verdean	**-0.52 (-0.71,-0.34)**	**-0.50 (-0.69,-0.32)**	**-0.30 (-0.49,-0.10)**
Turkish	**-0.76 (-0.88,-0.64)**	**-0.74 (-0.86,-0.61)**	**-0.54 (-0.67,-0.40)**
Moroccan	**-0.62 (-0.78,-0.47)**	**-0.59 (-0.74,-0.44)**	**-0.37 (-0.54,-0.20)**

Table is based on imputed dataset. Bold print indicates statistical significance. Values represent betas and 95% confidence intervals derived from (multiple) linear regression analyses. SEP= socioeconomic position.
* Adjusted for confounders: child's sex, child's age, and ethnic background.
** Additionally adjusted for all SEP indicators.
*** Adjusted for confounders: child's sex and child's age.
**** Additionally adjusted for all SEP indicators.

INEQUALITIES

AND

BEHAVIORS

LIFESTYLE

CHILDHOOD

OVERWEIGHT

6

PUBLIC HEALTH INTERVENTIONS

YOUNG

SOCIAL

IN

CHILDREN'S

CHAPTER

6.1

EFFECTIVENESS OF INTERVENTIONS AIMED TO IMPROVE LIFESTYLE BEHAVIORS OR PREVENT OVERWEIGHT AMONG YOUNG SOCIALLY DISADVANTAGED CHILDREN IN EUROPE: A SYSTEMATIC REVIEW OF (RANDOMIZED) CONTROLLED TRIALS

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Abstract

Objective: Unhealthy lifestyle behaviors and childhood overweight are more common among children of low socioeconomic position (SEP) and ethnic minority children, but knowledge on the effectiveness of interventions aimed to improve lifestyle behaviors and/or prevent overweight among these children is limited.

Methods: A systematic literature search was conducted in six major databases. Studies were included when they reported intervention effects on adiposity measures, sedentary behaviors, physical activity behaviors, or dietary behaviors among socially disadvantaged children (0-12) years in Europe. Studies were included when the study sample was comprised of at least 50% socially disadvantaged children or when results were presented for subgroups of socially disadvantaged children separately. Studies on treatment interventions (i.e. interventions targeting overweight/obese children), studies conducted among children >12 years, and studies without the proper study design (i.e. [randomized] controlled trials) were excluded. Methodological quality assessment was based on Cochrane criteria.

Results: Thirteen studies reporting on eleven interventions were identified. One of these interventions was performed during infancy (0-2 years), one during the preschool period (2-6 years), and nine during the primary school period (6-12 years). All but one intervention (infants) were based in the school setting. In general, interventions effective in improving adiposity measures were multi-component interventions targeting individual, family, and environmental determinants of multiple lifestyle behaviors. Interventions aimed to improve one particular behavior succeeded in improving this behavior, but not other (related) lifestyle behaviors.

Conclusion: Despite an urgent need, research on the effectiveness of interventions aimed to improve lifestyle behaviors and/or prevent overweight among young socially disadvantaged children is Europe is still scarce. Those interventions that have been evaluated show modest effects on adiposity measures and lifestyle behaviors, but long term follow up is needed to establish whether these effects are sustained over a longer period of time.

Introduction

Over the past three decades, childhood overweight and obesity have become a major public health concern [1,2]. In addition to an increased risk of overweight and obesity in adulthood [3], childhood overweight has been associated with adverse health outcomes during childhood, including (amongst others) type 2 diabetes, asthma, skeletomuscular difficulties, bullying, and social disadvantages [1,3-5]. Childhood overweight is not evenly distributed, disproportionally affecting children from low family socioeconomic position (SEP) and ethnic minority children (hereafter referred to as socially disadvantaged children) [6-11].

Although the etiology of childhood overweight is multifactorial, involving both environmental and non-environmental (i.e. genetic) factors, there is general consensus that adverse changes in lifestyle behaviors have been a major determinant of the overweight epidemic [12]. This premise has been substantiated by a wealth of observational research, showing both cross-sectional and longitudinal associations between lifestyle behaviors and childhood overweight [12-16]. Furthermore, interventions targeting these lifestyle behaviors have shown to have modest effects on adiposity measures [17-21]. There is evidence to suggest that lifestyle behaviors are established in early childhood [22] and track into adolescence and young adulthood [23,24], warranting preventive efforts in early childhood.

Studies on the effectiveness of interventions aimed to improve lifestyle behaviors and/or prevent overweight among socially disadvantaged children are limited and have mainly been conducted in the United States (US) and Oceania [21,25,26]. Findings of these studies cannot be generalized to European populations of socially disadvantaged children given their differences in cultural and immigration backgrounds. Furthermore, US interventions among ethnic minority groups are usually performed in one specific ethnic group (e.g. African American or Hispanic children) [25,27,28], while European ethnic minority populations are of a more diverse descent. Therefore, the aim of this systematic review is to synthesize the evidence on the effectiveness of interventions aimed to improve lifestyle behaviors and/or prevent overweight among young socially disadvantaged children (0-12 years) in Europe.

Methods

Literature search

A systematic literature search was conducted in PubMed, EMBASE, Web of Science, Medline (OvidSP), Google Scholar, and Cochrane Database of Systematic Reviews in November 2013. The complete search strategies can be found in Supplement 1. The search strategy was initially designed for PubMed and subsequently adapted for all other databases. Furthermore, references of manuscripts were searched for additional studies not identified by the original search strategy. A search update was performed in December 2014.

Inclusion criteria

Studies on the effectiveness of lifestyle interventions were included when they reported on the following outcome measures: adiposity measures (e.g. body mass index [BMI], weight status, waist circumference, skin fold thickness, or fat mass), sedentary behaviors, physical activity behaviors, or dietary behaviors. Two types of studies were eligible for inclusion in this review on the basis of presenting effects for socially disadvantaged children: 1) studies with a study sample of at least 50% socially disadvantaged children [29], or 2) studies reporting sub group results for socially disadvantaged children separately. Socially disadvantaged children were defined as children with a non-native ethnic background /immigrant status, children from families with a low parental educational level, low household income, low parental occupational class, or living in low income/ deprived areas [30,31]. Inclusion was restricted to studies among infants (0-2 years), preschool children (2-6 years), or primary school children (6-12 years) in Europe. Inclusion was furthermore limited to studies with a rigorous study design, i.e. (randomized) controlled trials with a concurrent group. Finally, the study had to be published in a English spoken peer-reviewed journal after 31 December 1989.

Exclusion criteria

Studies among secondary school children/adolescents (i.e. age > 12 years) were excluded. In case of studies conducted among a combination of primary and secondary school children (e.g. 7- to 14-year-old children), exclusion was based on the mean age of the population. Studies without a rigorous study design, e.g. post-measurements only, pre-posttest measurements without a proper control group, or observational studies, were excluded. Furthermore, intervention studies performed in laboratory settings, intervention studies performed among overweight/obese children only (i.e. 'treatment interventions'), and intervention studies not reporting effects for socially disadvantaged children were excluded.

Selection process

Titles and abstract were independently reviewed by two authors (AW en VvdG) to make the initial selection of relevant intervention studies. Then, reference lists were screened for other potentially relevant studies. All studies identified between the two reviewers were reviewed using full text by both reviewers (AW and VvdG) and in the case of discrepant findings, a third party (HR) was consulted until consensus was achieved.

Results

Search results

The original search strategy identified 6080 unique studies. After the selection process based on the formulated inclusion and exclusion criteria, eleven studies were eligible for inclusion in this review. Even though some studies could be excluded based on multiple exclusion criteria, a study is attributed one exclusion criterion only (top to bottom), thus adding up to hundred percent. The updated search (1334 new unique studies) identified an additional two studies to be included this review. In total, thirteen studies describing eleven interventions were included in this systematic review (Table 1). A flow chart of the selection process is shown in Figure 1. The methodological quality of the included studies was assessed according to Cochrane criteria [32] (Supplement Tables 1-3).

Effectiveness of interventions

Most studies include a wide array of outcome variables. However, presentation of results is limited to the outcome measures relevant to this review, i.e. adiposity measures, sedentary behaviors, physical activity behaviors, and dietary behaviors. An overview of the

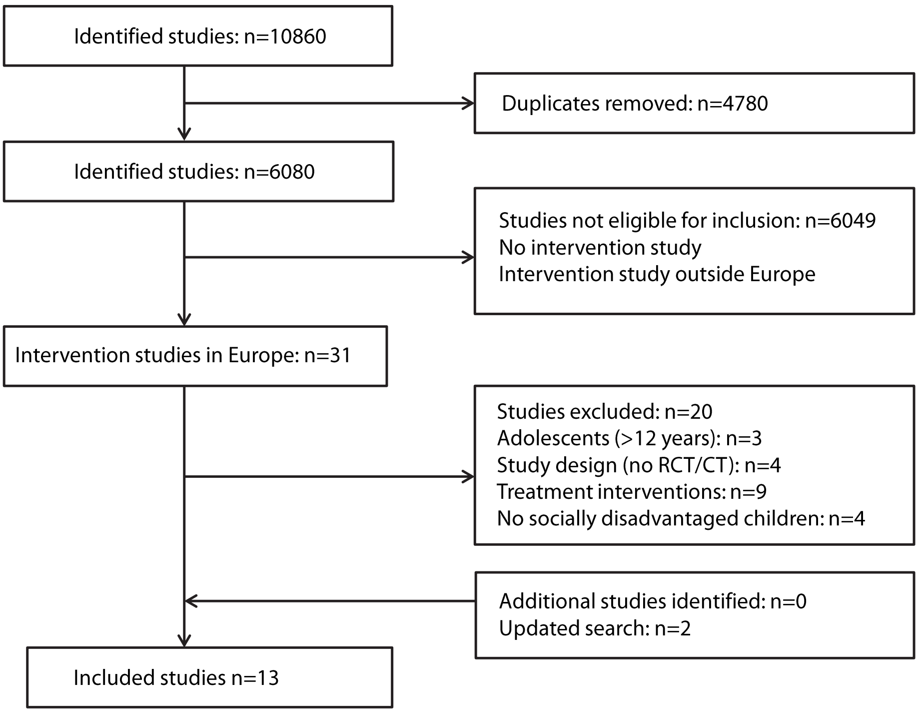

Figure 1. Flowchart of selection process.

Table 1. Description of included studies (n=13)

Study	Setting	Design	Population	N (cluster)[†]	Intervention duration	Age at baseline	Age at follow up
Watt et al. (2009) [34]	Family	RCT	Low income mothers and children living in two disadvantaged London boroughs.	312	9 mo	3 mo	12 mo (PI) 18 mo
Scheiwe et al. (2010) [33]	"	"	"	101	9 mo	3 mo	4.7 yrs
Puder et al. (2011) [35] "Ballabeina"	Preschool	Cluster RCT	Predominantly migrant preschool children of multicultural origin. 72% migrant children, 38% low education.	652 (40)	10 mo (SY)	5.2 yrs	6 yrs (PI)
Burgi et al. (2012) [36]	"	"	"	"	"	"	"
Adab et al. (2014) [37]	School	Cluster CT	Primary school children from inner Birmingham UK. 86% South Asian background.	574 (8)	1 yr	6.5 yrs	8.5 yrs
Jansen et al. (2011) [38] "Lekker Fit"	School	Cluster CT	Primary school children in more deprived inner-city areas in Rotterdam. 83% non-native Dutch children.	2622 (20)	10 mo (SY)	6-12 yrs	7-13 yrs (PI)
Muckelbauer et al. (2010) [39]	School	Cluster CT	Primary school children from low socioeconomic districts from two large cities in Germany. 44% immigrant children.	3190 (33)	10 mo (SY)	8.3 yrs	9.1 yrs (PI)
Armitage et al. (201) [40]	School	RCT	Primary school children from an inner city primary school in the UK (top 10% deprived areas).	77	-	8.1 yrs	8.1 yrs (PI)
De Meij et al. (2011) [41] "Jump-in"	School	Cluster CT	Primary school children in socially and economically deprived areas in Amsterdam. 85% non-native Dutch children.	2848 (19)	8 mo (SY) 9 mo (SY)	8.6 yrs	9.6 yrs (PI) 10.6 yrs (PI)
van Stralen et al. (2012) [42]	"	"	"	600 (19)	9 mo (SY)	9.8 yrs	10.6 yrs (PI)
Reinaerts et al. (2007) [43]	School	Cluster CT	Primary school children from schools in the south of the Netherlands.	1730 (12)	9 mo (SY)	9.0 yrs	9.8 yrs (PI)
Tak et al. (2007) [44] "School gruiten"	School	Cluster CT	Primary school children in the west and east of the Netherlands. 41% non-native Dutch children.	1328 (50)	10 mo (SY)	9.9 yrs	10.7 (PI)
Van de Gaar et al. (2014)[‡] [45]	School	Cluster CT	Primary school children in multi-ethnic, socially more deprived neighborhoods of Rotterdam. Depending on population for analysis 70-75% non-native Dutch children.	1175 (4)	14 months	-	-

RCT = randomized controlled trial; CT = controlled trial; SY= school year; PI= post intervention.
[†] Study sample at baseline; [‡] No age at baseline (years) provided. Population at baseline consisted of grade 2-7 children (6-12 years).

Table 2. Effect evaluation of included studies (n=13)

Study	Primary outcomes	Secondary outcomes
Watt et al. [34]	Vitamin C intake from fruit	F&V intake^{+}, weight and length^{0}
Scheiwe et al. [33]	Vitamin C intake from fruit	F&V intake^{0}, consumption of water and milk^{0}, BMI^{0}, % overweight^{0}
Puder et al. [35]	BMI^{0}	% Overweight^{0}, % body fat^{+}, waist circumference^{+}, sum of skinfolds^{+}, media use^{+}, physical activity^{+}, healthy eating^{+}, physical activity (objectively measured)^{0}
Burgi et al. [36]	*Immigrant children*: BMI^{0} *Low SEP children*: BMI^{0}	*Immigrant children:* % body fat^{+}, waist circumference^{+} *Low SEP children:* % body fat^{0}, waist circumference^{+}
Adab et al. [37]	BMI^{+}	% Obese^{+}, waist circumference^{0}, skinfold measurements^{0,} bioimpedance^{0}, physical activity (objectively measured)^{0}, school energy intake^{0}, school F&V intake^{+}, school sugar intake^{+}, home energy intake^{0}, home F&V intake^{0}, home sugar intake^{0}, 24h dietary energy intake^{0}, 24h dietary F&V intake^{0}
Jansen et al. [38][†]	BMI^{0}, % overweight^{+}, waist circumference^{+}	
Muckelbauer et al. [39]	*Immigrant children:* % overweight^{0}	*Immigrant children:* BMI^{0}, consumption of water^{0}, consumption of juice^{0}, consumption of soft drinks^{0}
Armitage et al. [40]	School play^{+}	
De Meij et al. [41]	Sports participation^{+}, physical activity (objectively measured)^{0} *Turkish and Moroccan children*: sports participation^{+}	BMI^{0}, waist circumference^{0}
van Stralen et al. [42]	Sports participation^{+}	Outdoor play^{0}, screen time^{0}
Reinaerts et al. [43][‡]	*Non-native children*: fruit intake (portions/day)$^{+}$, vegetable intake (grams/day)$^{+}$, F&V intake (times per day)$^{+}$	
Tak et al. [44][¥]	*Non-Western children*: vegetable intake^{+}, fruit intake^{0}	
Van de Gaar et al. [45][§]	Consumption of SSB^{+}	BMI^{-}, consumption of water^{0}

+ = Significant effect favoring the intervention group; - = Significant effect favoring the intervention group; 0 = No significant effect.
[†] Beneficial effects on overweight prevalence and waist circumference found only for children in grades 3-5, not grades 6-8; [†] Beneficial effects on vegetable intake found for the free distribution program only; [¥] Beneficial effect on vegetable intake found only for child-reported intake. No effects found for parent-reported intake; [§] Beneficial intervention effects were for parent-reported SSB intake and number of servings, and observed SSB bringing to school. No intervention effects found for child-reported SSB measures. Intervention effect on observed bringing to school found for children of high-educated parents only.

intervention effects is presented in Table 2. More detailed information on each of the interventions can be found in Table 3.

Interventions during infancy (0-2 years)

We identified two studies evaluating one intervention conducted among infants. These studies assessed the short-term and long-term effects of a social support intervention aimed to improve infant feeding practices among a sample of low income mothers in two disadvantaged London boroughs (UK) [33,34]. At the first follow up (12 months), children in the intervention group were more likely to consume pears (risk ratio [RR]: 1.4; 95% confidence interval [CI]: 1.1,1.8), apples (RR: 1.1; 95% CI: 1.0,1.3), and carrots (RR: 1.1; 95% CI: 1.0-1.2) compared with the children in the control group [34]. At 18 months, children in the intervention group were more likely to consume pears (RR: 1.3; 95% CI: 1.0,1.7) than children in the control group [34]. At follow up four years later, there were no differences in dietary behaviors or BMI between children in the intervention and control group [33].

Interventions during the preschool period (2-6 years)

We identified two studies evaluating one intervention conducted among preschool children. These studies assessed the effects of a culturally tailored multidimensional lifestyle intervention (Ballabeina) aimed to improve fitness and reduce adiposity in predominantly migrant preschool children in Switzerland, both in the total population [35] and stratified according to migrant status and SEP [36]. After the intervention, no group differences were seen in BMI (β: -0.07; 95% CI: -0.19,0.06) or overweight prevalence (OR: 0.65; 95% CI: 0.32,1.32). However, beneficial intervention effects were found for percentage body fat (β: -1.10; 95% CI: -2.02,-0.20), sum of skinfolds (β: -2.78; 95% CI: -4.35,1.20), and waist circumference (β: -1.00; 95% CI: -1.60,-0.42) [35]. Beneficial intervention effects were also found for reported media use, physical activity, and dietary behaviors (all $p<0.05$). No intervention effects were found for objectively measured physical activity [35]. Analyses stratified by migrant status and SEP showed similar results for migrant children and low SEP children [36]. Among migrant children, there were no intervention effects for BMI (β: -0.05; 95% CI: -0.18, 0.08) and beneficial intervention effects for percentage body fat (β: -1.14; 95% CI: -2.06, -0.22) and waist circumference (β: -1.02; 95% CI: -1.69,-0.36). Among low SEP children, there were no intervention effects for BMI (β: 0.04; 95% CI: -0.15,0.23) and percentage body fat (β: -0.43; 95% CI: -1.63, 0.77), and a beneficial intervention effect for waist circumference (β: -1.10; 95% CI: -2.00,-0.20).

Interventions during the school-aged period (6-12 years)

We identified nine studies evaluating nine interventions conducted among primary school children, all of which were based in the school setting. Three interventions

Table 3. Intervention content of interventions (n=11)

Study	Control condition	Intervention condition	Cultural tailoring
Watt et al. [34] Scheiwe et al. [33]	Standard professional support form health visitors and general practitioners (care as usual).	Mothers received monthly home visits during the first year by trained volunteers offering health education and social (peer) support.	Social support by women of the same background (local volunteers): - non-judgmental support - practical support
Puder et al. [35] Burgi et al. [36]	Continuation of regular school curriculum (45 minute physical activity lesson per week). Parents participated in one information and discussion evening.	Children were given physical activity and nutrition activity cards, promoting specific exercises to be done at home. Preschool teachers participated in two workshops to learn about the content and the practical aspects of the interventions. Parents participated in three interactive information and discussion evenings, and were given brochures and information leaflets. School curriculum changes included four 45 minute physical activity lessons per week, health education sessions, promotion of healthy snacks during recess and treats for anniversaries, exclusive offering of water and healthy food to the children by the preschool classes, and a Ballabeina games event. Adaption of the built environment in and around the preschool included the installation of fixed and mobile physical activity equipment.	Intervention was tailored to a culturally heterogenic group: - Identification of norms and needs through pilot studies, focus groups, and expert meeting. - Written information provided in ten languages. - Recommendations on physical activity and nutrition were kept simple and short and contained many pictures.
Adab et al. [37]	No intervention (curriculum as usual).	Multicomponent intervention consisting of physical activities during school hours, encouragement of physical activity outside of school hours, attendance at local sports club, cooking courses for family members, information on local leisure opportunities and taster sessions for families, and community walking programs.	Intervention was culturally tailored to South Asian communities: - involvement of key stake holders drawn from South Asian communities

Table 3. Intervention content of interventions (n=11) (continued)

Jansen et al. [38]	School curriculum as usual (two physical education lessons per week by classroom teacher of physical education teacher, depending on school policy).	At the beginning of the school year, there was a health promotion gathering for parents and local sports clubs. Children received three physical educational lessons per week, guided by a physical educational teacher. Additional sports and play activities were organized outside school hours (attendance voluntary). Children also received classroom education comprising of three main lessons on healthy nutrition, active living, and healthy lifestyle choices. Local sports clubs were involved in the intervention by providing some of the physical education lessons and sports activities outside school hours.	No specific information provided. Similarly, in design article no specific information provided [70]. Thus tailoring unlikely.
Muckelbauer et al. [39]	No intervention (curriculum as usual).	Installation of one or two water fountains with free access to cooled plain or carbonated water. School curriculum changes included four 45-minute lessons on water losses, water needs of the body, and on the water circuit in nature (led by classroom teachers). Lessons were not culture-specific adapted.	No tailoring.
Armitage et al. [40]	Children were asked to say out loud three times: "It's good to run around as much as possible".	Children were asked to perform an implementation intervention. Implementation interventions are "volitional strategies that work independently of motivation by ensuring decisions are acted upon" (page 362) [40]. Children were asked to say out loud three times: "If it is playtime, then I will run around as much as possible".	No tailoring.
De Meij et al. [41] van Stralen et al. [42]	School curriculum as usual.	Children and their parents were provided with personal workbooks including assignments to perform in class and at home. Parents were offered information meetings, courses, and sports activities. School staff received instruction books. Accessible school sports activities are offered on a daily basis ("school sports clubs"). Children can join the club during out-of-school hours. Furthermore, children are offered recurrent breaks for physical activity, relaxation exercises, and posture exercise during regular lessons.	No specific information provided. According to the design article, parental information was provided in parents' own language [71].

Table 3. Intervention content of interventions (n=11) (continued)

Reinaerts et al. [43]	School curriculum as usual.	*Free fruit and vegetables distribution* Every week, children were provided with a serving of fruit (twice per week), fruit juice (once per week), or raw vegetables (once per week). *Multicomponent program* Children were provided with a lunchbox to bring fruit and vegetables from home undamaged. Furthermore, classroom activities and homework activities were organized. To involve the local environment, posters of the project were displayed at several supermarkets stimulating parents to buy fruit and vegetables.	No specific information provided, thus tailoring unlikely. No design article available.
Tak et al. [44]	School curriculum as usual.	Free fruit or ready-to-eat vegetables twice per week. Furthermore, children were offered a school curriculum aimed to increase knowledge and skills related to fruit and vegetable consumption.	No specific information provided, thus tailoring unlikely. No design article available.
Van de Gaar et al. [45]	School curriculum as usual. This includes the regular health promotion program Lekker Fit!	Use of promotion material and water promoting activities (e.g. pimp up your water bottle, pimp up your water jug). Free water was provided at school during the day and water breaks during physical education lessons offered. Children furthermore received special education water lessons and fun games. Parents were involved in the water promoting activities and received water education.	Specific tailoring to two ethnic minority groups, Turkish and Moroccan children and their families. This was done by intervention mapping in combination with social marketing techniques (e.g. focus group interviews). Although the intervention was tailored to, pre-tested in, and developed for these specific groups, the intervention was delivered to all children and their families.

primarily aimed to improve adiposity measures [37-39], two interventions aimed to improve physical activity [40-42], and four interventions aimed to improve dietary behaviors (i.e. promote intake of fruit and vegetables [F&V] [43,44] and reduce intake of sugar sweetened beverages [SSB] [45]) .

In a feasibility study, Adab et al. evaluated the effect of multifaceted, culturally appropriate intervention among mostly South Asian primary school children from inner city schools in Birmingham, UK [37]. Beneficial intervention effects were found for the prevalence of obesity (OR: 0.41; 95% CI: 0.19,0.89) and BMI (β: -0.15; 95% CI: -0.15, -0.27,-0.03). Beneficial intervention effects were also found for specific dietary behaviors, including intake of F&V and sugar during school hours (both $p<0.05$). No intervention effects were found for the other anthropometric or dietary variables, nor for physical activity variables. Jansen et al. evaluated a multi-component intervention (e.g. physical education (PE) lessons by a certified PE teacher, additional sports and play activities outside school hours, classroom education on healthy nutrition and active living) among primary school children from multi-ethnic, low income, inner-city neighborhoods of Rotterdam, the Netherlands (Lekker Fit!) [38]. After the intervention, beneficial intervention effects were found for overweight prevalence (OR: 0.53; 95% CI: 0.36,0.78) and waist circumference (β: -1.29; 95% CI: -2.16,-0.42) for children in grades 3-5 (6- to 9-year-olds). No group differences were found for BMI (β: -0.10; 95% CI: -0.22,-0.03) or for children in grades 6-8 (9- to 12-year-olds) [38]. Muckelbauer et al. assessed a combined environmental and educational intervention targeting water consumption only among primary school children in deprived neighborhoods of Dortmund and Essen, Germany [39]. Stratified analyses according to immigration background showed that the intervention was not effective in changing the risk of overweight (OR: 1.02; 95% CI: 0.63,1.65) or BMI ($p=0.97$) among migrant children. Beneficial intervention effects were found for water consumption (β: 1.0; 95% CI: 0.6,1.4) but not for juice consumption or soft drink consumption [39]. Armitage and Spriggs evaluated the formulation of an implementation intention in enhancing physical activity (school play) among low SEP primary school children from an inner city school in the UK [40]. Following the implementation intention, children in the control group had not changed in physical activity ($p=0.19$), while children in the intervention group showed significant improvements in physical activity ($p<0.01$) [40]. De Meij et al conducted an effect evaluation of an intervention aimed to promote physical activity among children in socially and economically deprived areas in Amsterdam, the Netherlands [41]. After the intervention, children in the intervention group were significantly more likely to participate in sports compared with the control group (OR: 2.80; 95% CI: 2.18,3.62). Stratified by ethnic background, beneficial effects of sports participation were found to be stronger for Turkish children (OR: 3.20; 95% CI: 1.91,5.21) and Moroccan children (OR: 4.20; 95% CI: 3.63,5.70) compared with native Dutch children [41]. No effects were found for BMI (β: 0.07; 95% CI: -0.02,0.16), objectively measured physical activity (subgroup) (β: 40; 95% CI: -27, 106), or hip and waist circumferences [41]. Furthermore, a second study by van Stralen et al. did not find any intervention effects on outdoor play or screen time [42].

Reinaerts et al. evaluated two interventions aimed to promote fruit and vegetable (F&V) intake among primary school children in the South of the Netherlands, one being a free distribution program (DI) and one being a multicomponent program (MC) involving a classroom curriculum and parental involvement [43]. Among non-native children, beneficial intervention effects were found for fruit intake for both programs (DI, β: 0.10, $p<0.001$; MC, β: 0.11, $p<0.001$), for vegetables intake for the distribution intervention only (β:10.10, $p<0.01$), and for 24-hour fruit, juice and vegetable intake (times per day) for both programs (DI, β: 0.81, $p<0.01$; MC, β: 10.30, $p<0.01$). Tak et al. examined the effects of a combined environmental (free distribution) and educational intervention aimed to promote F&V intake among primary school children in two regions of the Netherlands (Schoolgruiten) [44]. Among non-Western children, there were beneficial intervention effects for children-reported vegetable intake (β: 20.7; 95% CI: 7.6,33.7), but not fruit intake (β: 0.1; 95% CI: -0.1,0.4). No intervention effects were found for F&V intake based on parent-report. Van de Gaar et al. investigated the effects of a water intervention (i.e. school lessons and integrated community activities to promote water consumption) on the consumption of sugar sweetened beverages (SSBs) among 6- to 12-year-old children who lived in multi-ethnic, socially deprived neighborhoods in Rotterdam, the Netherlands [45]. Beneficial intervention effects were found for parent-reported SSB intake in liters (β: 0.19; 95% CI: -0.28,-0.10) and number of SSB servings (β: -0.54; 95% CI: -0.82,-0.26). No intervention effects were found for parent-reported daily intake of SSB (yes, no) or any of the child-reported SSB measures. Lastly, a beneficial intervention effect was found for bringing SSB to school based on observational data (OR: 0.51; 95% CI: 0.36,0.72). However, stratified analyses on these observed data showed that this effect was not present among children from low SEP families. No effects were observed for water consumption ($p>0.05$) and an adverse intervention effect was found for BMI (β: 0.26; 95% CI: 0.11-0.40). Intervention effects were similar among children from different ethnic groups (i.e. Turkish, Moroccan, and native Dutch children).

Discussion

This systematic review aimed to synthesize the evidence on the effectiveness of interventions aimed to improve lifestyle behaviors and/or overweight among socially disadvantaged children (0-12 years) in Europe. In total we found thirteen studies describing the effects of eleven interventions. One intervention targeted infants, one intervention targeted preschool children, and nine interventions targeted primary school children.

Four interventions had a primary aim of improving at least one adiposity measure, two interventions had a primary aim of improving physical activity behaviors, and five interventions had a primary aim of improving dietary behaviors.

Effectiveness of interventions

Effect evaluations regarding adiposity measures showed inconsistent results. The Ballabeina intervention showed beneficial effects on percent body fat (not for low SEP children), waist circumference, and sum of skinfolds, but not on BMI or overweight prevalence. The intervention evaluated by Adab et al. showed beneficial effects on BMI and overweight prevalence, but not on other adiposity measures. The Lekker Fit! Intervention showed beneficial effects on overweight prevalence and waist circumference, but not BMI. The water intervention by Muckelbauer et al., the social support intervention, and the Jump-in intervention were not effective in changing any of the adiposity measures. Finally, the water intervention by van de Gaar et al. seemed to negatively affect BMI.

Taken together, the Ballabeina intervention and Lekker Fit! intervention appear to be most effective in improving children's adiposity measures. These interventions are typical multicomponent interventions, targeting individual level determinants, family level determinants, and environmental determinants of lifestyle behaviors and childhood overweight. Furthermore, these interventions aimed to improve multiple lifestyle behaviors related to childhood overweight instead of focusing on one specific behavior. These findings are plausible given the complex etiology of childhood overweight involving risk factors from all domains ranging from the most proximal lifestyle behaviors to wider environmental and societal determinant [1,2,21,26,46]. In general, effect on children's adiposity were more often found using sensitive adiposity measures, i.e. percent fat mass, waist circumference, and sum of skinfolds [47], rather than weight driven measures, i.e. weight status and BMI.

The effect evaluation regarding lifestyle behaviors showed inconsistent results. The Jump-in intervention and implementation intention intervention by Armitage were effective in increasing children's sports participation and school play, respectively. The Jump-in intervention did not improve objectively measured physical activity, outdoor play, or screen time. The social support intervention was effective in improving short-term F&V intake, but not long term dietary behaviors. The three F&V interventions were effective in improving children's F&V intake. The water intervention by van de Gaar et al. beneficially affected SSB consumption but not water consumption. The Ballabeina intervention was effective in improving parent-reported media use, physical activity, and healthy eating, but not objectively measured physical activity. The feasibility study by Adab et al. showed no effects on lifestyle behaviors, except for school F&V intake and sugar intake. The water intervention by Muckelbauer et at. did not affect consumption of water, juice, or soft drinks.

Except for the water consumption by Muckelbauer et al., all interventions aimed to improve a specific lifestyle behaviors succeeded in improving that behavior. With the exception of the water intervention by van de Gaar et al., those behaviors were also actually targeted by the intervention. Behaviors that were not specifically targeted showed no improvements, e.g. outdoor play and screen time for the Jump-in intervention and consumption of juices and soft drinks for the water consumption intervention. These results suggest that intervention developers should not rely on assumed spill-over effects (e.g. effects of a physical activity intervention on screen time or effects of a water consumption intervention on the consumption of sugar sweetened beverages) but rather should target the behaviors that they aim to improve.

All interventions included some form of health education (except for the DI program) and environmental change (except for the social support intervention), such as changes in the built environment, changes in the quantity and quality of PE lessons, and free distribution of F&V and water. The social support intervention, which relied heavily on health education, showed only limited, short-term, effects on F&V intake. In contrast, the other F&V interventions, most of which relied heavily on environmental change, showed more substantial effects of F&V intake. These results are in line with the notion that interventions targeting structural and financial barriers may be more effective in promoting healthy lifestyle behaviors among socially disadvantaged children compared with knowledge-based or motivational interventions [48,49].

Few of the interventions appeared to culturally tailor the intervention to the target population, despite evidence that cultural adaptation has the potential to enhance intervention relevance, effectiveness, and feasibility of interventions for ethnic minority groups especially [50,51]. Cultural tailoring of the intervention was most apparent for the intervention by Adab et al., the intervention by van de Gaar et al., and the Ballabeina intervention. Effect evaluation of these interventions, the Ballabeina intervention in particular, offer support to the premise that cultural tailoring is an important intervention element when designing effective interventions for socially disadvantaged children. However, given that the more environmental interventions (Jump-in intervention, F&V interventions) also positively affected children's lifestyle behaviors without any apparent tailoring, cultural tailoring may be especially important when it comes to health education and the overall design of the intervention (e.g. selection of intervention elements).

Some methodological considerations should be taken into account when interpreting the intervention effects on children's lifestyle behaviors and adiposity measures. Studies reporting effect estimates for subgroups were not initially designed for testing interaction effects and conducting subgroup analyses, and therefore are likely to lack power to detect significant effects in subgroups [35,36,39,43,44,52]. Additionally, the feasibility study by Adab et al. was not yet powered to examine intervention outcomes [37]. Also, effect evaluations were generally performed immediately post intervention, thus precluding any conclusions regarding long term intervention effects. Those studies who did perform a follow up evaluation showed that initial beneficial intervention effects (i.e. F&V consumption) were no longer observed at follow up [33,34]. An elaborate quality assessment of the included studies is presented in Supplement Tables 1-3. In general, studies included in this review scored low risk or unclear risk on most criteria. Overall, the most common limitations included lack of blinding of participants (often not possible due to nature of interventions) and the use of questionnaires the assessment of lifestyle behaviors, which together may have led to socially desirable answering [53].

Research gaps

Based on this systematic review, a number of research gaps can be identified. First and foremost, we found that the number of studies investigating the effectiveness of interventions aimed to improve lifestyle behaviors and/or adiposity measures among socially disadvantaged children in Europe is still scarce, especially among young children (i.e. < 6 years of age). Based on current evidence that very young children already display unhealthy lifestyle behaviors such as high screen time and consumption of sugar sweetened beverages [54-57], intervening at a young age seems paramount. Fortunately, in line with findings from a recent similar systematic review among 0- to 5-year-old socially disadvantaged children (worldwide) [25], we found that all studies were published in the last ten years (n=13) and the majority in the last five years (n=10, 77%), indicating that this is a growing area of research. Second, with the exception of one study, all interventions were conducted in the (pre)school setting, hampering conclusions regarding differential effects according to intervention setting. The school setting offers major advantages that may be especially important for socially disadvantaged children [36,41], including easily implemented changes in the school without need for parental involvement or motivation, the mandatory character of interventions elements (e.g. school curriculum changes and changes in the environment), and a large reach across all social groups. However, prevention in very early childhood also requires interventions outside the school setting. Furthermore, previous research has shown that the effectiveness of school-based interventions can be substantially improved by incorporating family and community components [58-62]. Third, this review identified only one intervention that primarily aimed to reduce SSB consumption and no studies that primarily aimed to reduce screen time. This finding is surprising given that SSB consumption and screen time, television viewing in particular, are two major risk factors of childhood overweight [12,13,16] that are more common among socially disadvantaged children [63-67]. Lastly, long-term follow up of interventions is needed to confirm whether positive intervention effects are sustained over a long period of time.

Review strengths and limitations

The main strength of this review is the extensive systematic literature search performed in multiple databases. A number of limitations should be considered when interpreting our results. This systematic review relied on studies published in English spoken, peer-reviewed journals in the past twenty-five years. As a consequence, studies published in other languages and/or published before 1990 would have been missed. Perhaps even more important, publication bias favoring studies showing significant intervention effects over studies showing no interventions effects may have biased the results. Socially disadvantaged children were defined as ethnic minority children and low SEP children. It should be acknowledged that although highly related, ethnic background and family SEP are different socio-demographic characteristics likely to moderate the associations of risk factors with children's lifestyle behaviors and adiposity measures. Furthermore, studies were included only when the study sample consisted of at least 50% socially disadvantaged children to ensure that the study results would be informative for socially disadvantaged children. Albeit this cut-off point was used to reach uniformity in study inclusion and based on previous research [29], the cut-off point itself is arbitrary and may have led to exclusion of potentially informative studies (e.g. non-stratified results by Muckelbauer et al. [52]). Process evaluation and effectiveness of secondary prevention interventions, or so called 'treatment' interventions, were outside the scope of the current review, precluding any conclusions regarding important process variables (e.g. intervention reach and sustainable implementation) and recommendations on how best to 'treat' childhood overweight among socially disadvantaged children in Europe. Also outside the scope of this study was the effect of interventions on reducing social inequalities in children's lifestyle behaviors and adiposity. When implementing an intervention in the general population that is more effective among non-socially disadvantaged children compared with socially disadvantaged children, social inequalities may increase even when socially disadvantaged children benefit from the intervention [68]. This systematic review was furthermore limited to studies employing rigorous study designs, i.e. those using (randomized) controlled trials with a concurrent control group. As a consequence, broader policies that may be specifically effective in improving lifestyle behaviors and adiposity among socially disadvantaged children (e.g. tax policies, policies to ban unhealthy-food advertisement, policies for changing the built environment [48,69]) and that are difficult to assess by (randomized) controlled trials [48,68] were excluded from this review. Finally, meta-analysis of the results was not possible due to the heterogeneity in study populations, interventions, outcome measures, and statistical analyses.

Conclusion

Given the high prevalence of unhealthy lifestyle behaviors and childhood overweight among socially disadvantaged children in Europe, preventive interventions are highly warranted. This systematic review shows that "although the relevant evidence base is involving, it is not keeping pace with the need for solutions" (page 178) [29]. Those interventions that have been evaluated show modest effects on adiposity measures and lifestyle behaviors, but long term follow up is needed to establish whether these effects are sustained over a longer period of time.

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Supplement 1

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OR program* OR promotion* OR promoting) AND (migrant* OR immigrant* OR ethnic* OR multiethnic* OR minorit* OR race OR racial OR african* OR hispanic OR asian OR (low* NEAR/1 income*) OR povert* OR poorer OR underserv* OR (under NEAR/1 serv*)) AND (child* OR schoolchild* OR preschool* OR (pre NEAR/1 school*)) AND (evaluat* OR effect* OR efficac* OR (follow* NEAR/1 up) OR followup OR outcome* OR assesment*))

Medline (OvidSP)

(((“life style”/ OR “sedentary lifestyle”/ OR “body mass index”/ OR “body weight”/ OR exp “body weight changes”/ OR exp “Overweight”/ OR “waist circumference”/ OR “Obesity, Abdominal”/ OR “Motor Activity”/ OR exp Exercise/ OR exp diet/ OR exp “diet therapy”/ OR “diet therapy”.xs. OR “feeding behavior”/ OR exp “Food Habits”/ OR “Eating”/ OR (lifestyle OR “life style” OR (body ADJ (mass OR weight)) OR (weight ADJ3 (gain OR chang* OR control* OR fluctuat* OR reduc*)) OR bmi OR Quetelet OR obes* OR adiposit* OR overweight* OR (over ADJ weight*) OR (physical* ADJ3 (activ* OR inactiv*)) OR sedentary OR diet* OR food OR feeding OR eating OR (Portion ADJ siz*) OR (excess* ADJ3 intake*)).ab,ti.) AND (“Intervention Studies”/ OR “Program Evaluation”/ OR exp “health promotion”/ OR (intervention* OR program* OR promotion* OR promoting).ab,ti.))) AND (exp “Human Migration”/ OR “Emigrants and Immigrants”/ OR exp “Ethnic Groups”/ OR “Minority Groups”/ OR “ethnology”.xs. OR exp Poverty/ OR (migrant* OR immigrant* OR ethnic* OR multiethnic* OR minorit* OR race OR racial OR african* OR hispanic OR asian OR (low* ADJ income*) OR povert* OR poorer OR underserv* OR (under ADJ serv*)).ab,ti.) AND (exp child/ OR exp “child behavior”/ OR “Child Nutritional Physiological Phenomena”/ OR (child* OR schoolchild* OR preschool* OR (pre ADJ school*)).ab,ti.) AND (“Program Evaluation”/ OR “Evaluation Studies”.pt. OR “Follow-Up Studies”/ OR “Outcome Assessment (Health Care)”/ OR (evaluat* OR effect* OR efficac* OR (follow* ADJ up*) OR followup OR outcome* OR assesment*).ab,ti.) NOT (Congresses OR Editorial OR Erratum OR Letter).pt. AND english.la.

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(lifestyle|”life style”|”body (mass|weight)”|”weight (gain|reduction)”|bmi|obesity|overweight exercise|diet|dietary) (intervention|program|promotion) (migrants|ethnic|minorities|”low income”|poverty) (child|children) (evaluation|effectivity|efficacy)

Cochrane

((((lifestyle OR ‘life style’ OR (body NEXT/1 (mass OR weight)) OR (weight NEAR/3 (gain OR chang* OR control* OR fluctuat* OR reduc*)) OR bmi OR Quetelet OR obes* OR adiposit* OR overweight* OR (over NEXT/1 weight*) OR (physical* NEAR/3 (activ* OR inactiv*)) OR exerci* OR sedentary OR diet* OR food OR feeding OR eating OR (Portion NEXT/1 siz*) OR (excess* NEAR/3 intake*)):ab,ti) AND ((intervention* OR program* OR promotion* OR promoting):ab,ti))) AND ((migrant* OR immigrant* OR ethnic* OR multiethnic* OR minorit* OR race OR racial OR african* OR hispanic OR asian OR (low* NEXT/1 income*) OR povert* OR poorer OR underserv* OR (under NEXT/1 serv*)):ab,ti) AND ((child* OR schoolchild* OR preschool* OR (pre NEXT/1 school*)):ab,ti) AND ((evaluat* OR effect* OR efficac* OR (follow* NEXT/1 up*) OR followup OR outcome* OR assesment*):ab,ti)

Supplement Table 1. Quality assessment of randomized controlled trials (n=2)*

Criteria	Watt et al. [34] Scheiwe et al. [33]	Armitage et al. [40]
Selection bias 1. Random sequence generation 2. Allocation concealment	1. Random digit computer tables. 2. Sequential allocation. *Low risk*	1. Coin toss. 2. Sequential coin toss. *Low risk*
Performance bias 1. Blinding of participants and personnel	1. No. *Unclear risk*	1. No. *Unclear risk*
Detection bias 1. Blinding of outcome assessment	1. Yes. *Low risk*	1. No. *High risk*
Attrition bias (n follow up/n baseline)	At 12 months 239/312= 77% At 18 months 212/312= 68% At 4.7 years 101/212= 48% *Low risk*	71/77= 92% *Low risk*
Reporting bias 1. Study design published	1. No. *Unclear risk*	1. No. *Unclear risk*
Other bias: Baseline imbalance 1. Baseline differences present 2. Adjustment for potential confounders	1. No. 2. No. *Low risk*	1. No. 2. No. *Low risk*
Other bias: Outcome assessment 1. Self-reported or objectively measured data 2. Validity and reliability of assessment tools reported	1. Lifestyle behaviors measured by questionnaire (parent) and interview. Anthropometric variables objectively measured. 2. Yes (satisfactory). *Unclear/low risk*	1. Physical activity self-reported by the children. 2. Internal reliability reported (satisfactory). *Unclear risk*

* Quality assessment based on Cochrane criteria [32].

Supplement Table 2. Quality assessment of cluster randomized controlled trials (n=3)

Criteria	Puder et al.[35] Burgi et al. [36]	Jansen et al. [38]	Van de Gaar et al. [45]
Selection bias 1. Random sequence generation 2. Allocation concealment 3. Individuals recruited after randomization of clusters	1. Opaque envelopes. 2. Randomization at once. 3. No. *Low risk*	1. Coin toss. 2. Sequential coin toss. 3. No. *Low risk*	1. Coin toss. 2. Sequential coin toss. 3. No *Low risk*
Performance bias 1. Blinding of participants and personnel	1. No. *Unclear risk*	1. No. *Unclear risk*	1. No. *Unclear risk*
Detection bias 1. Blinding of outcome assessment	1. Yes. *Low risk*	1. No. *Unclear risk*	1. No. *Unclear risk*
Attrition bias 1. Clusters 2. Individuals (n follow up/n baseline)	1. 40/40= 100% 2. 626/652= 96% *Low risk*	1. 20/20= 100% 2. 2416/2622= 92% *Low risk*	1. 4/4= 100% 2. 2. 1068/1175=91% *Low risk*
Reporting bias 1. Study design published	1. Yes. *Low risk*	1. Yes. *Low risk*	1. No. *Unclear risk*
Other bias: Baseline imbalance 1. Pair matched randomization 2. Baseline differences present 3. Adjustment for potential confounders	1. All clusters randomized. 2. Yes. 3. Yes. *Low risk*	1. Yes. 2. Yes. 3. Yes. *Low risk*	1. Yes. 2. Yes. 3. Yes. *Low risk*
Other bias: Outcome assessment 1. Self-reported or objectively measured data 2. Validity and reliability of assessment tools reported	1. Lifestyle behaviors measured by questionnaire (parent). Physical activity additionally objectively measured. Anthropometric variables objectively measured. 2. Yes (satisfactory). *Unclear/low risk*	1. Anthropometric variables objectively measured. 2. Yes (satisfactory). *Low risk*	1. Dietary behaviors assessed by questionnaire (child, parent) and observation (school). 2. No *Unclear/low risk*
Other bias: Statistical analysis 1. Taking clustering into account	1. Yes. *Low risk*	1. Yes. *Low risk*	1. No (too few clusters). *Low risk*

* Quality assessment based on Cochrane criteria [32].

Supplement Table 3. Quality assessment of cluster controlled trials (n=5)

Criteria	Adab et al. [37]	Muckelbauer et al. [39]	De Meij et al. [41] van Stralen et al. [42]
Performance bias 1. Blinding of participants and personnel	1. No. *Unclear risk*	1. No. *Unclear risk*	1. No. *Unclear risk*
Detection bias 1. Blinding of outcome assessment	1. NI *Unclear risk*	1. NI *Unclear risk*	1. No. *Unclear risk*
Attrition bias 1. Clusters 2. Individuals (n follow up/n baseline)	1. 8/8= 100% 2. 488/574= 85% *Low risk*	1. 32/33= 97% 2. 2950/3190= 93% *Low risk*	1.NI 2. At 8 months 2363/2848= 83% At 20 months 1824/2848= 64% *Unclear/low risk*
Reporting bias 1. Study design published	1. Yes. *Low risk*	1. No. *Low risk*	1. Yes. *Low risk*
Other bias: Baseline imbalance 1. Pair matched randomization 2. Baseline differences present 3. Adjustment for potential confounders	1. Yes. 2. Yes. 3. Yes. *Low risk*	1. Yes. 2. Yes. 3. Yes. *Low risk*	1. Yes. 2. Yes. 3. Yes. *Low risk*
Other bias: Outcome assessment 1. Self-reported or objectively measured data 2. Validity and reliability of assessment tools reported	1. Anthropometric variables objectively measured. Dietary behaviors measured by researchers (school) and questionnaires (parent). Physical activity objectively measured. 2. Yes (satisfactory). *Unclear/low risk*	1. Anthropometric variables objectively measured. Dietary behaviors measured by questionnaire (child). *2* Yes (satisfactory). *Unclear/low risk*	1. Sports participation measured by interview. Other lifestyle behaviors measured by questionnaire (child). Physical activity additionally objectively measured. Anthropometric variables objectively measured. 2. No. *Unclear/low risk*
Other bias: Statistical analysis 1. Taking clustering into account	1. No (too few clusters). *Low risk*	1. Yes. *Low risk*	1. Yes. *Low risk*

* Quality assessment based on Cochrane criteria [32]. NI= no information provided.

Continuation Supplement Table 3. Quality assessment of cluster controlled trials (n=5)

Criteria	Reinaerts et al. [43]	Tak et al. [44]
Performance bias 1. Blinding of participants and personnel	1. No. *Unclear risk*	1. No. *Unclear risk*
Detection bias 1. Blinding of outcome assessment	1. No. *Unclear risk*	1. No. *Unclear risk*
Attrition bias 1. Clusters 2. Individuals (n follow up/ baseline)	1. NI 2. 939/1730= 54% *Unclear/high risk*	1. 45/50= 90% 2. 1140/1328= 86%% *Low risk*
Reporting bias 1. Study design published	1. No *Low risk*	1. No *Low risk*
Other bias: Baseline imbalance 1. Pair matched randomization 2. Baseline differences present 3. Adjustment for potential confounders	1. Yes. 2. Yes. 3. Yes. *Low risk*	1. Yes. 2. Yes. 3. Yes. *Low risk*
Other bias: Outcome assessment 1. Self-reported or objectively measured data 2. Validity and reliability of assessment tools reported	1. Dietary behaviors assessed by questionnaire (parent). 2. Yes (satisfactory). *Unclear risk*	1. Dietary behaviors assessed by questionnaire (child, parent). 2. Yes (satisfactory). *Unclear risk*
Other bias: Statistical analysis 1. Taking clustering into account	1. Yes. *Low risk*	1. Yes. *Low risk*

* Quality assessment based on Cochrane criteria [32]. NI= no information provided.

INEQUALITIES
AND
BEHAVIORS
LIFESTYLE
CHILDHOOD
OVERWEIGHT

7

GENERAL DISCUSSION

YOUNG
SOCIAL
IN
CHILDREN'S

Summary of findings

Social inequalities in childhood overweight

Chapters 2.1 and *2.2* describe the independent associations of key lifestyle behaviors with body fat indicators at the age of 6 years. Results from these studies showed that sports participation (negative) and breakfast skipping (positive) were independently associated with percent fat mass. No independent associations were found for other physical activity behaviors or sedentary behaviors (e.g. television viewing), or other meal skipping behaviors. Furthermore, no associations were found for other body fat indicators, including BMI and weight status. *Chapter 2.3* assessed the development of the association between family socioeconomic position (SEP), as indicated by maternal educational level and household income, and children's body fat. Furthermore, factors from the prenatal period, perinatal period, and postnatal were investigated as potential mediators in the inverse association between family SEP and body fat at age 6 years. The inverse SEP association emerged around the preschool period and increased thereafter. Important mediators of the inverse association at age 6 years included parental BMI, maternal smoking during pregnancy, and children's lifestyle behaviors (i.e. television viewing, sports participation, and breakfast skipping).

Social inequalities in children's lifestyle behaviors

Socioeconomic inequalities

Chapters 3.1, 4, and *5* describe the associations between socioeconomic position and children's sedentary behaviors, physical activity behaviors, and dietary behaviors. Preschool children from educated mothers were significantly more likely to exceed entertainment-media guidelines (i.e. watch television ≥ 2 hours/day) (*chapter 3.1*) and to consume excessive amounts of sugar-containing beverages and high-calorie snacks (*chapter 5.1*). Mediators of the first association included parental television viewing time, parental BMI, financial difficulties, maternal age, TV set in the child's bedroom, and maternal depression. Mediators of the latter associations included parental consumption of sugar-containing beverages, children's television viewing time, and parental feeding practices. School-aged children from low family SEP were also more likely not to participate in sports, display low levels of outdoor play, and skip main meals, breakfast in particular (*chapters 4.2* and *5.2*). Independent associations between different SEP indicators (i.e. parental educational level, parental employment status, and household income) and these lifestyle behaviors were observed, indicating that different pathways specifically related to these indicators underlie these SEP associations. In contrast to all other findings relating family SEP to children's lifestyle behaviors, we did not find an association between family SEP and objectively measured physical activity in two-year-old toddlers (*chapter 4.1*). Variables associated with more physical activity and less sedentary time included child's sex (boy), child's age (older), number of siblings (more), and season of measurement (spring/summer/fall).

Ethnic inequalities

Chapters 3.2, 4.2, and *5.2* describe the associations between ethnic background and children's sedentary behaviors, physical activity behaviors, and dietary behaviors. Preschool children and young school-aged children with ethnic minority backgrounds were significantly more likely to exceed entertainment-media guidelines, not to participate in sports and display low levels of outdoor play, and skip main meal, breakfast in particular. A low family SEP among these children explained a large part, but not all, of these associations. Additionally, we found a significant interaction effect between ethnic background and maternal educational level on children's television viewing (*chapter 3.2*), with growing ethnic inequalities in television viewing as maternal educational level increased.

Effectiveness of interventions among socially disadvantaged children in Europe

Chapter 6.1 contains a systematic literature review on the effectiveness of interventions aimed to improve lifestyle behaviors and/or prevent overweight among socially disadvantaged children (0-12 years) in Europe. Results from this review showed that few interventions have been evaluated, especially in young children, and even fewer have shown substantial effects. In general, interventions effective in improving adiposity measures were multi-component interventions targeting individual, family, and environmental determinants of multiple lifestyle behaviors. Interventions aimed to improve one particular behavior succeeded in improving this behavior, but not other (related) lifestyle behaviors.

In summary, the inverse association between family SEP and childhood overweight becomes apparent around the preschool age and increases thereafter. At early school-age, the inverse association is mostly explained by prenatal factors and postnatal factors (i.e. children's television viewing, sports participation, and daily breakfast association). This finding is substantiated by our studies showing independent associations between sports participation and breakfast consumption with childhood overweight. Social inequalities in children's sedentary behaviors, physical activity behaviors, and dietary behaviors were consistently observed, with the exception of objectively measured physical activity among two-year-old toddlers. Variables relating to the family home environment, parental behaviors especially explained a large part of the observed socioeconomic inequalities. Ethnic inequalities were for a large part, but not completely, explained by underlying socioeconomic inequalities. Research on the effectiveness of interventions aimed to improve lifestyle behaviors and prevent childhood overweight among socially disadvantaged children in Europe is still scarce, especially among young children. An overview of the results from the studies included in this thesis are presented in Table 1.

Table 1. Overview of main results

Chapter	Main exposures	Main outcomes	Main results
2. Social inequalities in childhood overweight			
2.1	Sedentary behaviors and physical activity behaviors	Childhood overweight, BMI SDS, % fat mass	Sports participation is independently associated with a lower % fat mass. No other independent associations were observed.
2.2	Meal skipping behaviors	Childhood overweight, BMI SDS, % fat mass	Breakfast skipping at age 4 years is independently associated with a higher % fat mass at age 6 years. No other independent associations were observed.
2.3	Maternal educational level, household income	BMI SDS, % fat mass	The independent SEP association with childhood overweight emerges in the preschool period and increased with age. Important mediators of the inverse SEP association at age 6 include parental BMI, maternal smoking during pregnancy, and children's lifestyle behaviors (television viewing, sports participation, daily breakfast consumption)
3. Social inequalities in children's sedentary behaviors			
3.1	Maternal educational level	Television viewing time	Maternal educational level is inversely associated with children's television viewing time. Mediators of this association include parental television viewing time, parental BMI, financial difficulties, and the presence of a television set in the child's bedroom.
3.2	Ethnic background	Television viewing time	Ethnic minority children are more likely to display high levels of television viewing. Differences between ethnic minority children and native Dutch children increase with increasing maternal educational level.
4. Social inequalities in children's physical activity behaviors			
4.1	Multiple exposures	Objectively measured physical activity	Toddlers spent a high percentage of monitored time in sedentary behavior (±85%). Correlates of sedentary behavior and moderate-to-vigorous physical activity include child's sex, child's age, number of siblings, and season.
4.2	Different SEP indicators, ethnic background	Sports participation, outdoor play	Low SEP children and ethnic minority children are more likely not to participate sports and display low levels of outdoor play. Sports participation is more strongly socially patterned compared with outdoor play. Independent SEP associations were found for both physical activity behaviors, indicating different pathways linking SEP to these behaviors (e.g. social, cultural, and economic resources).

Table 1. Overview of main results (continued)

5. Social inequalities in children's dietary behaviors			
5.1	Maternal educational level	Consumption of high-calorie snacks, consumption of sugar-containing beverages	Maternal educational level is inversely associated with children's consumption of high-calorie snacks and sugar-containing beverages. Mediators of these associations include parental consumption of sugar-containing beverages, children's television viewing time, and parental feeding practices (monitoring, restriction, pressure to eat)
5.2	Different SEP indicators, ethnic background	Meal skipping behaviors	Low SEP children and ethnic minority children are more likely to skip main meals, breakfast especially. Independent SEP associations were found for all meal skipping behaviors, indicating different pathways linking SEP to these behaviors ((e.g. social, cultural, and economic resources).
6. Public health interventions			
6.1	Interventions to improve lifestyle behaviors or prevent overweight among socially disadvantaged children (0-12 years) in Europe		Few effect studies were identified. Those interventions that were evaluated generally showed only modest effects.

SEP = socioeconomic position. BMI = body mass index. SDS = standard deviation score.

Interpretation of findings

Social inequalities in childhood overweight

Childhood overweight is multifactorial problem, encompassing both genetic and non-genetic factors [1,2]; however, lifestyle behaviors are considered to be the most proximal determinants of childhood overweight [3]. Most observational research investigating associations between lifestyle behaviors and measures of body fat has been hampered by a lack of control for co-occurring lifestyle behaviors [4,5]. Furthermore, the majority of these studies have used BMI or weight status as indicators of body fat, even though these measures do not distinguish between fat mass and lean mass [6]. The studies described in this thesis underscore the added value of using a more accurate measure of body fat (i.e. percent fat mass) in addition to BMI or weight status in establishing associations between lifestyle behaviors and childhood overweight.

Associations of sports participation and breakfast skipping with children's body fat have been reported by previous studies [7-10]. Our findings add to the literature by showing that these associations were independent of other lifestyle behaviors. Physical activity is likely to impact children's body fat by its direct effect on energy expenditure. The reason that sports participation, but not other physical activity behaviors (i.e. outdoor play and active transport to/from school), was associated with children's fat mass may be explained by the activity levels associated with this behavior. In a study among 6-10 year old Danish children, activity levels during organized sports were substantially higher than activity levels in other contexts [11,12]. Alternatively, children participating in organized sports at this young age, may be particularly more likely to come from higher SEP families with an overall healthy lifestyle. However, adjustment for a wide range of social factors, as well as other lifestyle behaviors, did not fully explain the association between sports participation and % fat mass.

In contrast to our findings, television viewing has been identified as an important risk factor of childhood overweight in earlier studies [13,14]. We speculate that the young children in our study (aged 6 years) may not have been exposed sufficiently to excessive levels of television viewing in order to detect any effects on body fat. This could relate both to the duration of exposure (i.e. over the life course) as well as the amount of exposure to television viewing. Indeed, compared to children in the US or Australia (where most previous research has been conducted), children within the Generation R Study show relatively low levels of television viewing [15,16]. Alternatively, dietary behaviors such as consumption of sugar-containing beverages and high-calorie snacks may be part of the causal pathway leading from children's television viewing to body fat [17-20], and therefore the effects of television viewing time may have been underestimated when adjusting for these behaviors.

Possible mechanisms underlying the association between breakfast skipping and children's body fat include increased consumption of unhealthy snacks (later in the day), lower overall diet quality, increased irregularity of eating patterns, and eating late at night [21-23]. Furthermore, daily breakfast consumption has been associated with engagement in physical activity behaviors [24,25]. It may be hypothesized that similar pathways relate lunch skipping and dinner skipping to children's body fat; therefore, our findings of a sole association with breakfast skipping seem unexpected. One explanation may be that not the meal itself, but rather the types of food consumed during breakfast, are associated with children's body fat [24,26]. Secondly, breakfast skipping was more likely to track (i.e. be more persistent over time) compared with lunch and dinner skipping and therefore more exposure to this risk factor was probably more prolonged. Finally, breakfast consumption may be a marker for an overall healthy lifestyle. However, this explanation can be deemed less important as adjustment for an array of social factors and lifestyle behaviors did not alter the results.

In developed countries, the prevalence of childhood overweight and obesity is higher among children from low SEP families [27-30]. Based on evidence that high SEP children are born with a higher birth weight and have a higher BMI in the early years, the association must reverse somewhere between the early years and school-age [31-34]. In agreement with earlier studies [32,33], we found that the inverse association between family

SEP (as indicated by maternal educational level and household income) and children's body fat emerges around the preschool period and becomes more pronounced with age.

At school-entry, a large part of this association could be explained by parental BMI, maternal smoking during pregnancy, and children's lifestyle behaviors. The effect of lifestyle behaviors is direct, i.e. through their effects on energy intake and expenditure. Previous studies on the mediating effects of lifestyle behaviors in the association between family SEP and childhood overweight have been conflicting [35-37], with most consistent evidence for the role of television viewing [36,37]. Again, this may be due to the use of BMI, instead of more accurate measures as indicator of children's body fat [35-37]. Parental BMI may contribute through the inheritance of genes, through a shared family eating and physical activity environment, or through the intrauterine environment [38]. Furthermore, overweight parents may be more inclined to engage in sedentary behaviors, rather than physic activity behaviors with their children. Smoking may influence childhood overweight through its effects on birth weight (which in followed by rapid weight gain, a risk factor of childhood overweight [39]), or through its effects on neural regulation, which may lead to increased appetite [40]. Taken together, our findings indicate that low SEP children may start with a disadvantage due to a genetic disposition for adiposity, as well as adverse exposures in utero, which may be further augmented by adverse lifestyle behaviors of which the influences are likely to increase with age.

Social inequalities in children's lifestyle behaviors

Socioeconomic inequalities

The studies described in this thesis consistently show that socioeconomic inequalities in children's lifestyle behaviors are already present in young preschool and school-aged children (4-6 years). These results are in accordance with previous research showing these associations among adolescents and older school-aged children [11,16,23,41-51]. Our finding of a null-association between family SEP and objectively measured activity may be explained by the age of the study population. Most children master walking alone (i.e. without assistance) by the age of 12 months [52]. As the mean age of children in our study was 25 months, it is possible that the variability in physical activity at that age is (still) small and therefore socioeconomic patterning may not be detected. However, our results are supported by studies conducted among older children that also did not find socioeconomic inequalities in objectively measured physical activity [11,53-59]. In order to establish which explanation is more plausible, additional measurements of objectively measured physical activity within the Generation R Study is merited.

Studies on the pathways underlying socioeconomic inequalities in children's lifestyle behaviors are essential in order to design effective interventions to reduce these inequalities [60]; however, such studies are still scarce. We performed mediation analyses on the associations of family SEP, as indicated by maternal educational level, with children's television viewing and consumption of sugar-containing beverages and high-calorie snacks (*chapters 3.1* and *5.1*). Mediators of the first association included parental television viewing time (largest contribution), financial difficulties, BMI of the mother, and the presence of a television set in the child's bedroom. These findings are in accordance with previous studies that also found media (television set) in the bedroom and/or parental television viewing to mediate the association between maternal education and children's television viewing [16,58]. The mediating effect of parental behaviors may be explained in several ways. First, parents are likely to act as role models for their children [3]. Second, parents are gatekeepers of the social (e.g. parenting practices and rules) and physical environments (e.g. presence of television set in the child's bedroom, availability and accessibility of unhealthy food items) to which children are exposed [3]. Financial difficulties may represent a lack of resources to facilitate children's participate in alternative activities (e.g. participation in music clubs or organized sports). Alternatively, financial difficulties may lead to stress within the household or the need to juggle jobs which may lead to using the television as a babysitter [61].

Identified mediators of the association between maternal educational level and children's consumption of sugar-containing beverages and high-calorie snacks included parental consumption of sugar-containing beverages, children's television viewing time, and parental feeding practices. Of these, parental consumption of sugar-containing beverages and children's television time seemed to be the most important mediators. Mediating effects of parental feeding practices and parental consumption have been reported by earlier studies [44,50]. The mediating effect of television viewing has not been reported previously; however, these is an abundance of studies showing a strong association between screen time and the consumption of unhealthy food items including high-calorie (sweet and savory) snacks and sugar-containing beverages [19,62-64].

The results from these mediation analyses highlight the important role parents play in shaping young children's lifestyle behaviors [3,65,66]. In both studies, about half of the effect of low educational level was explained by the mediators under study, implying that alternative mediators are likely to add to the explanation of socioeconomic inequalities in children's television viewing and consumption of sugar-containing beverages and high-calorie snacks. These mediators may include, amongst others, parental perceptions and norms, household rules, family functioning, parental knowledge, additional characteristics of the home environment, and sleeping behavior of the children [16,58]. Over and beyond these individual-level characteristics of the children and their family, characteristics of the school environment and physical (built) environment to which low SEP children are exposed are likely to contribute to socioeconomic inequalities in children's lifestyle behaviors [67-72].

A more indirect manner of inferring potential pathways underlying socioeconomic inequalities in children's lifestyle behaviors was used in our studies on social inequalities in young children's sports participation, outdoor play, and meal skipping behaviors (*chapters 4.2* and *5.2*) [73-77]. Results from these studies suggest that different pathways, including parental knowledge and skills (e.g. parenting practices), material resources, and residential environment, may play a role in explaining socioeconomic inequalities in children's sports participation, outdoor play, and meal skipping behaviors. However, further research, including quantitative studies performing formal mediation analyses and qualitative studies, are warranted to provide a deeper understanding of the mechanisms linking family SEP with children's physical activity behaviors and meal skipping behaviors.

In sum, results of our studies indicate that socioeconomic inequalities in lifestyle behaviors are present at a young age and that factors related to the home environment, parental behavior especially, make an important contribution to these inequalities. Combined with evidence that childhood/adolescent overweight impairs future socioeconomic attainment [78-81], our results suggest that early childhood lifestyle behaviors and overweight, and home influences thereon, may contribute to intergenerational transmission of social disadvantage [78]. Consequently, adequate prevention of unhealthy lifestyle behaviors and overweight in early childhood may not only benefit one generation, that in which action is taken, but also future generations.

Ethnic inequalities

The studies described in this thesis furthermore support the existence of ethnic inequalities in lifestyle behaviors in young children (4-6 years). These results are in line with previous studies reporting ethnic inequalities in these behaviors in school-aged children and adolescents [23,47,49,51,82,83]. In addition to confirming results from these earlier studies, our studies add to the existing literature by showing these inequalities in preschool children and young school-aged children, as well as showing that the risks are not uniform across all ethnic minority groups.

Our studies showed that a low SEP among ethnic minority groups accounted for a large part of the observed inequalities in children's television viewing, physical activity behaviors, (sports participation in particular), and meal skipping (breakfast skipping in particular). However, ethnic inequalities could not be completely reduced to socioeconomic inequalities. These results indicate that, in addition to socioeconomic factors and associated recourses, factors specifically associated with ethnic background are involved in the observed ethnic inequalities in young children's lifestyle behaviors. Such factors may include, but are not limited to, cultural and religious norms and values, discrimination processes, residential environment, and acculturation characteristics (e.g. language and generational status) [84-87].

The association between acculturation characteristics and children's lifestyle behaviors was specifically assessed in our study on the association between ethnic background and children's television viewing. Results of this study did not show effects of acculturation characteristics, such as generational status, age at immigration, and Dutch language proficiency. This is in contrast with a US study that found television viewing to be less prevalent among first and second generation immigrant children than third generation children [88]. Studies on the association between acculturation characteristics are important in identifying high risk groups as well as identifying potential underlying mechanisms underlying ethnic inequalities. For example, increased acculturation may promote physical activity among ethnic minority children due to an increase in knowledge about the organization of sports and physical activity opportunities in the host country [89]. In contrast, increased acculturation may promote unhealthy lifestyle behaviors such as sedentary behaviors (television viewing) and fast food consumption due to increased exposure to media and fast food outlets or the need to 'conform' to native peers [90-93]. Alternatively, variables inherent to migration processes such as language difficulties and stress may impact on children's lifestyle behaviors [85]. Few such studies have been conducted in Europe [94], and even fewer have been conducted among young children. Therefore, more research in this area is warranted.

In the same study, we found an interaction effect between SEP, as indicated by maternal educational level, and ethnic background. Among low educated women, we found small ethnic inequalities in children's excessive television viewing. However, when we compared children of middle or high educated mothers (higher vocational training [HBO] and university/PhD), differences between ethnic minority children and native Dutch children became more pronounced. Interaction effects between SEP and ethnic background/race are frequently observed and can take different forms [95,96]. Our findings are in line with the 'diminishing return' hypothesis, which states that ethnic inequalities are greatest at the highest levels of SEP [96]. This interaction effect occurs when SEP indicators are not commensurate (i.e. in terms of conveying skills, knowledge, employment, income etc.) between ethnic groups [95-101]. Processes that may lead to a diminished return for education among ethnic minority women may include, but are not limited to, discrimination processes (e.g. on the work floor) or differences in the quality of education between ethnic groups [95-101]. Although the latter explanation does not seem likely for mothers educated in the Netherlands, it may explain differences between native mothers and first generation mothers educated abroad.

An alternative explanation can be found in the 'diffusion theory' that was developed to explain the course of the epidemic of cardiovascular disease (CVD) in the second half of the previous century [102,103]. This theory states that the rise in CVD started first in high SEP individuals in high-income countries because they were the first who could afford 'new' behaviors such as smoking, sedentary lifestyles and diets rich in fat (resulting in a positive association between SEP and CVD). With time, these behaviors were adopted by low SEP individuals and individuals from low income countries, partly due to rising living standards and partly as a results of imitation. Higher SEP individuals were also the first to adopt healthy behaviors, leading to a reversal in the association between SEP and CVD. Since most ethnic minority families originate from middle- and low-income countries, the absence of a SEP gradient (or a smaller gradient) in lifestyle behaviors may reflect an earlier stage of the epidemiologic transition in their original country [102,103].

Effectiveness of interventions among socially disadvantaged children in Europe

Given the evidence showing that unhealthy lifestyle behaviors and childhood overweight are more common among socially disadvantaged children, the last study presented in this thesis consisted of a systematic literature review aimed to synthesize the evidence on the effectiveness of interventions aimed to improve lifestyle behaviors and/or prevent overweight among 0- to 12-year-old socially disadvantaged children in Europe. Results of this systematic review first and foremost showed that effect evaluations among socially disadvantaged children are still scarce, especially among very young children.

The most substantial effects on children's body fat were observed for multicomponent interventions targeting multiple lifestyle behaviors. This seems plausible since the etiology of childhood overweight involves many behaviors related to both energy intake and expenditure [1,2,104-106]. However, identifying the effective components of these complex interventions is difficult. For interventions targeting specific lifestyle behaviors, beneficial effects were found for that specific behavior but not for other behaviors. In comparison with interventions relying heavily on health education, interventions consisting of at least one environmental component seemed to positively impact children's lifestyle behaviors and adiposity. These results indicate that interventions that remove structural and/or financial barriers may be especially effective among socially disadvantaged children [107,108].

It is noteworthy that only few interventions focused on reducing screen time or consumption of sugar-containing beverages, lifestyle behaviors that are established as behavioral risk factors for childhood overweight [14,104,109,110] and that are highly common among socially disadvantaged children [42-46,50,111-114]. Furthermore, only one out of eleven interventions was based in the home setting, while the studies described in this thesis emphasize the importance of the family (social and physical) home environment in shaping socially disadvantaged children's lifestyle behaviors. A recent Cochrane review that aimed to determine the effectiveness of interventions intended to prevent obesity in children supports the importance of the home setting, especially for young children (0-5 years) [106]. Indeed, a home-based intervention targeting household routines among low income, ethnic minority families of young children has shown to positively affect sleeping duration (increased), television viewing (decreased), and BMI (decreased) [115].

Methodological considerations

Study design

The studies described in this thesis are embedded in the Generation R Study, a population-based birth cohort study. In a cohort study, individuals are classified according to an exposure, followed over a period of time, and compared on a particular outcome. One advantage of this particular design is that many (rare) exposures can be studied. However, this design is not well suited to study rare outcomes. It may also take a long time before a certain outcome occurs.

Similar to other observational study designs, causation cannot be inferred from a cohort study. In contrast with experimental studies, exposures of interest are not randomly distributed among all people and therefore groups with and without the exposure may differ with respect to other characteristics. When these characteristics are also associated with the outcome, confounding can occur. Even though we adjusted for most potential confounders, residual confounding by poorly measured confounders or unmeasured confounders may have occurred (for a more elaborate discussion of confounding, see paragraph on confounding, mediation, and moderation).

Furthermore, reverse causation, in which case the supposed outcome affects the supposed exposure, cannot be excluded. This bias may be especially likely in our cross-sectional study on the associations of children's sedentary behaviors and physical activity behaviors with body fat, as a small body of evidence suggest that fatness may lead to reduced levels of physical activity and increased levels of sedentary behavior [116-118]. Most probable, the relationships are bidirectional. Our study on the association between children's breakfast skipping and body fat is less likely to suffer from reverse causation due to its prospective design and control for body fat at baseline. Reverse causation is also not a likely explanation for the observed social inequalities in children's lifestyle behaviors as it is improbable that lifestyle behaviors of the children are responsible for a lower educational attainment or household income of their parents [119].

Bias in epidemiological studies

Selection bias

Generally, participation rates of large birth cohorts are around 30-40% [120]. With an initial participation rate of 61%, the participation rate within the Generation R Study was relatively high [121]. A study suffers of selection bias when the association between the exposure and the outcome is different for those who participate in the study and those who were initially eligible to be included in the study (including those who do not participate). Selection bias can occur as a result of selective participation, either at the start of the study (i.e. initial participation) or during follow-up. Initial participation in the Generation R Study was non-random; i.e. participants in the study are more often higher-educated, more affluent, more often native Dutch, and healthier compared to the source population (pregnant women with an expected delivery date between 2002-2006, living in Rotterdam, the Netherlands) [121]. However, the association between the exposure and the outcome will only be biased when (non-)participation is associated with both the exposure and the outcome. When non-response is associated with the exposure only, this affects the distribution (i.e. prevalence) of the exposure. If non-response is associated with the outcome only, this affects the distribution (i.e. prevalence) of the outcome. Because the decision to participate in a prospective cohort study cannot be based on future outcomes, the effects of selection bias due to non-participation are often considered to be small. Studies on the effects of selective non-participation in similar large cohorts have shown that exposure-disease associations are not heavily influenced by selective non-participation [120,122,123].

Selective participation during follow-up refers to selective non-response to questionnaires and visits to the research centers and selective loss to follow-up (study drop out). Loss to follow-up during the first postnatal phase (0-4 years) and the school age period was rather low, with general follow-up rates until the age of 6 years exceeding 80% [121]. The main sources for missing data in the postnatal phase are non-response to questionnaires or visits and non-response to specific items within questionnaires. Non-response analyses in the separate studies presented in this thesis showed that data were more often missing for individuals with a low educational level and a non-native ethnic background, indicating selective non-response. Similar to selective initial participation, this selective non-response only introduces bias when it is also associated with the outcome, i.e. when the association between exposure and outcome is different for participants and non-participants. However, as we have no data on non-participants, this is difficult to ascertain. It may be assumed that non-responders or participants lost to follow-up with a low SEP of from ethnic minority background are worse off in terms of outcomes compared to participants with the same characteristics, leading to an underestimation of exposure-outcome associations.

A recent study investigating the effects of loss to follow-up on socioeconomic inequalities in multiple outcomes, concluded that loss to follow-up was related to both SEP and outcomes, resulting in biased estimates of socioeconomic inequalities [124]. However, even with considerable loss to follow-up, qualitative conclusions about the direction and magnitude of inequalities did not change [124]. Accordingly, we assume that the results presented in this thesis do not suffer markedly from selection bias due to selective loss to follow-up.

Information bias

Most of the information used in this thesis was collected by parent-reported questionnaires. Self-reported data are prone to measurement error, often referred to as misclassification. There are two types of misclassification: non-differential misclassification and differential misclassification. Non-differential misclassification occurs when misclassification of the outcome does not depend on the exposure, and when misclassification of the exposure does not depend on the outcome. Examples of non-differential misclassification include typing errors during measurements or data entry, and therefore cannot be prevented completely. Misclassification of a dichotomous exposure leads to an underestimation of association measures. Misclassification of a dichotomous outcome, as was the case in most of the studies presented in this thesis, also leads to an underestimation of association measures. Therefore, we hypothesize that our results may have been underestimations of the true associations.

Differential misclassification occurs when the misclassification of the outcome is related to the exposure, and vice versa. If low educated participants are more likely to report socially desirable answers (i.e. more likely to report healthier lifestyle behaviors), then observed associations are underestimating true associations. If contrast, if low educated parents are more likely to overestimate unhealthy lifestyle behaviors, then observed associations are overestimating true associations. Little is known about the effects of family SEP and ethnic background on the under- or over reporting of lifestyle behaviors. Information on mediating and confounding variables was also assessed by parent-reported questionnaires. Measurement error in these variables may bias their association with both exposures and outcomes, and thus bias their contribution to explaining social inequalities in lifestyle behaviors.

Confounding

Confounding variables are variables that distort the association between exposure and outcome. Confounding may result in a spurious association, may strengthen or attenuate an association, or may obscure an association. In order to be a confounding variable, a variable must 1) be associated with the outcome, 2) be associated with the exposure, and 3) not be an intermediary factor (should not be on the causal pathway between exposure and outcome) [125]. Adjustment for confounding variables is needed to obtain an unbiased estimate of the association of interest. In most studies presented in this thesis, we first selected potential confounders on the basis of existing literature. Subsequently, we used the 'change in coefficient' method to select the confounders for the analyses. With this method, confounders were included in the analyses when they changed the association of interest with at least 10% [126]. Despite these efforts to adjust for confounding factors, residual confounding by unmeasured or poorly measured variables (e.g. due to misclassification) cannot be ruled out.

Confounding, mediation, and moderation

When interested in a specific relationship between exposure and outcome, third variables can play different roles. The first role is that of a confounder, as described in the previous paragraph. In addition to acting as a confounder, third variables may also act as mediators or moderators of the relationship between exposure and outcome. Mediators (or intermediary variables) are variables that are associated with both the exposure and the outcome, and are on the causal pathway between exposure and outcome [127]. Confounding and mediation are statistically identical and can only be distinguished on conceptual grounds, such as assumptions about directionality and causality of associations [127]. Since causality cannot be established in observational research, we cannot exclude the possibility that the observed associations were not causal. In some cases, the association between an exposure and outcome varies according to (strata of) another variable. This third variable is known as a moderator, or effect modifier [128]. There is evidence to suggest that ethnic background may moderate the effects of family SEP, and vice versa. When preliminary analyses indicated the presence of an interaction effect (i.e. moderation), the study was restricted to Dutch children only (*chapters 3.1* and *5.1*), or stratified analyses were presented for different subgroups (*chapter 3.2*). If no interaction effects were found, socioeconomic inequalities and ethnic inequalities were assessed simultaneously (*chapters 4.2* and *5.2*). In these studies, associations between family SEP and the outcome variable(s) were adjusted for ethnic background, and vice versa. Figure 1 presents the relationships between exposure, outcome, and third variables for confounders, mediators, and moderators.

Measurements

In the majority of the studies presented in this thesis, family SEP and ethnic background were the main exposures of interest. Both of these variables are complex constructs, and we will elaborate on these variables in this section.

Socioeconomic position

Socioeconomic position refers to the "social and economic factors that influence what positions individuals or groups hold within the structure of a society" [129]. Socioeconomic position is a complex, multidimensional, construct that can be captured by indicators at different levels (i.e. individual level, household level, neighborhood level) [73-75]. The most common individual-level SEP indicators, and those used in this thesis, include education, income, and occupation/employment status [73-75]. As recommended by previous scholars, the choice of indicator should ideally depend on the research question and the proposed pathways linking SEP to the outcome [73-75]. When interested in the (general) association between family SEP and health outcomes, different indicators can be used; however, using different indicators of SEP may result in different associations [73-75]. Because young children cannot yet be classified according to these indicators, they are classified according to their parents' SEP (hence the term family SEP).

In most studies presented in this thesis, we used maternal educational level (i.e. educational level of the commonest primary caregiver) as SEP indicator. There are several reasons for using educational level as indicator of SEP. First, educational level is relatively easy to measure in questionnaires and often has a high response rate. Second,

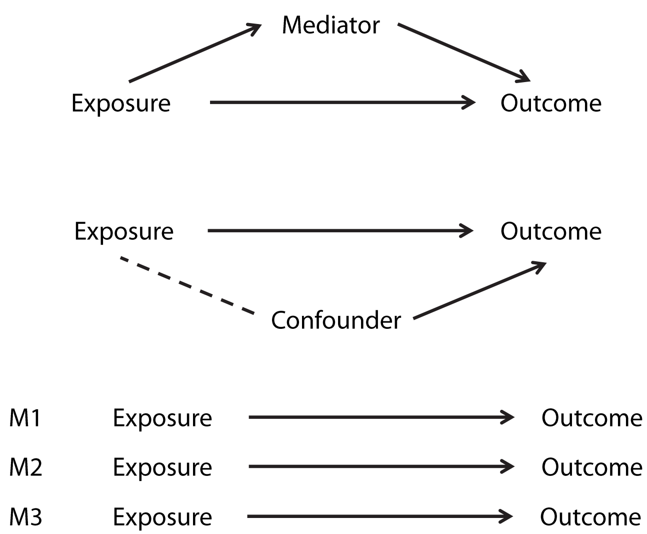

Figure 1. Schematic representation of relationships between exposure, outcome, and third variables. Mediators are third variables that lie on the causal pathway linking exposure to outcome. In contrast, confounders are third variables that are associated with both the exposure and the outcome, but are not part of the causal pathway. Statistical adjustment for these variables is necessary in order to assess the unconfounded exposure-outcome association. Moderators are third variables that affect the exposure-outcome association. Stratification according to different strata of the mediator will yield different exposure-outcome associations.

educational level is a relatively stable variable accomplished in early adult life. Third, educational level is relevant to people regardless of age and working circumstances (in contrast to income and occupation). Lastly, educational level is considered to be an appropriate measure of SEP for the Netherlands specifically [130]. The pathways through which education is hypothesized to affect health and health behaviors include knowledge and skills, as well as increased receptiveness to health education messages [73-75]. Since educational level may not capture other aspects of family SEP, we often performed sensitivity analyses using alternative indicators such as paternal educational level and household income and found similar (yet weaker) results (e.g. *chapters 3.1* and *5.1*).

Household income is the SEP indicator that most directly represents material resources of the family [73-75]. In general, income is considered a sensitive issue and therefore information on this indicator is more subject to non-response compared with information on education or occupation/employment. Furthermore, this SEP indicator is the most dynamic, i.e. most likely to change over a short period of time. Therefore, when using this SEP indicator, we aimed to use an income variable most closely measured (in time) to the outcome. As previous research has shown similar associations for household income and household income adjusted for the number of family members (i.e. to grasp the disposable income per individual in the household) [131], we used total net household income as SEP indicator. The third main SEP indicator used in our studies was parental employment status [73-75]. The advantage of employment status over occupation is that unemployed individuals can be retained in the analyses. Potential mechanisms through which employment status may affect children's lifestyle behaviors include a lack of material resources (i.e. via household income), social isolation/support (stress), or logistics (e.g. available time to spend with the children) [73-75].

The influences of SEP are likely to act over the life course, starting as early as the fetal period [73,101,132,133]. There are several theoretical life course models that conceptualize how SEP operates in different life stages [73,101,132,133]. The first life course model is related to a critical or sensitive period where exposure to low SEP shapes outcomes that may not be evident for years. These adult health outcomes may be permanent (i.e. non subject to change), for example due to fetal programming as a response to adverse prenatal influences. The second life course model hypothesizes that exposure to low SEP leads to adverse social conditions in adult life, which in turn affect adult health outcomes. The final and most complete life course model, also known as the cumulative risk model, combines these two approaches. According to this model, early life exposures and late life exposures to low SEP jointly affect adult health outcomes. Mortality from CVD has been shown to be strongly related to cumulative social disadvantage, particularly to socioeconomic circumstances during early childhood [134].

Ethnic background

Ethnicity is a complex concept, with several definitions referring to shared origins and culture, traditions, language, religious traditions, and links with geographical areas [135]. Furthermore, ethnicity may be measured in different ways, including country of birth and ethnic self-identification [135,136]. In this thesis, we used country of birth to establish ethnic background of a person [135,137]. According to the standard definition of Statistics Netherlands, a person is considered non-native Dutch if at least one of his/her parents is born abroad [137]. If both parents are born abroad, country of birth of the mother decides on ethnic background. People born abroad themselves are considered first generation; people born in the Netherlands (with at least one parent born abroad) are considered second generation. An advantage of this method is that it is stable and objective. The main criticism of this definition is that people born in the same country may differ in culture and ethnic identity [135]. Furthermore, the definition does not distinguish between Dutch individuals and third-generation immigrants.

With the exception of our studies on the associations of lifestyle behaviors with children's body fat (*chapters 2.1* and *2.2*), we used ethnic background of the mother in our analyses on ethnic background. This choice was based on both conceptual and practical grounds. Conceptually, we were interested in the cultural/religious influences on children's lifestyle behaviors and as they are still so young, cultural background of the parents will determine their behaviors. Again, we chose maternal ethnic background because mothers are most often primary caregivers of their children. Practically, we aimed to reach agreement between SEP and ethnic variables (both of parents) because they need be mutually adjusted for in the analyses. Furthermore, within the Generation R study, agreement between maternal ethnic background is 88% and 83% for paternal ethnic background and child ethnic background, respectively. Therefore, results are likely not to have changed substantially when using either other ethnic background variable. Of the non-native Dutch mothers, 68% are first-generation and 32% are second generation immigrants.

Statistical analyses

Assessing social inequalities

An important aim of this study was to assess socioeconomic and ethnic inequalities in young children's lifestyle behaviors and childhood overweight. The effects of family SEP were assessed in unadjusted models and models adjusted for confounders such as child's sex, child's age, and season of measurement (physical activity behaviors). In several studies presented in this thesis, family SEP was considered a confounder for which adjustments should be made. This was especially important when assessing ethnic inequalities, as ethnic background is so closely related to family SEP [98,99,138,139]. In the studies presented in this thesis, we controlled for the most common individual level SEP indicators covering cultural, economic, and social dimensions of SEP (i.e. educational level, income, and employment status). However, residual SEP confounding may still play a role due to a lack of control for additional SEP indicators (e.g. neighborhood level SEP indicators), categorization of SEP indicators (i.e. residual confounding within a category), measurement error in SEP indicators, or incommensurate SEP indicators [98,99,138,139]. It should be noted that SEP may partly be regarded as a mediating variable in the associations between ethnicity and health outcomes, rather than a confounding variable, when access to education and employment is limited by impaired language proficiency or discrimination [98]. As a consequence, the effect of ethnic background may have been partly underestimated when adjusted for family SEP.

Explaining social inequalities

In addition to assessing socioeconomic and ethnic inequalities in childhood overweight and related lifestyle behaviors, the studies in this thesis aimed to explain these inequalities. In the studies presented in *chapters 2.3, 3.1,* and *5.1* we used Baron and Kenny's step approach to assess the mediating effects of selected potential mediators in the associations of family SEP with lifestyle behaviors and childhood overweight [140]. According to this method, mediation is established when the following conditions are met: 1) the exposure is (causally) associated with the outcome, 2) the exposure is (causally) associated with the (potential) mediator, 3) the (potential) mediator is (casually) associated with the outcome (adjusted for the exposure), and 4) if previous conditions are met, a model including the mediator should attenuate the initial association between the exposure and the outcome [140]. Perfect mediation holds if the association between exposure and outcome no longer exists after adjustment for the mediator. In our studies using this approach, we first established an association between family SEP and the outcome, adjusted for confounders (basic models). This association was considered to be the overall (or total) effect of SEP. Then, associations between SEP and separate potential mediators were assessed. Third, associations between separate potential mediators and the outcome was assessed, controlling for SEP. Potential mediators that were associated with both SEP and the outcome were considered 'true' mediators and added separate to the basic model to assess their mediating effect. The percentage change in excess risk (i.e. odds ratio -1) was considered the size of the mediating effect. A full model containing all mediators was used to assess the joint effects of the mediators.

Baron and Kenny's step approach to test mediation has been critiqued [141,142]. First, this method has been shown to be a conservative method, which in some cases can lead to failure to identify possible meaningful mediators. Second, the method does not go beyond the four criteria of mediation by offering a method to estimate the size of the mediating effect. In our studies, we have addressed this notion by quantifying the

change in the excess risk and interpreting this as the mediating effect. However, this method does have its drawback since different absolute changes can have similar percentage changes. Third, the use of regression techniques to establish mediation requires fulfillment of a number of assumptions, including causality, unmeasured confounding of the mediating effect, and absence of exposure-mediator interaction [141,143,144], which are difficult to verify. Currently, more advanced methods that address and deal with these obstacles/ assumptions are being developed [145,146].
In *chapters 4.2* and *5.2*, we used a more indirect method to infer potential pathways underlying the associations of family SEP and ethnic background with lifestyle behaviors. Instead of studying SEP and ethnic background simultaneously with lifestyle behaviors and more proximal determinants of these behaviors (i.e. performing mediation analysis), we assessed the independence and relative strength of the associations between different indicators of SEP and ethnicity with lifestyle behaviors [73-77,147]. As mentioned previously, socioeconomic position is a complex construct with related social, cultural, and economic dimensions, and different indicators are likely to represent different pathways underlying associations with health outcomes (for a more elaborate discussion of SEP, see paragraph on measurements) [73-77,147]. For example, parental educational level is likely to act upon health through knowledge and skills (e.g. parenting practices), whereas income represent the material resources of the family [75]. In order to tease out the independent effects of these different, yet strongly related, aspects of SEP, associations between each of the indicators need to be adjusted for other indicators. It should be noted that socioeconomic indicators are related in such a way that they can both confound and mediate the effects of other indicators [76]. For example, higher levels of education may lead to better health outcomes through occupation and income. As a consequence, independent associations may have underestimated true associations, especially with respect to educational level.

Missing data

Similar to other large cohort studies, missing data frequently occur. Missing values can be handled in different ways, including complete case analysis, simple imputation techniques (e.g. last value carried forward and imputation with the mean), and multiple imputation [148]. The correct way to deal with missing values depends on the type of missing values. Data can be missing for different reasons: missing completely at random (MCAR), missing at random (MAR), and missing not at random (MNAR) [149,150]. MCAR means that missing data are due completely to chance, for example when equipment fails. In this case, missingness is unrelated to any of the variables measured in the study. More often, missing data are missing at MAR, which means that missingness is related to variables measured in the study. MNAR means that missingness of data is related to variables that are not measured in the study.

The commonest solution for handling missing data is complete-case analysis. Advantages of this method is that it is simple and that all (sub-)analyses are based on the same participants. A drawback of this method is that as the number of variables in the analyses increases, the number of participants decreases, thereby reducing statistical power. More importantly, results of these analyses will only be valid if missing data are MCAR. Disadvantages of single imputation techniques are that results may still be biased when data are MCAR, and that obtained confidence intervals are too small, unrightfully suggesting large precision of the effect estimates. These disadvantages, i.e. loss of information, potential bias, too small confidence intervals, can be overcome using multiple imputation. With this method, multiple (often 5) imputed datasets are created. In these datasets, missing values are replaced by imputed values that are based on the observed data. Each dataset is then analyzed separately and results are combined in a way that takes account of the variability in results between the separate datasets [148]. Results of analyses using multiple imputation are only valid when data are MAR [148]. It is not possible to distinguish between data MAR and MNAR using measured data; in this thesis, we assumed data were MAR.

Implications for policy and practice

Taken together, our studies on social inequalities in young children's lifestyle behaviors and childhood overweight indicate that policies/interventions aimed to promote healthy lifestyle behaviors and prevent childhood overweight among young socially disadvantaged children are highly warranted. Several strategies can be employed to reduce inequalities in health and underlying health behaviors [151]. Two important strategies specifically applicable to the research findings described in this thesis are those that target social disadvantage itself (e.g. antipoverty policies, social benefit, early educational interventions) and those that target factors that mediate the effects of social disadvantage (e.g. promotion of healthy lifestyle behaviors and healthy working conditions) [151].

Arguments in favor of the first strategy can be found in Link and Phelan's theory on the fundamental causes of disease, which they developed to explain the omnipresence and persistence of SEP gradients in mortality and morbidity despite changes in major diseases and their risk factors [152,153]. According to this theory, access to resources such as money, power, prestige, knowledge, social support and social networks enables high SEP individuals to avoid risk or minimize consequences of disease once it occurs, no matter what mechanisms (pathways) are relevant at any given time [153]. Based on this theory, we should not invest in reduction of individual risk-factors (e.g. specific behaviors) as they are likely to be replaced by other mechanisms linking to ill health [152,153].

Rather, investments should be made in policies that aim to (re-)distribute these resources equally (i.e. those that improve people's access to education, employment, and income) or in policies that are beneficial to all, irrespective of available resources (e.g. changing the built environment instead of advising people to become more active) [152]. In addition to improving these distal socioeconomic factors, efforts should be made to ensure that all groups can reap the same benefits of improved education, employment, and income [154]. Therefore, policies should additionally aim to target factors that may contribute to 'diminishing returns' among ethnic minority groups, including discrimination processes, segregation processes, and lack of acculturation (e.g. in terms of language) [154].

Although distal socioeconomic factors are considered highly difficult to change, education especially, there is evidence to suggest that intensive education in early childhood can improve later SEP in socially disadvantaged children [155,156]. Studies on the long-term effects of early educational enrichment programs have shown that preschool education among low income, minority children beneficially affects school drop-out, high-school completion, attendance of 4-year college, and years of education [157-160]. In addition, positive effects have been shown for employment and health insurance coverage. However, the effects on lifestyle behaviors such as alcohol use, smoking, and drug use were more equivocal and effects on the lifestyle behaviors described in this thesis (i.e. sedentary behaviors, physical activity behaviors, and dietary behaviors), were not (separately) assessed in these studies [157-160]. Given these promising results from foreign programs, early educational enrichment programs have been developed in the Netherlands. Unfortunately, short-term effect evaluation of these programs have not shown any effects on language or early mathematic skills, nor on social-emotional outcomes [161]. Long-term follow-up of these children is necessary to evaluate program effects on educational and related SEP outcomes. Other policies that help (re-)distribute resources include minimum wages, social housing, social security benefits, college-admission policies, and parenting leave [152].

Evidence on the persistence (and sometimes even widening) of social inequalities in health in modern welfare states, i.e. countries that have extensive arrangements for reducing inequalities in socioeconomic factors, indicates that solely targeting these distal determinants is not sufficient to reduce social inequalities in health and health behaviors [162]. Consequently, additional strategies that target the more proximal factors (mediators) of social disadvantage are required. Results from the studies described in this thesis provide specific entry points for such strategies aimed to reduce social inequalities in young children's lifestyle behaviors and childhood overweight, both with respect to the optimal timing of these strategies as well as the behaviors and underlying risk factors that need to be targeted.

First, because social inequalities in lifestyle behaviors were already present among pre-school aged children, interventions should ideally start in or before the preschool period. Given the importance of parental BMI and parental lifestyle behaviors, it may be argued that interventions should take place as early as the prenatal or even preconception phase (e.g. lifestyle counseling of future parents) in order to establish an environment conducive to healthy lifestyle behaviors of their children. However, interventions should not be limited to these early life phases; important developmental/transitional periods such as transition from pre-school to primary school, or primary school to secondary school (i.e. adolescence) may warrant extra attention as children's lifestyle behaviors are likely to be affected during these periods due to changing social and physical environmental circumstances [163-169].

Second, our results suggest that interventions aimed to prevent socioeconomic inequalities in childhood overweight should target television viewing, sports participation, and daily breakfast consumption. Television in particular may act as a triple threat, possibly reducing resting metabolic rate, displacing physical activity, and promoting consumption of unhealthy food items [20]. Although not investigated in the studies presented in this thesis, we suggest that these interventions should additionally target consumption of sugar-containing beverages. This recommendation is based on a vast amount of literature showing socioeconomic inequalities in children's consumption of sugar-containing beverages as well as observational and experimental research linking the consumption of sugar-containing beverages with childhood overweight [44,50,109,110,170]. These associations have also been observed in studies conducted within Generation R [171], one of which is presented in this thesis (*chapter 5.1*). Ethnic inequalities in childhood overweight have not been investigated in this thesis; however, they have been investigated within the larger Generation R study [172]. Results from this study showed that all ethnic minority children were more likely to have overweight compared with native Dutch children [172]. Results from our studies furthermore showed that ethnic minority children were more likely to display unhealthy lifestyle behaviors. Therefore, we recommend that the same lifestyle behaviors, i.e. television viewing, sports participation, daily breakfast consumption, and consumption of sugar-containing beverages, should be targeted in interventions aimed to prevent ethnic inequalities in childhood overweight [173,174].

The potential impact of interventions targeting these behaviors may be substantial. In a German study on population attributable fractions (PAFs) of childhood overweight and obesity, it was estimated that nearly 40% of overweight cases among 5- to 6-year old children was due to excessive levels of television viewing, irregular eating, and decreased physical activity [175]. The PAF for consumption of sugar-containing beverages could not be estimated due to a lack of information on this variable. Given that the population for this study was not especially disadvantaged [175], the impact of targeting these behaviors may be even greater when employed in our population due to a higher prevalence of unhealthy behaviors. For some lifestyle behaviors investigated in this thesis, e.g. outdoor play and active commuting to and from school, no associations were found with childhood overweight. However, these results do not imply that these lifestyle behaviors should not be targeted among socially disadvantaged children, as they affect health outcomes over and beyond weight maintenance [176]. Furthermore, associations with adiposity may become apparent in older children when these behaviors become more frequent and more intense.

Finally, results from our systematic review showed that current interventions provide limited possibilities to substantially improve children's lifestyle behaviors and prevent childhood overweight among socially disadvantaged children (0-12 years) in Europe. Findings from our mediation studies showed that the direct (social and physical) home environment, and parental lifestyle behaviors in particular, are important mediators of social inequalities in young children's lifestyle behaviors. Therefore, future interventions should aim to effectively change the home environment and include and involve parents, not only as facilitators of change but also as objects of change.

A first approach to changing the home environment of socially disadvantaged families would be to target efforts at socially disadvantaged families specifically [107]. Strategies that may be used include motivational interviewing, parent empowerment, skill building, and health education [115,177-179]. Bottom-up approaches where interventions are developed in collaboration with the target group may assist in motivating socially disadvantaged parents and their children by actively engaging them in the design, implementation, and evaluation of such interventions [115,180,181]. Furthermore, a bottom-up approach may be especial helpful for cultural adaptation of the interventions, i.e. tailoring the interventions to the cultural values and believes of the target group [86,87,182,183]. The most obvious setting for such interventions is the home setting [115,184], but the primary health care setting may constitute another promising setting for recruiting and involving socially disadvantaged families [185,186]. Although the effects of primary care based interventions have thus far been weak to modest [187-190], this setting has major potential given its wide reach. For example, In the Netherlands, growth, development, and health of all children is regularly monitored by the preventive youth health care, first during well-baby and well-child visits and later by visits to the school nurse [191]. The youth health care is offered free of charge, i.e. does not require any material resources, and coverage rates of 90%-100% have been reported.

In addition to these interventions, broader public health interventions/policies aimed at the entire population may assist in improving lifestyle behaviors and prevent childhood overweight among socially disadvantaged children [107,192,193]. Such policies may include mass-media educational campaigns [194], tax policies (e.g. excise taxes for unhealthy food items [195-197] or tax credit policies for physical activity programs [198,199]), policies for banning of unhealthy-food advertisement targeting children [200,201], and policies for changing the built environment [202,203]. These policies may positively impact children's lifestyle behaviors directly, e.g. by increasing physical activity opportunities through changing the built environment, or indirectly via the home environment, e.g. by changing the availability and accessibility of unhealthy food items within the household or by improving lifestyle behaviors of parents. However, there is evidence to suggest that some of these universal policies may actually widen social inequalities due to a lower effectiveness among socially disadvantaged groups [108,204]. For example, educational strategies may actually benefit highly educated individuals more due to their receptiveness and skills to act on health promotion messages [108,204]. Additionally, tax credit policies using delayed reimbursement or income reduction methods may actually benefit those that are able to spend money upfront and those with higher tax payments (i.e. high income families) [198,199]. In contrast, excise taxes (e.g. on sugar-containing beverages) and subsidized physical activity program (i.e. no upfront costs) may reduce inequalities as they directly appeal to the financial barriers experienced by socially disadvantaged groups [192,196,198,199]. In a recent US study, the impact of three federal policies (i.e. subsidized afterschool physical activity programs, sugar-sweetened beverages excise tax, and ban on child-directed fast food television advertising) on childhood obesity prevalence in 2032 was assessed [192]. Results from this study showed that all three policies would be effective in reducing obesity and improve lifestyle behaviors. Furthermore, all three policies would be effective in reducing social inequalities in these outcomes, with the sugar-sweetened excise tax reducing obesity inequalities the most. Once children reach school age, school-based policies and interventions may also assist positively impact the lifestyle behaviors and overweight prevalence among socially disadvantaged children [205-209]. Changes in the school setting are relatively easy implemented and require no parent involvement or motivation (i.e. do not require family recourses). Furthermore, all children irrespective of social background will be reached.

It should be noted that despite obvious ethical incentives to tackle the childhood overweight problem, implementation of interventions and broader policies may also suffer from potential ethical objections [210,211]. Ethical considerations include potential harmful effects on physical and psychosocial health (e.g. stigmatization and discrimination), the potential to increase health inequalities, the distribution of inadequate information leading to reduced informed choice, lack of consideration of social and cultural values, disrespect of privacy, unbalanced attribution of responsibilities (individual versus collective), and interference with liberty and freedom of choice [210,211]. Intervention developers and policy makers should be aware of, and ideally take into account, these ethical issues when designing and supporting interventions to prevent childhood overweight.

In summary, results from the studies presented in this thesis indicate that strategies to improve lifestyle behaviors and prevent childhood overweight among young socially disadvantaged children are highly warranted. Variables related to the physical and social home environment, parental lifestyle behaviors in particular, emerged as important mediators of social inequalities in children's lifestyle behaviors. Policies likely to improve lifestyle behaviors and prevent childhood overweight among socially disadvantaged children include social policies targeting SEP itself, as well as broader health policies (e.g. excise taxes for sugar-containing beverages or changes in the built environment) and interventions targeting socially disadvantaged families specifically (e.g. interventions that educate, motivate, and empower socially disadvantaged parents in changing the social and physical home environment).

Directions for future research

Since the studies described in this thesis are among the first to assess social inequalities in lifestyle behaviors and childhood overweight among young ethnically diverse children, replication in other populations is merited. As social inequalities are dependent on the larger economical-political environment, replication studies in similar countries as well as countries with a different economical-political environment would be recommended. Follow-up studies within Generation R are needed to evaluate whether the observed inequalities persist into adolescence and young adulthood, and whether they underlie inequalities in health outcomes. Furthermore, more prospective research is warranted, especially with respect to the associations between lifestyle behaviors and overweight (or other health outcomes) where reverse causation may play a role [116-118].
The studies described in this thesis underscore the need for more knowledge on the pathways underlying social inequalities in young children's lifestyle behaviors and childhood overweight. For example, acculturation characteristics, household routines, stress, sleep, the physical and social home environment (e.g. availability and accessibility of food items and play equipment, rules), parental attitudes and subjective norms may further explain the observed inequalities [16,58,85,212,213]. The importance of these variables and other potential mediators should ideally be investigated in both quantitative studies (i.e. those performing official mediation analyses) and qualitative studies. Qualitative studies involving the target groups (i.e. socially disadvantaged children and their parents) may be especially informative as barriers and facilitators of healthy lifestyle behaviors are not limited to those available in a pre-defined dataset. Moreover,

further well-designed studies (i.e. randomized controlled trials) on the effectiveness of interventions aimed to positively impact young children's lifestyle behaviors and/or prevent overweight are needed.

Continued measurement of the prevalence of lifestyle behaviors and overweight, as well as social inequalities therein, remains important to identify trends in these behaviors and establish public health priorities. Even though it is generally accepted that the childhood overweight epidemic is for a large part determined by unfavorable changes in children's lifestyle behaviors, secular trends in children's sedentary behaviors, physical activity behaviors, and dietary behaviors have not been well documented [214,215]. Furthermore, more research on the dose-response associations between lifestyle behaviors and health outcomes in very young children is warranted in order to establish evidence-based guidelines for these children (e.g. [216-218]). Finally, future studies should consider upcoming lifestyle behaviors such as the consumption of energy drinks [219-221] and the use of new media (e.g. cell phones, tablets and social media) [222,223] that may further contribute to the obesogenic lifestyles of (young) children.

Finally, future research may benefit from improved measurements. In research on body fat in young children, fat mass as derived from DXA scans is preferred over weight driven measures such as BMI and (over)weight status [6]. However, is should be noted that DXA scans are expensive and therefore not always suitable for large epidemiological studies. Furthermore, when assessing total physical activity and its antecedents and physiological health outcomes, objectively measured physical activity is preferred over parent-reported and self-reported total physical activity. Because SEP is a multi-dimensional construct operating over the life course, multiple indicators, both individual-level and area-level, starting in early life and measured continuously throughout the life course, should be measured in research on the complex interactions between SEP, ethnic background, and health outcomes.

General conclusions

The following conclusions can be drawn from the studies presented in this thesis. First, socioeconomic inequalities in childhood overweight become apparent in the preschool period and increase with age. Lifestyle behaviors that contribute to these inequalities include television viewing, sports participation, and daily breakfast consumption. Second, substantial social inequalities in various sedentary behaviors, physical activity behaviors, and dietary behaviors are present among young preschool aged and school-aged children. Variables related to the social and physical home environment partly mediate these inequalities; however further pathways relating low family SEP and ethnic minority background to unhealthy lifestyle behaviors remain poorly understood.

Adjustment for family SEP substantially reduces but does not eliminate ethnic inequalities in young children's lifestyle behaviors. Lastly, few interventions aimed to improve lifestyle behaviors and/or prevent overweight among socially disadvantaged children in Europe have been evaluated and even fewer have shown substantial effects. Taken together, our findings indicate that social inequalities in lifestyle behaviors and childhood overweight originate in early childhood, forming an early base for health inequalities in later life. A collaborative effort between parents, schools, community, public health professionals and policy makers is needed to reduce these inequalities. Future research is required to expand our knowledge on pathways linking low family SEP and ethnic minority background to unhealthy lifestyle behaviors and childhood overweight.

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8

SUMMARY & SAMENVATTING

Summary

Childhood overweight and obesity is a major public health concern. Both short term and long term adverse health outcomes have been reported, including (amongst others) elevated blood pressure and hypertension, type 2 diabetes, asthma, sleeping disorders, low self-esteem, decreased quality of life, adulthood overweight, and increased risk of adult cardiovascular morbidity and premature mortality. Although there are early signs of childhood overweight stabilization, the worldwide prevalence remains high with 20-30% of all children being overweight in North America, Europe, and parts of the Western Pacific. Risk factors of childhood overweight are multi-dimensional, including both genetic and non-genetic factors. The social-ecological model of childhood overweight postulates that the development of childhood weight is most directly influenced by children's lifestyle behaviors that determine energy intake and expenditure, including sedentary behaviors, physical activity behaviors, and dietary behaviors.

The burden of childhood overweight is unequally distributed; children from low socio-economic position (SEP) and ethnic minority children are more likely to have overweight compared with children from high SEP and ethnic majority children, respectively. Similar inequalities have been reported for sedentary behaviors, physical activity behaviors, and dietary behaviors among school-aged children and adolescents. There is evidence to suggest that lifestyle behaviors establish around the preschool period and 'track' (i.e. are persistent) throughout childhood and into adolescence. Therefore, social inequalities in childhood overweight and lifestyle behaviors may originate in early childhood. However, research on social inequalities in young children's lifestyle behaviors is scarce. Furthermore, there is paucity of studies investigating the pathways relating family SEP and ethnic background to children's lifestyle behaviors.

The aim of this thesis is to develop a further understanding of social inequalities in young children's lifestyle behaviors and childhood overweight. For this purpose, the following research questions were formulated:

1. To what extent are young children's lifestyle behaviors independently associated with body fat?
2. To what extent do social inequalities in childhood overweight exist and how can these inequalities be explained?
3. To what extent do social inequalities in young children's lifestyle behaviors exist and how can these inequalities be explained?
4. What is the effectiveness of interventions aimed to improve lifestyle behaviors and/or prevent overweight among socially disadvantaged children (0-12 years) in Europe?

The first three research questions were addressed by studies conducted within the Generation R Study, a population-based cohort study from fetal life until young adulthood, conducted in Rotterdam, the Netherlands. The final research question was addressed by performing a systematic review of the scientific literature.

In the studies presented in *chapter 2*, we assessed the independent associations between key lifestyle behaviors and children's body fat and the mediation effect of these lifestyle behaviors in the association between family SEP and body fat at age 6 years. *Chapter 2.1* shows that sports participation was inversely associated with percent fat mass. No independent associations were found for other indicators of body fat (i.e. BMI SDS and overweight status), or for other lifestyle behaviors (e.g. television viewing and outdoor play). *Chapter 2.2* shows that breakfast skipping at age 4 years is positively associated with percent fat mass at age 6 years. No independent associations were found for other indicators of body fat (i.e. BMI SDS and overweight status), or for other meal skipping behaviors (i.e. lunch and dinner skipping). *Chapter 2.3* shows that the inverse association between family SEP and children's body fat emerges around the preschool period (around 4 years of age) and increases with age. At the age of 6 years, the inverse association between family SEP and children's body fat is mainly explained by parental BMI, maternal smoking during pregnancy, and children's lifestyle behaviors (i.e. television viewing, sports participation, and breakfast skipping).

In the studies presented in *chapter 3*, we assessed social inequalities in young children's sedentary behaviors. *Chapter 3.1* shows that maternal educational level is inversely associated with children's risk of excessive television viewing (≥2 hours per day). This association is partly explained by parental BMI, parental television viewing time, financial difficulties, and the presence of a television set in the child's bedroom. *Chapter 3.2* shows that children from ethnic minority background (i.e. Turkish, Moroccan, and Surinamese children) are more likely to display excessive levels of television viewing compared with native Dutch children. These ethnic inequalities increased with increasing maternal educational level. No associations were found for acculturation characteristics (i.e. generational status, age at immigration, Dutch language skills) and children's television viewing time.

In the studies presented in *chapter 4*, social inequalities in young children's physical activity behaviors were assessed. *Chapter 4.1* aimed to examine levels of physical activity among toddlers, and correlates thereof. Results from this study showed that 2-year-old toddlers spend most of their time (around 85%) in sedentary behavior. Correlates of physical activity included child's sex (boys more active), child's age (older children more active), season of measurement (children less active during winter), and number of siblings (children with two or more siblings more active). No associations were found with indicators of family SEP (i.e. parental educational level, parental employment sta-

tus, and household income). *Chapter 4.2* shows that high SEP, irrespective of indicator, is positively associated with children's sports participation at age 6 years. Independent associations with sports participation are found for maternal and paternal educational level and household income. High SEP is also associated with higher levels of outdoor play, although this association is only found for household income. Independent associations with outdoor play are found for maternal educational level and household income. These independent associations underscore the need for use of different SEP indicators as they are likely to represent different pathways relating family SEP to these behaviors (e.g. cultural resources such as knowledge and skills for educational level and material resources for income). Ethnic minority children are more likely not to participate in sports and show low levels of outdoor play compared with native Dutch children. Ethnic inequalities were for a large part, but not all, explained by family SEP.
Chapter 5 contains studies on social inequalities in young children's dietary behaviors. *Chapter 5.1* shows that maternal educational level is inversely associated with excessive consumption of high-calorie snacks and sugar-containing beverages. These associations are partly explained by parental consumption of sugar-containing beverages, children's television viewing time, and parental feeding practices (i.e. monitoring, pressure to eat, and restriction). *Chapter 5.2* shows that children from low SEP are more likely to skip main meal at the age of 6 years, breakfast in particular. Independent associations between several SEP indicators and meal skipping are observed, indicating different pathways. Ethnic minority children are more likely to skip main meals compared with native Dutch children. Ethnic inequalities were for a large part, but not all, explained by family SEP.
Chapter 6.1 synthesizes the literature on the effectiveness of interventions aimed to positively affect lifestyle behaviors and/or prevent overweight among socially disadvantaged children (0-12 years) in Europe. Results from this systematic review show that few studies have investigated the effects of such interventions among socially disadvantaged children and even fewer studies have shown substantial and sustained effects.
Finally, *chapter 7* provides an overall discussion, including a description and interpretation of the main findings of this thesis, methodological considerations, implications for policy and practice, and directions for future research.

Several conclusions can be drawn from the studies presented in this thesis. First, socioeconomic inequalities in childhood overweight become apparent in the preschool period and increase with age. Lifestyle behaviors that contribute to these inequalities include television viewing, sports participation, and daily breakfast consumption. Second, substantial social inequalities in sedentary behaviors, physical activity behaviors, and dietary behaviors are present among young preschool aged and school-aged children, with a higher prevalence of unfavorable lifestyle behaviors among socially disadvantaged children. Variables related to the social and physical home environment partly mediate these inequalities. Adjustment for family SEP substantially reduces but does not eliminate ethnic inequalities in young children's lifestyle behaviors. Lastly, only few studies have evaluated the effectiveness of interventions aimed to improve lifestyle behaviors and/or prevent childhood overweight among socially disadvantaged children in Europe and even fewer have shown to be effective. Taken together, these studies highlight the need for preventive interventions aimed to improve lifestyle behaviors and prevent childhood overweight among socially disadvantaged children. The social and physical home environment of socially disadvantaged children and their parents may constitute a suitable target for such interventions.

Samenvatting

Overgewicht bij kinderen vormt een groot probleem voor de huidige publieke gezondheidszorg. Overgewicht bij kinderen is geassocieerd met een minder goede gezondheid op zowel de korte als lange termijn, zoals een verhoogde bloeddruk en hypertensie, type 2 diabetes, astma, slaap problemen, een verminderd zelfvertrouwen, een verminderde kwaliteit van leven, overgewicht op de volwassen leeftijd, en een verhoogd risico op cardiovasculaire ziekten en vroegtijdige mortaliteit. Ondanks positieve signalen dat de overgewicht epidemie bij kinderen stabiliseert, blijft de wereldwijde prevalentie van overgewicht bij kinderen hoog. Overgewicht bij kinderen wordt door verschillende factoren veroorzaakt, bestaande uit zowel genetische factoren als omgevingsfactoren (niet-genetische factoren). Volgens het sociaal-ecologisch model vormen leefstijl gedragingen die bijdragen aan energie inname en energie verbruik (sedentair gedrag, fysieke activiteit, en eetgedrag) de meest directe oorzaken van overgewicht bij kinderen
Overgewicht komt niet bij alle kinderen evenveel voor. Kinderen uit families met een lage sociaal economische positie (SEP) en kinderen van etnische minderheden hebben een verhoogd risico op overgewicht vergeleken met kinderen uit families met een hoge SEP of kinderen van etnische meerderheden. Zulke ongelijkheden zijn ook gerapporteerd voor leefstijl gedragingen onder oudere kinderen en adolescenten. Er is bewijs dat (ongunstige) leefstijl gedragingen reeds worden gevormd op de voorschoolse leeftijd en persisteren tot in de jong volwassen leeftijd. Het is daarom plausibel dat sociale verschillen in leefstijl gedragingen en overgewicht hun origine hebben in de vroege kinderleeftijd. Er is echter nog weinig onderzoek verricht naar sociale verschillen in leefstijl gedragingen op een jonge leeftijd. Daarnaast is er nog weinig bekend over de mechanismen die ten grondslag kunnen liggen aan associaties tussen familie SEP en etnische achtergrond en leefstijl gedragingen bij jonge kinderen.

Het doel van dit proefschrift is om verder inzicht te krijgen in sociale verschillen in leefstijl gedragingen en overgewicht bij jonge kinderen. Wij hebben hiervoor de volgende specifieke onderzoeksvragen opgesteld:

1. In hoeverre zijn leefstijl gedragingen van jonge kinderen onafhankelijk geassocieerd met lichaamsvet?
2. In hoeverre zijn er sociale verschillen in overgewicht bij jonge kinderen en hoe kunnen deze verschillen worden verklaard?
3. In hoeverre zijn er sociale verschillen in leefstijl gedragingen bij jonge kinderen en hoe kunnen deze verschillen worden verklaard?

4. Wat is de effectiviteit van interventies gericht op het verbeteren van leefstijl gedragingen en/of de preventie van overgewicht bij sociaal achtergestelde kinderen (0-12 jaar) in Europa?

De eerste drie onderzoeksvragen zijn behandeld in studies ingebed in het Generation R onderzoek te Rotterdam. Het Generation R onderzoek is een prospectief cohort onderzoek dat kinderen volgt vanaf het foetale leven tot de jong volwassen leeftijd. De vierde en laatste onderzoeksvraag is behandeld in een systematisch review van de wetenschappelijke literatuur.

In de studies beschreven in *hoofdstuk 2* hebben we de onafhankelijke associaties van een aantal leefstijl gedragingen met lichaamsvet bij jonge kinderen geëvalueerd. Daarnaast hebben wij gekeken of deze leefstijl gedragingen een verklarende rol spelen in de associatie tussen SEP en lichaamsvet op de leeftijd van 6 jaar. *Hoofdstuk 2.1* laat zien dat sport participatie negatief geassocieerd is met het percentage lichaamsvet op 6 jaar. Er werden geen onafhankelijke associaties gevonden met andere indicatoren van lichaamsvet (BMI SDS of overgewicht status) of met andere leefstijlgedragingen (bijvoorbeeld televisie kijken of buiten spelen). *Hoofdstuk 2.2* laat zien dat het overslaan van ontbijt op de leeftijd van vier jaar positief geassocieerd is met het percentage lichaamsvet op de leeftijd van 6 jaar. Er werden geen onafhankelijke associaties gevonden met andere indicatoren van lichaamsvet (BMI SDS of overgewicht status) of met het overslaan van andere maaltijden (lunch of diner). *Hoofdstuk 2.3* laat zien dat de negatieve associatie tussen SEP en lichaamsvet bij kinderen op de voorschoolse leeftijd verschijnt en met het ouder worden toeneemt. Op de leeftijd van 6 jaar is de negatieve associatie tussen SEP en lichaamsvet deels te verklaren door BMI van de ouders, het roken van de moeder tijdens de zwangerschap, en leefstijl gedragingen van het kind zelf (televisie kijken, sport participatie, dagelijks ontbijten).

In de studies beschreven in *hoofdstuk 3* hebben we sociale verschillen in sedentaire gedrag bij jonge kinderen onderzocht. *Hoofdstuk 3.1* laat zien dat het opleidingsniveau van de moeder negatief is geassocieerd met het risico op overmatig televisie kijken (≥2 uur per dag). Deze associatie wordt deels verklaard door BMI van de ouders, televisie kijken van de ouders, financiële moeilijkheden in het gezin, en de aanwezigheid van een televisie in de slaapkamer van het kind. *Hoofdstuk 3.2* laat zien dat kinderen van Turkse, Marokkaanse, en Surinaamse afkomst een verhoogd risico hebben op overmatig televisie kijken vergeleken met Nederlandse kinderen. Deze etnische verschillen worden groter naarmate het opleidingsniveau van de moeder toeneemt. Er werden geen associaties gevonden tussen overmatig televisie kijken en acculturatiekenmerken van de moeder (1^e versus 2^e generatie, leeftijd tijdens immigratie, en beheersing van de Nederlandse taal).

De studies in *hoofdstuk 4* richten zich op het evalueren van sociale verschillen in fysieke activiteit bij jonge kinderen. *Hoofdstuk 4.1* beschrijft het patroon en de correlaten van fysieke (in-)activiteit bij kleuters met een leeftijd van 2 jaar. Resultaten van deze studie laten zien dat 2-jarige kleuters voor het overgrote deel van hun gemeten tijd sedentair gedrag vertonen (85%). Correlaten van fysieke activiteit bij kinderen van deze jonge leeftijd zijn geslacht van het kind (jongens meer actief), leeftijd van het kind (oudere kinderen meer actief), seizoen tijdens de meting (tijdens de winter minder actief), en het aantal broertjes en/of zusjes (meer actief bij 2 of meer broertjes/zusjes). Geen associaties werden gevonden met indicatoren van SEP (opleidingsniveau, baanstatus, gezinsinkomen). *Hoofdstuk 4.2* laat zien dat hoge SEP, ongeacht welke indicator, positief geassocieerd is met sport participatie op de leeftijd van 6 jaar. Onafhankelijke associaties met sport participatie werden gevonden voor opleidingsniveau van de ouders en gezinsinkomen. Hoge SEP is ook positief geassocieerd met buiten spelen, al werd deze associatie alleen gevonden met gezinsinkomen. Onafhankelijke associaties met buiten spelen werden gevonden voor opleidingsniveau van de moeder en gezinsinkomen. De onafhankelijke associaties onderstrepen het belang van het gebruik van verschillende SEP indicatoren in onderzoek naar sociale verschillen in leefstijl gedragingen bij jonge kinderen. Daarnaast representeren deze onafhankelijke associaties zeer waarschijnlijk verschillende mechanismen die ten grondslag liggen aan sociale verschillen in leefstijl. Zo is het aannemelijk dat opleidingsniveau van de ouders werkt via sociale middelen (bijvoorbeeld kennis en vaardigheden), terwijl gezinsinkomen meer werkt via materiële en financiële middelen. Kinderen van etnische minderheden doen minder vaak aan sport en spelen minder lang buiten dan Nederlandse kinderen. Deze etnische verschillen zijn voor een substantieel deel, maar niet volledig, te verklaren door SEP van de familie.

Hoofdstuk 5 bevat studies naar sociale verschillen in eetgedrag bij jonge kinderen. *Hoofdstuk 5.1* laat zien dat het opleidingsniveau van de moeder negatief is geassocieerd met het risico op overmatige consumptie van calorierijke tussendoortjes en suikerhoudende dranken. Deze associaties worden deels verklaard door de consumptie van suikerhoudende dranken door de ouders, televisie kijken van de kinderen, en opvoedkundige praktijken op het gebied van eten (monitoren, druk om te eten, en restrictie). *Hoofdstuk 5.2* laat zien dat kinderen van een lage SEP een verhoogd risico hebben op het overslaan van hoofdmaaltijden, ontbijt in het bijzonder. Ook hier werden verschillende onafhankelijke SEP associaties waargenomen, duidend op verschillende onderliggende mechanismen. Kinderen van etnische minderheden slaan vaker hoofd maaltijden over dan Nederlandse kinderen. Deze etnische verschillen zijn voor een substantieel deel, maar niet volledig, te verklaren door SEP van de familie.

Hoofdstuk 6.1 bestaat uit een systematisch review naar de effectiviteit van interventies gericht op het verbeteren van leefstijl gedragingen en/of preventie van overgewicht bij sociaal achtergestelde kinderen (0-12 jaar) in Europa. Resultaten van deze review

laten zien dat effect evaluaties bij sociaal achtergestelde kinderen schaars zijn en dat de effecten over het algemeen bescheiden zijn.
Hoofdstuk 7 bestaat uit een algemene discussie, inclusief een beschrijving en interpretatie van de hoofdbevindingen, methodologische overwegingen, implicaties voor beleid en praktijk, en aanbevelingen voor toekomstig onderzoek.

Er kunnen verschillende conclusies worden getrokken uit de studies die zijn gepresenteerd in dit proefschrift. Sociale verschillen in lichaamsvet verschijnen op de voorschoolse leeftijd en worden groter naarmate kinderen ouder worden. Leefstijl gedragingen die aan deze verschillen bijdragen, zijn televisie kijken, sport participatie, en het overslaan van ontbijt. Daarnaast bestaan reeds op jonge leeftijd sociale verschillen in sedentaire gedrag, fysieke activiteit, en eetgedrag, waarbij ongezonde leefstijl gedragingen vaker voorkomen bij sociaal achtergestelde kinderen. Factoren gerelateerd aan de fysieke en sociale thuisomgeving kunnen deze verschillen deels verklaren. Etnische verschillen in leefstijl gedragingen worden deels, maar niet volledig, verklaard door een lagere SEP van de familie. Tot slot kan worden geconcludeerd dat in Europa slechts weinig interventies zijn geëvalueerd op hun effectiviteit in het verbeteren van leefstijl gedragingen en/of de preventie van overgewicht bij sociaal achtergestelde kinderen, en dat weinig onderzochte interventies substantiële effecten laten zien. Samenvattend benadrukken de studies die zijn gepresenteerd in dit proefschrift, de behoefte aan preventieve interventies gericht op het verbeteren van leefstijl gedragingen en het voorkómen van overgewicht bij jonge sociaal achtergestelde kinderen. Het aanpakken van de sociale en fysieke thuisomgeving van sociaal achtergestelde kinderen en hun ouders vormt een goed aanknopingspunt voor dergelijke interventies.

INEQUALITIES
LIFESTYLE
AND
BEHAVIORS
CHILDHOOD
OVERWEIGHT

9

AUTHORS' AFFILIATIONS - LIST OF PUBLICATIONS - PHD PORTFOLIO - ABOUT THE AUTHOR - DANKWOORD

YOUNG
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List of publications

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Wijtzes AI, Jansen W, Jaddoe VW, Franco OH, Hofman A, van Lenthe FJ, Raat H. Social inequalities in young children's meal skipping behaviors: the Generation R study. *Submitted for publication.*

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Bird PK, Pickett KE, Graham H, Faresjö T, Jaddoe VW, Ludvigsson J, Raat H, Seguin L, **Wijtzes AI**, McGrath JJ. Social gradients in child health in relation to income inequality: a comparison of cohort studies from six high-income countries. *Submitted for publication.*

PhD portfolio

Name PhD student: Anne I. Wijtzes
Erasmus MC Department: Public Health/ Generation R Study Group
Research School: Netherlands Institute for Health Sciences (NIHES)
PhD period: 15 Nov 2010 – 14 Nov 2014
Promotors: Prof.dr. H. Raat, Prof.dr. J.P. Mackenbach
Copromotor: Dr. W. Jansen

PhD training, teaching activities, and other activities	**Year**	**Workload (ECTS)**
1. PhD training		
Master degree Health Sciences, specialization Epidemiology, NIHES, Erasmus University Rotterdam, the Netherlands		
Principles of Research in Medicine	2011	0.7
Introduction to Global Public Health	2011	0.7
Methods of Public Health Research	2011	0.7
Primary and Secondary Prevention Research	2011	0.7
Social Epidemiology	2011	0.7
Health Economics	2011	0.7
Maternal and Child Health	2011	0.9
Biostatistical Methods I: Basic Principles	2011	5.7
Biostatistical Methods II: Popular Regression Models	2011	4.3
Conceptual Foundation of Epidemiologic Study Design	2012	0.7
Causal Inference	2012	0.7
Markers and Prognostic Research	2012	0.7
Principles of Epidemiologic Data-analysis	2012	0.7
Ethnicity, Health and Health Care	2012	1.1
Nutrition & Physical Activity	2012	1.4
Study Design	2012	4.3
Methodological Topics in Epidemiologic Research	2012	1.4
Public Health Research	2012	4.2
Women's Health	2013	0.9
Psychiatric Epidemiology	2013	1.1
Extracurricular courses, Erasmus University Rotterdam/Erasmus Medical Center (MC) Rotterdam, the Netherlands		
Minicursus Methodologie van Patiëntgebonden Onderzoek en Voorbereiding van Subsidieaanvragen	2011	0.6
Werken met Endnote (Medical Library)	2013	0.2
Systematisch Literatuur Onderzoek in PubMed (Medical Library)	2013	0.2
Basiscursus Regelgeving en Organisatie voor Klinisch Onderzoekers (BROK)	2014	0.6

Cursus Wetenschappelijke Integriteit	2014	0.6
Starten met Leidinggeven in de Wetenschap	2014	0.6
Didactische Training Lesgeven Kleine Groepen	2014	0.4
Seminars and workshops		
Generation R Research meetings, Erasmus MC, the Netherlands	2010-2014	1.0
Seminars Department of Public Health, Erasmus MC, the Netherlands	2010-2014	1.0
Seminars Department of Public Health, Section Youth Health Care, Erasmus MC, the Netherlands	2010-2014	1.0
Seminars Department of Public Health, Social Epidemiology, Erasmus MC, the Netherlands	2010-2014	0.2
Seminars CEPHIR, Rotterdam, the Netherlands	2010-2014	0.2
Meetings Adviesgroep Sociale ongelijkheden in leefstijl en cardiovasculaire risicofactoren, Erasmus MC, the Netherlands	2013-2014	0.2
Seminars Netwerk beweeggedrag/fysieke activiteit, Erasmus MC, the Netherlands	2014	0.2
(Inter)national conferences and presentations		
NWO Retraite Jeugd en Gezondheid, Soesterberg, the Netherlands. Oral presentation.	2011	0.7
Municipality of Rotterdam, Sport en Recreatie, Rotterdam, the Netherlands. Oral presentation.	2012	0.7
International Society of Behavioral Nutrition and Physical Activity. Austin, Texas, United States of America. Poster presentation.	2012	0.7
Generation R Research Meeting, Erasmus MC, the Netherlands. Oral presentation.	2012	0.7
Research Seminar Department of Public Health, Erasmus MC, the Netherlands. Oral presentation.	2012	0.7
International Society of Behavioral Nutrition and Physical Activity. Gent, Belgium. Oral presentation.	2013	0.7
Adviesgroep Sociale oongelijkheden in leefstijl en cardiovasculaire risicofactoren, Rotterdam, the Netherlands. Oral presentation.	2013	0.7
NWO Retraite Jeugd en Gezondheid, Soesterberg, the Netherlands. Oral presentation.	2014	0.7
Haagsche Praat, Municipality, The Hague, the Netherlands. Oral presentation.	2014	1.4
CEPHIR seminar, Erasmus MC, Rotterdam, the Netherlands. Oral presentation.	2014	0.7

2. Teaching activities

Supervision of Master student 'Correlates of physical activity in 2-year-old toddlers: the generation R study'	2011-2012	4.0
Teaching third year students of the Bachelor program of Medicine, 'Primaire preventie in de artsenpraktijk'	2014	1.0

3. Other activities

Peer review for Quality of Life Research, Pediatrics, Nutrition Journal, Pediatric Obesity, Journal of the American College of Nutrition	2011-2014	1.5
Collaborating Researcher CHICOS (Developing a Child Cohort Research Strategy for Europe), Work package 3: Social and Cultural determinants of child health	2011-2013	4.0
Collaborating Researcher RICHE (Research Inventory for Child Health in Europe), Work package 2: Child health measurements and indicators - Equity	2011-2013	4.0
Collaborating Research EPOCH (Elucidating Pathways of Child Health Inequalities: An International Perspective)	2013-2014	2.0
Collaborating Researcher Municipality of Rotterdam: Promotion of sports participation among adults 18-44 years	2013-2014	1.0
Grant application CardioVasculair Onderzoek Nederland (CVON), Work package 2.2. of CORDUROY (Combatting Cardiovascular Risks in Disadvantaged Groups by Reduction of Overweight and Obesity in the Young): Developing, implementing and evaluating novel interventions to prevent overweight/obesity in children - Schools	2014	3.0
Application Medical Ethical Committee, Stevig Ouderschap: Het versterken van eigen kracht van ouders/verzorgers met een verhoogd risico op opvoedingsproblematiek	2014	3.0

About the author

Anne Irene Wijtzes was born on February 20th 1985 in The Hague, the Netherlands. In 2003 she completed high school at Gymnasium Haganum in The Hague. In the same year, she started her study Biology at Leiden University. In 2007 she obtained her Bachelor degree in Biology (with honors) and started a pre-master program in Human Movement Sciences at VU University Amsterdam. In 2009, she obtained her Master degree in Human Movement Sciences (specialization Sports Psychology) (with honors). In 2010, she started her PhD project at the Generation R Study Group and the Department of Public Health at the Erasmus Medical Center in Rotterdam, the Netherlands, the results of which are presented in this thesis. In 2013, as part of her PhD program, she obtained a second Master degree in Epidemiology at the National Institute for Health Sciences in Rotterdam.

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IN

CHILDREN'S

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