Growth, Overweight and Related Health Behaviors in Childhood

Lu Wang

Growth, Overweight and Related Health Behaviors in Childhood

Lu Wang

Growth, Overweight and Related Health Behaviors in Childhood

ISBN: 978-94-6380-519-3

Printed by: ProefschriftMaken || Proefschriftmaken.nl

The thesis was printed with the financial support of the Department of Public Health and the Erasmus MC.

Growth, Overweight and Related Health Behaviors in Childhood

Groei, overgewicht en gerelateerd gezondheidsgedrag van kinderen

Thesis

to obtain the degree of Doctor from the

Erasmus University Rotterdam

by command of the rector magnificus

Prof. dr. R.C.M.E. Engels

and in accordance with the decision of the Doctorate Board

The public defense shall be held on

Tuesday 8th of October at 15: 30 hours

by

Lu Wang

born in Dezhou, China

Erasmus University Rotterdam

DOCTORAL COMMITTEE

Promotor	Prof.dr. H. Raat
Other members	dr. E.L.T. van den Akker
	Prof.dr. V.W.V. Jaddoe
	Prof.dr.ir. J.C. Seidell
Co-promotors	Dr. A. van Grieken
	Dr.ir. W. Jansen

Table of contents

CHAPTER 1

General Introduction

1 Childhood overweight

1.1 Epidemiology of childhood overweight

Childhood overweight is recognized as a serious public health concerns in the 21th century. Worldwide, it is estimated that over 41 million children under the age of 5 were overweight in 2016 [1]. In the Netherlands, the prevalence of overweight was 12.8% and 14.8% among Dutch boys and Dutch girls aged 2 to 21 years old respectively in 2009, suggesting a 2- to 3- times increase in overweight prevalence compared to 1980 [2].

Childhood overweight and obesity may undermine children's physical health and psychosocial well-being both immediately and in the long-term [3]. Childhood overweight and obesity have been linked to numerous medical conditions, such as high blood pressure [4], Type 2 diabetes [5], cardiovascular disease [6], asthma [7], and sleep apnea [8]. In addition, excessive fat tissue among children can impose increased mechanic stress and thereby contribute to pulmonary and orthopedic complications [9]. Furthermore, overweight and obesity can adversely affect children's psychosocial well-beings [10]. Children who are overweight or obese are less likely to engage in physical activities, as overweight and obesity may impede children's motor development [11] and may result in shortage of breath. This may in turn make it difficult to reverse the status of overweight and obesity, and contribute to the tracking of overweight and obesity into later life. Prevention of childhood overweight and obesity is therefore a priority.

1.2 Rapid infant weight gain

Increased weight gain during infancy -in varying age windows from the first week of life to the first two years of life- has been consistently associated with childhood obesity at a later age [12-14]. In addition, increased weight gain during infancy has been associated with increased risk of cardiovascular risk factors in later life, such as high blood pressure, insulin resistance, and endothelial dysfunction [15-20]. Identifying modifiable risk factors for rapid weight gain during infancy is important for the development of effective early-life interventions for obesity prevention. Although mounting evidence from developed countries have suggested that lower socioeconomic status is associated with increased risk of childhood overweight [21, 22], few studies have looked into the socioeconomic gradient regarding weight gain during infancy. The current thesis will examine the socioeconomic differences in weight gain during the first year of life, and explore the modifiable factors explaining these differences.

2 Health behaviors related to childhood overweight

2.1 Children's dietary behavior, physical activity, and sedentary behaviors.

Weight gain occurs when an individual consumed more energy than energy he/she expended, i.e. to support normal growth and development (for children), metabolism, and physical activity. This imbalance between energy intake and energy expenditure results from the interactions of multiple factors, including genetic, behavioral, and environmental factors. Genetic factors can influence individual's susceptibility for excessive weight gain [23]. However, the raising epidemic of overweight and obesity in general population during the last several decades cannot be attributed to genetic factors, as the genetic characteristics of the population were relatively stable [24]. Rather, individual behavioral factors in the context of an obesogenic environment contribute to the increased prevalence of overweight and obesity [25]. A number of lifestyle behaviors have been identified to contribute to energy imbalance and therefore the occurrence of overweight and obesity, including frequent snacking on energy-dense nutrition-poor foods, frequent consumption of sugar-containing beverages, decreasing level of physical activity, and increased sedentary time (e.g., time spend on TV viewing and computer use) [26]. Since these dietary behaviors, physical activity- and sedentary behaviors are formed in early life stages and may track into later life [27], understanding the determinants of these behaviors in childhood is of great importance.

2.2 Clustering of children's dietary behavior, physical activity, and sedentary behaviors

Recent studies have suggested that unhealthy diet, physical activity, and sedentary behaviors tend to co-occur or 'cluster' in certain subgroups of children [28-30]. For instance, Miguel-Berges et al (2017) identified six subgroups of children with different lifestyle behavior patterns. One of these clusters was characterized by unhealthy lifestyles behaviors including high sugar-containing drinks consumption, high screen time, and lower fruit and vegetable and physical activity level among children 4-6 years from six European countries (n=5357) [30]. 'Clustering' of lifestyle behaviors refers to a combination of behaviors that are more prevalent than expected from the prevalence of the separate behaviors; this is also referred to an 'behavior pattern' [31]. Understanding the empirical co-occurring patterns of lifestyle behaviors may inform intervention developers about which behavior factors need to be targeted simultaneously and to which subgroups the behavior change interventions should be targeted. Few studies have examined the clustering patterns of diet, physical activity, and sedentary behavior in preschool children. This thesis will therefore address the current research gaps by examining the clustering patterns of lifestyle behaviors in 3 years old children, exploring factors associated with the clustering patterns, and investigating the association between the clustering patterns with child BMI.

2.3 Children's sleep duration and sleep problems

Increasing evidence suggests that shorter sleep duration is associated with increased risk of childhood overweight [32-36]. Several pathways have been proposed to explain the effect of shorter sleep duration on weight gain [37]. Firstly, shorter sleep duration may result in longer time to eat /be fed by parents and therefore may lead to higher calorie intake. Secondly, shorter sleep duration is associated with reduced leptin and increased ghrelin levels, causing increased appetite and finally higher calorie intake. Furthermore, insufficient sleep duration may cause tiredness and therefore reduced physical activity level, which may decrease energy expenditure. For non-causal pathways, insufficient sleep duration might reflect lower levels of parental vigilance about other aspects of health behaviors (such as diet and exercise) [38]. Relatively few studies are available on the association between sleep and BMI/overweight during infancy and early childhood, and the findings are mixed [39-44]. Furthermore, most of the previous studies have only considered the effect of short sleep duration, while omitting the effect of other sleep dimensions, such as sleep problems. Recent studies have found indications that sleep problems such as excessive night awakenings and sleep onset difficulties are associated with increased risk of overweight in children and adolescents [45-49]. This thesis will therefore address the association between characteristics of sleep (sleep duration and sleep problems) and BMI during infancy and early childhood.

2.4 Infant feeding practices

Weight gain during infancy is closely related to infant feeding practices. Independent of breastfeeding, early introduction of complementary foods (before 4 months) have been reported to be associated with more rapid infant weight gain [50-52]. In addition to timing of introduction of complementary feeding, types of complementary feeding consumed by infants are also important. High intake of, for example, sweet deserts [53] and sweet beverages [54] during infancy have been associated with a high intake of these food types in later life, and is associated with childhood overweight and obesity [53]. Gaining more knowledge on factors associated with complementary feeding is important for the development of effective intervention programs to improve infant feeding practices. This thesis will therefore explore factors associated with early introduction of complementary feeding and the consumption of non-recommended foods by infants.

3 Environmental influences on health behaviors related to childhood overweight

This ecological model provided a useful concept framework for understanding the risk factors of childhood overweight. According to the 'ecological model of predictors of childhood overweight' [55], child overweight is influenced by multiple levels of factors, including child characteristics and lifestyle factors, family characteristics, and larger community, demographic, and societal characteristics. Firstly, children's lifestyle behaviors including dietary intake, physical activity, and sedentary behavior are considered direct risk factors for child weight gain and therefore childhood overweight. The effect of these lifestyles behaviors on the development of childhood overweight may be moderated by child characteristics including genetic susceptibility, age, and gender. In turn, children's overweight related dietary, physical activity, and sedentary behaviors are mainly shaped in the context of family. Previous studies have shown that a range of family characteristics may be related to the children's lifestyle behaviors, including parental attitude and beliefs regarding children's lifestyle behaviors, parental role modelling (e.g. TV viewing, dietary intake, and physical activity), parenting styles, feeding styles, parenting practices (e.g. encouragement, restrictions, and monitoring), and the availability of foods, TV set and physical activity facilities at home [56]. Further, larger community, demographic, and societal characteristics such as work status of parents, ethnic background, socioeconomic status of the family, accessibility of recreational facilities and availability of convenience foods in the neighborhood, intervention programs, may influence child weight status as a result of their influence on parenting practices and children's lifestyle behaviors.

According to the ecological model [55], a broader context such as community, ethnic background, and socioeconomic position may moderate the influence of family environmental factors on the children's lifestyle behaviors. However, few studies investigating the family environmental influences on children's lifestyle behaviors have considered the contextual influence of a broader environment such as ethnic background. This thesis will specifically explore the potential moderation effect of ethnic background on the association between family environmental factors and child snacking behaviors.

4 Research questions addressed in this thesis

The overall goal of this thesis is to provide insight in the determinants of growth, overweight, and health behaviors related to overweight in childhood (i.e., infant feeding practices, dietary intake, sedentary behavior, physical activity, and sleep duration), with the purpose to support the development of evidence-based prevention programs regarding childhood overweight and obesity. The 'ecological model of predictors of childhood overweight' [55] is adopted in this thesis to organize the determinants of childhood overweight and overweight related health behaviors that are addressed in the current thesis (Figure 1).

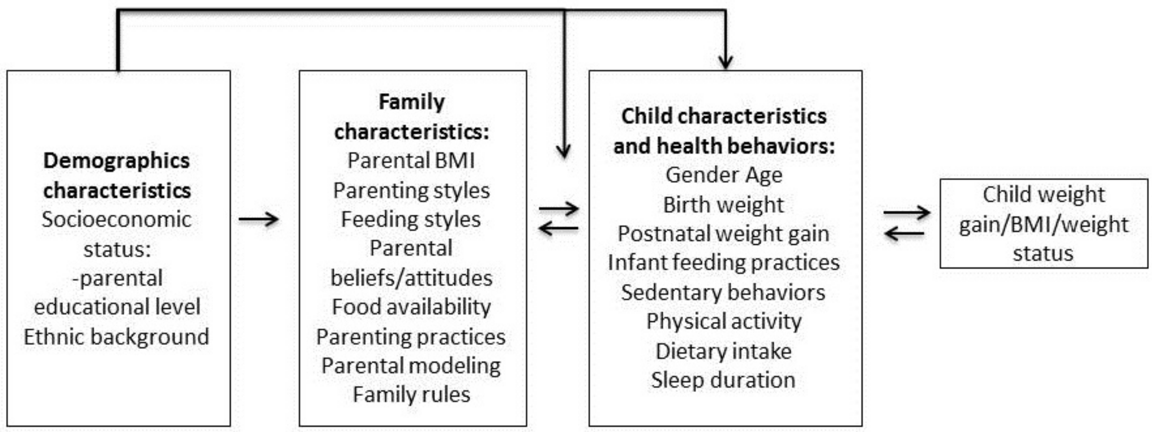

Figure 1. research framework for the present thesis based on the ecological model of predictors of childhood overweight [55].

Part 1: Socioeconomic differences in risk of childhood overweight

1. What are the socioeconomic differences on weight gain during infancy (0-12 months), and if there are, what factors can explain these differences (chapter 2)?

Part 2: Health behaviors and childhood overweight

2. What are the clustering patterns of diet, physical activity, and sedentary behaviors among children aged 3 years, what are the parental and child characteristics associated

with the clustering patterns, and what is the association between the clustering patterns and child BMI and weight status (chapter 3)?

3. What is the cross-sectional and longitudinal association between sleep and child BMI during infancy and early childhood (6-36 months) (chapter 4)?

Part 3: Factors associated with health behaviors

4. What are the family and child characteristics associated with early introduction of complementary feeding and the consumption of non-recommended foods during infancy (chapter 5)?
5. What are the cross-sectional and longitudinal associations between parental bedtime practices during in and child sleep outcomes in infancy and early childhood (chapter 6)?
6. What are the family characteristics associated with snack intake in school-aged children, and do the associations differ by child ethnic background (chapter 7, chapter 8)?

We present the overview of all the studies in this thesis in Table 1.

Table 1. Overview of studies presented in this thesis.

	Study sample	Study design	Main exposures	Main outcomes
Chapter 2	Children participating the BeeBOFT study (n=2513)	Longitudinal	Family socioeconomic status, with maternal educational level as the main indicator;	Infant weight gain between 0-3, 3-6 and 6-12 months
Chapter 3	Children participating the follow-up of the BeeBOFT study at age 3 years (n=2092)	Cross-sectional	Social-demographic characteristics, family characteristics, child characteristics; Child health behaviors including sugar-containing drink consumption, unhealthy snack consumption, fruit consumption, vegetable consumption, screen time, and physical activity at age 3 years;	Child health behaviors including sugar-containing drink consumption, unhealthy snack consumption, fruit consumption, vegetable consumption, screen time, and physical activity at age 3 years; Child BMI and weight status at age 3 years;
Chapter 4	Children participating the BeeBOFT study (n=2308)	Longitudinal	Child sleep duration and child sleep problems measured at age 6, 14 and 36 months; Child BMI at 14 and 36 months;	Child BMI measured at age 6, 14 and 36 months; Child sleep duration measured at 14 and 36 months;
Chapter 5	Children participating the follow-up of the BeeBOFT study at age 6 months(n=2159)	Cross-sectional	Social-demographic characteristics, maternal characteristics, child characteristics:	Introduction of complementary feeding before 4 month; Consumption of non-recommended complementary foods at child age 6 months;
Chapter 6	Children participating the BeeBOFT study (n=2041)	Longitudinal	Parental bedtime practices	Child sleep outcomes measured at 6, 14, and 36 months;
Chapter 7	Children participating the baseline assessment for the Water Campaign Study (n=644)	Cross-sectional	Feeding style, parenting style	Child snack consumption;
Chapter 8	Children participating the baseline assessment for the Water Campaign Study (n=644)	Cross-sectional	Social-demographic characteristics, parental attitudes, perceived behavior control, home availability, parenting practices, parental modelling, family rules, habit strength, taste preferences	Child snack consumption;

5 Data sources

Data from two different studies were used for the analyses described in the current thesis. The design of each study is described shortly below.

5.1 The BeeBOFT study

For chapter 2 to chapter 6, data from the BeeBOFT study were used [57, 58]. The BeeBOFT study is a 3-armed cluster randomized controlled trial (c-RCT) with two intervention conditions (the 'BBOFT+' intervention group and the 'E-health4Uth Healthy Toddler' intervention) and a control condition ('usual care') (Netherlands Trial Register NTR1831). The aim of the interventions was to support parents of 0-3 year children to promote healthy nutrition and activity behaviors of their child, including breastfeeding (only in the 'BBOFT+' intervention), daily exercise/outdoor playing, breakfast daily, few sweet drinks, and minimal TV time. The 'BBOFT+ study' also aimed to promote healthy sleep behaviors of the child.

In 2009, 51 Youth Health Care teams covering both rural and urban regions in the Netherlands participated in the study. The 51 YHC teams were randomly assigned to one of the three study arms. In the 'BBOFT+' intervention group, parents received advice on child rearing skills to promote children's health behaviors at each Youth Health Care routine visit (scheduled at child age 0.5, 1, 2, 3, 4, 6, 9, 11, 14, 18, 24 and 36 months). In the 'E-health4Uth' intervention group, parents received tailored advice on children's health behaviors after they finished an online survey at child age 18 and 24 months, respectively.

Parents were invited to participate in the study by the 51 participating YHC teams during the first home visit at around 2 weeks after the child birth. Parents were also asked to provide written informed consent to participate in the 3-year study. From January 2009 through September 2010, a total of 3003 parents agreed to participate in the BeeBOFT study and provided written informed consent. At inclusion, parents were asked to complete a baseline questionnaire, which assessed social demographic characteristics and pregnancy and child birth related information. The follow-up questionnaires were collected at the child age 6, 14, and 36 months respectively. Children's overweight related behaviors, parenting style and parenting practices, and parents' attitude and cognitive regarding overweight were measured at the follow-ups. The response rates at the three ages were 77.62% (2331/3003), 77.20% (2318/3003), and 73.46% (2206/3003), respectively. The growth characteristics (height, weight) were measured during each YHC routine visits, which were scheduled at child age 0.5, 1, 2, 3, 4, 6, 9, 11, 14, 18, 24, and 36 months. The Medical Ethics Committee of the Erasmus Medical Centre has reviewed the study protocol of the BeeBOFT study and declared that the Dutch Medical Research Involving Human Subjects Act (in Dutch: Wet medisch-wetenschappelijk onderzoek met mensen) did not apply to this research proposal (proposal number MEC-2008-250).

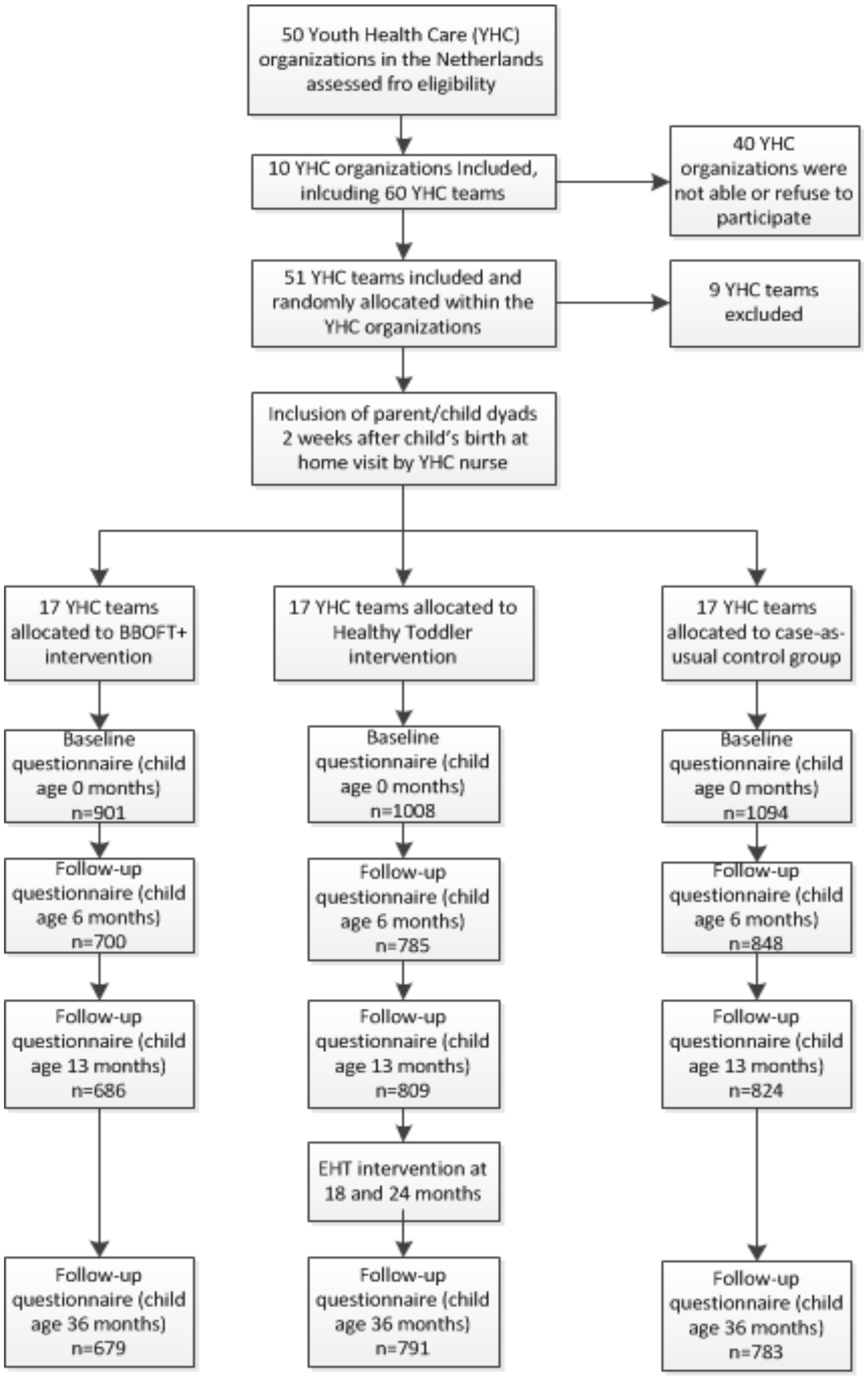

Figure 2. The flow-chart for the study population of the BeeBOFT study

5.2 The Water Campaign study

Chapter 7 and chapter 8 of this thesis used baseline data from the Water Campaign study [59]. The Water campaign study is a controlled intervention trial which aimed to reduce children's sugar sweetened beverage consumption. Four primary schools located in two multi-ethnic, disadvantaged neighborhoods in Rotterdam, the Netherlands were included in the study. All children of grades 2–8 (aged 6–13 years old) within each of the four included schools were invited to participate, resulting in a total of 1288 invited children. Parents (and children) were informed about the intervention and study participation and were free to refuse participation without giving any explanation. Parents of all the invited children received the baseline questionnaires from the teachers. Parents of 644 children returned the baseline questionnaire, and were available for analyses.

References

1. Organization, W.H. *Report of the commision on ending childhood obesity*. 2016 [cited 2018; Available from: http://apps.who.int/iris/bitstream/handle/10665/204176/9789241510066_eng.pdf?sequence=1.
2. Schönbeck, Y., et al., *Increase in prevalence of overweight in Dutch children and adolescents: a comparison of nationwide growth studies in 1980, 1997 and 2009.* PloS one, 2011. **6**(11): p. e27608.
3. Sahoo, K., et al., *Childhood obesity: causes and consequences.* Journal of family medicine and primary care, 2015. **4**(2): p. 187.
4. Reinehr, T., et al., *Intima media thickness in childhood obesity: relations to inflammatory marker, glucose metabolism, and blood pressure.* Metabolism, 2006. **55**(1): p. 113-118 %@ 0026-0495.
5. Hannon, T.S., G. Rao, and S.A. Arslanian, *Childhood obesity and type 2 diabetes mellitus.* Pediatrics, 2005. **116**(2): p. 473-480 %@ 0031-4005.
6. Lloyd, L.J., S.C. Langley-Evans, and S. McMullen, *Childhood obesity and adult cardiovascular disease risk: a systematic review.* International journal of obesity, 2010. **34**(1): p. 18.
7. Black, M.H., et al., *Increased asthma risk and asthma-related health care complications associated with childhood obesity.* American journal of epidemiology, 2013. **178**(7): p. 1120-1128 %@ 1476-6256.
8. Arens, R. and H. Muzumdar, *Childhood obesity and obstructive sleep apnea syndrome.* Journal of applied physiology, 2009. **108**(2): p. 436-444 %@ 8750-7587.
9. Valerio, G., et al., *[Health consequences of obesity in children and adolescents]*

Conseguenze dell'obesita sulla salute del bambino e dell' adolescente. Minerva Pediatr, 2014. **66**(5): p. 381-414.

10. Rankin, J., et al., *Psychological consequences of childhood obesity: psychiatric comorbidity and prevention.* Adolescent health, medicine and therapeutics, 2016. **7**: p. 125.
11. D'Hondt, E., et al., *A longitudinal analysis of gross motor coordination in overweight and obese children versus normal-weight peers.* International journal of obesity, 2013. **37**(1): p. 61.
12. Baird, J., et al., *Being big or growing fast: systematic review of size and growth in infancy and later obesity.* Bmj, 2005. **331**(7522): p. 929.
13. Monteiro, P.O. and C.G. Victora, *Rapid growth in infancy and childhood and obesity in later life--a systematic review.* Obes Rev, 2005. **6**(2): p. 143-54.
14. Salgin, B., et al., *Even transient rapid infancy weight gain is associated with higher BMI in young adults and earlier menarche.* Int J Obes (Lond), 2015. **39**(6): p. 939-44.
15. Singhal, A., et al., *Promotion of faster weight gain in infants born small for gestational age is there an adverse effect on later blood pressure?* Circulation, 2007. **115**(2): p. 213-220.
16. Singhal, A., et al., *Is slower early growth beneficial for long-term cardiovascular health?* Circulation, 2004. **109**(9): p. 1108-13.
17. Taine, M., et al., *Rapid Early Growth May Modulate the Association Between Birth Weight and Blood Pressure at 5 Years in the EDEN Cohort StudyNovelty and Significance.* Hypertension, 2016. **68**(4): p. 859-865.
18. Leunissen, R.W., et al., *Timing and tempo of first-year rapid growth in relation to cardiovascular and metabolic risk profile in early adulthood.* Jama, 2009. **301**(21): p. 2234-42.
19. Voerman, E., et al., *Critical periods and growth patterns from fetal life onwards associated with childhood insulin levels.* Diabetologia, 2017. **60**(1): p. 81-88.
20. Marinkovic, T., et al., *Early Infant Growth Velocity Patterns and Cardiovascular and Metabolic Outcomes in Childhood.* J Pediatr, 2017. **186**: p. 57-63 e4.

21. Morgen, C.S., et al., *Socioeconomic disparities in birth weight and body mass index during infancy through age 7 years: a study within the Danish National Birth Cohort.* BMJ Open, 2017. **7**(1): p. e011781.
22. Morris, T.T., K. Northstone, and L.D. Howe, *Examining the association between early life social adversity and BMI changes in childhood: a life course trajectory analysis.* Pediatr Obes, 2016. **11**(4): p. 306-12.
23. Albuquerque, D., et al., *Current review of genetics of human obesity: from molecular mechanisms to an evolutionary perspective.* Mol Genet Genomics, 2015. **290**(4): p. 1191-221.
24. Albuquerque, D., et al., *The contribution of genetics and environment to obesity.* Br Med Bull, 2017. **123**(1): p. 159-173.
25. Watanabe, E., et al., *Clustering patterns of obesity-related multiple lifestyle behaviours and their associations with overweight and family environments: a cross-sectional study in Japanese preschool children.* BMJ Open, 2016. **6**(11): p. e012773.
26. te Velde, S.J., et al., *Energy balance-related behaviours associated with overweight and obesity in preschool children: a systematic review of prospective studies.* Obes Rev, 2012. **13 Suppl 1**: p. 56-74.
27. Craigie, A.M., et al., *Tracking of obesity-related behaviours from childhood to adulthood: a systematic review.* Maturitas, 2011. **70**(3): p. 266-284.
28. Gubbels, J.S., P. van Assema, and S.P. Kremers, *Physical Activity, Sedentary Behavior, and Dietary Patterns among Children.* Curr Nutr Rep, 2013. **2**(2): p. 105-112.
29. Leech, R.M., S.A. McNaughton, and A. Timperio, *The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review.* Int J Behav Nutr Phys Act, 2014. **11**: p. 4.
30. Miguel-Berges, M.L., et al., *Clustering of energy balance-related behaviours and parental education in European preschool children: the ToyBox study.* Br J Nutr, 2017. **118**(12): p. 1089-1096.
31. Schuit, A.J., et al., *Clustering of lifestyle risk factors in a general adult population.* Preventive medicine, 2002. **35**(3): p. 219-224.
32. Felső, R., et al., *Relationship between sleep duration and childhood obesity: Systematic review including the potential underlying mechanisms.* Nutrition, Metabolism and Cardiovascular Diseases, 2017. **27**(9): p. 751-761.
33. Ruan, H., et al., *Habitual Sleep Duration and Risk of Childhood Obesity: Systematic Review and Dose-response Meta-analysis of Prospective Cohort Studies.* Sci Rep, 2015. **5**: p. 16160.
34. Fatima, Y., S.A. Doi, and A.A. Mamun, *Longitudinal impact of sleep on overweight and obesity in children and adolescents: a systematic review and bias-adjusted meta-analysis.* Obes Rev, 2015. **16**(2): p. 137-49.
35. Liu, J., A. Zhang, and L. Li, *Sleep duration and overweight/obesity in children: review and implications for pediatric nursing.* J Spec Pediatr Nurs, 2012. **17**(3): p. 193-204.
36. Miller, M.A., et al., *Sleep duration and incidence of obesity in infants, children, and adolescents: a systematic review and meta-analysis of prospective studies.* Sleep, 2018. **41**(4): p. zsy018.
37. Chen, X., M.A. Beydoun, and Y. Wang, *Is sleep duration associated with childhood obesity? A systematic review and meta-analysis.* Obesity (Silver Spring), 2008. **16**(2): p. 265-74.
38. Glaser, N. and D. Styne, *Weighing the Causal Evidence That Associates Short Sleep Duration With Obesity.* Pediatrics, 2017. **140**(3): p. e20172015.
39. Taveras, E.M., et al., *Short sleep duration in infancy and risk of childhood overweight.* Arch Pediatr Adolesc Med, 2008. **162**(4): p. 305-11.
40. Hiscock, H., et al., *Sleep duration and body mass index in 0-7-year olds.* Arch Dis Child, 2011. **96**(8): p. 735-9.
41. Klingenberg, L., et al., *No relation between sleep duration and adiposity indicators in 9-36 months old children: the SKOT cohort.* Pediatr Obes, 2013. **8**(1): p. e14-8.

42. Bolijn, R., et al., *Daytime sleep duration and the development of childhood overweight: the KOALA B irth C ohort S tudy.* Pediatric obesity, 2016. **11**(5): p. e1-e5 %@ 2047-6302.
43. Derks, I.P.M., et al., *Longitudinal Associations of Sleep Duration in Infancy and Early Childhood with Body Composition and Cardiometabolic Health at the Age of 6 Years: The Generation R Study.* Child Obes, 2017. **13**(5): p. 400-408.
44. Collings, P.J., et al., *Sleep Duration and Adiposity in Early Childhood: Evidence for Bidirectional Associations from the Born in Bradford Study.* Sleep, 2017. **40**(2).
45. Tikotzky, L., et al., *Sleep and physical growth in infants during the first 6 months.* J Sleep Res, 2010. **19**(1 Pt 1): p. 103-10.
46. Jarrin, D.C., J.J. McGrath, and C.L. Drake, *Beyond sleep duration: distinct sleep dimensions are associated with obesity in children and adolescents.* Int J Obes (Lond), 2013. **37**(4): p. 552-8.
47. Golley, R.K., et al., *Sleep duration or bedtime? Exploring the association between sleep timing behaviour, diet and BMI in children and adolescents.* Int J Obes (Lond), 2013. **37**(4): p. 546-51.
48. Miller, A.L., J.C. Lumeng, and M.K. LeBourgeois, *Sleep patterns and obesity in childhood.* Curr Opin Endocrinol Diabetes Obes, 2015. **22**(1): p. 41-7.
49. Alamian, A., et al., *Infant sleep problems and childhood overweight: Effects of three definitions of sleep problems.* Prev Med Rep, 2016. **4**: p. 463-8.
50. van Rossem, L., et al., *Weight change before and after the introduction of solids: results from a longitudinal birth cohort.* Br J Nutr, 2013. **109**(2): p. 370-5.
51. Vail, B., et al., *Age at Weaning and Infant Growth: Primary Analysis and Systematic Review.* J Pediatr, 2015. **167**(2): p. 317-24 e1.
52. Baker, J.L., et al., *Maternal prepregnant body mass index, duration of breastfeeding, and timing of complementary food introduction are associated with infant weight gain.* Am J Clin Nutr, 2004. **80**(6): p. 1579-88.
53. Rose, C.M., L.L. Birch, and J.S. Savage, *Dietary patterns in infancy are associated with child diet and weight outcomes at 6 years.* International Journal of Obesity, 2017. **1**: p. 6.
54. Park, S., et al., *The association of sugar-sweetened beverage intake during infancy with sugar-sweetened beverage intake at 6 years of age.* Pediatrics, 2014. **134**(Supplement 1): p. S56-S62.
55. Davison, K.K. and L.L. Birch, *Childhood overweight: a contextual model and recommendations for future research.* Obes Rev, 2001. **2**(3): p. 159-71.
56. Kremers, S.P.J., et al., *Environmental influences on energy balance-related behaviors: a dual-process view.* International Journal of Behavioral Nutrition and Physical Activity, 2006. **3**(1): p. 9.
57. Raat, H., et al., *Primary prevention of overweight in preschool children, the BeeBOFT study (breastfeeding, breakfast daily, outside playing, few sweet drinks, less TV viewing): design of a cluster randomized controlled trial.* BMC Public Health, 2013. **13**: p. 974.
58. van Grieken, A., et al., *Personalized Web-Based Advice in Combination With Well-Child Visits to Prevent Overweight in Young Children: Cluster Randomized Controlled Trial.* J Med Internet Res, 2017. **19**(7): p. e268.
59. van de Gaar, V.M., et al., *Effects of an intervention aimed at reducing the intake of sugar-sweetened beverages in primary school children: a controlled trial.* Int J Behav Nutr Phys Act, 2014. **11**: p. 98.

PART I

Socioeconomic Differences

CHAPTER 2

Relationship between socioeconomic status and weight gain during infancy: The BeeBOFT study

PLOS ONE 2018 Nov 2;13(11):e0205734

Lu Wang, Amy van Grieken, Junwen Yang-Huang, Eline Vlasblom, Monique P L'Hoir, Magda M Boere-Boonekamp, Hein Raat

Abstract

Background

Increased weight gain during infancy is a risk factor for obesity and related diseases in later life. The aim of the present study was to investigate the association between socioeconomic status (SES) and weight gain during infancy, and to identify the factors mediating the association between SES and infant weight gain.

Methods

Subjects were 2513 parent-child dyads participating in a cluster randomized controlled intervention study. Family SES was indexed by maternal education level. Weight gain in different time windows (infant age 0-3, 0-6, and 6-12 months) was calculated by subtracting the weight for age -score (WAZ) between the two time-points. Path analysis was performed to examine the mediating pathways linking SES and infant weight gain.

Results

On average, infants of low-educated mothers had a lower birth weight and caught-up at approximately 6 months. In the period of 0-6 months, infants with low-educated mothers had an 0.42 (95% CI 0.27–0.57) higher gain in weight for age z-score compared to children with high-educated mothers. The association between maternal education level and increased infant weight gain in the period of 0-6 months can be explained by infant birth weight, gestational age at child birth, duration of breastfeeding, and age at introduction of complementary foods. After adjusting all the mediating factors, there was no association between maternal education level and infant weight gain.

Conclusion

Infants with lower SES had an increased weight gain during the first 6 months of infancy, and the effect can be explained by infant birth weight, gestational age at child birth, and infant feeding practices.

Introduction

The high prevalence of child obesity and concomitant effects on morbidity and mortality constitute a major public health concern [1]. In developed countries, low socioeconomic status (SES) is consistently associated with a higher prevalence of childhood obesity [2-5]. Understanding the origins of socioeconomic inequalities in childhood obesity may contribute to the development of intervention programs.

Increased weight gain during infancy -in varying age windows from the first week of life to the first two years of life - has been consistently associated with childhood obesity [6-8]. In addition, increased weight gain during infancy has been associated with increased risk of cardiovascular risk factors in later life, such as high blood pressure, insulin resistance, and endothelial dysfunction [9-14]. Only two previous studies have focused on examining the association between SES and weight gain during infancy [15, 16]. These two studies suggested that lower SES is associated with increased weight gain during the first three months [15] and the first year of life [16]. In both studies, only two time points were used to assess weight gain during infancy, which may not be sufficient to capture the differences in the weight gain trajectories during infancy [15, 16]. It is not known whether the SES differences in infant weight gain is consistent during infancy. In addition, some important potential confounding factors/mediating factors were missing in these studies, such as parental height, and maternal pregnancy complications.

Previous studies have indicated that the determinants of infant weight gain include prenatal factors such as parental body mass index (BMI), parental height, gestational age, infant birth weight, and infant feeding practices such as breastfeeding duration and age at introduction of complementary feeding [17-22]. Yet, it is not clear to what extent the association between SES and infant weight gain can be explained by these determinants. To develop interventions to reduce the SES-related inequality in childhood obesity prevalence, insight in the factors that are most important for explaining the association between SES and infant weight gain is needed.

Therefore, the aim of the present study was to investigate the association between SES and weight gain during infancy, and to identify the mediating factors explaining the association between SES and infant weight gain.

Methods

Study design and study population

This study used data from the 'BeeBOFT Study', a population-based 3-armed cluster randomized trial for the primary prevention of overweight among younger children (Netherlands Trial Register: NTR1831) [23]. The 'BeeBOFT study' has been conducted within 51 regional Youth health care (YHC) teams. Parents who were allocated to the first arm of the trial, the 'BBOFT+' intervention, received intervention on healthy behavioral life-style habits of the children from birth onward at each YHC routine visit (at child age 0, 1, 2, 3, 4, 6, 9, 11, 14, 24, 36, and 48 months). The 'E-health4Uth Healthy toddler' intervention, the second arm of the trial, provided the parents tailored health education regarding healthy child nutrition and activity behaviors at the child age of circa 18 and 24 months old. Parents in the control group received care as usual. The research proposal was reviewed by the Medical Ethics Committee of the Erasmus Medical Center. Based on their review, the Committee concluded that the Dutch Medical Research Involving Human Subjects Act (in Dutch: Wet medisch-wetenschappelijk onderzoek met mensen) did not apply to this research proposal. The Medical Ethics Committee therefore had no objection to the execution of this study (proposal number MEC-2008-250). Further details about the study design and the interventions are described in the design paper published by Raat et al [23].

Parents were invited to participate in the 'BeeBOFT' study when the Youth Health Center (YHC) nurses visited them at home in the second week after child birth, between 2009 and 2010. Written informed consent to participation was gained from the parents of 3003 infants. For the present study, we only included infants with weight measurements available at birth, and at least 1 measurement at 3, 6 or 12 months' age (n=2552). We excluded participants with no information on maternal education level (n=39). Eventually 2513 infants were included in the present study.

Measurement

Socioeconomic status

Maternal education level was used as the main indicator of family social economic status. Other indicators of family socioeconomic status included paternal education level, and both maternal and paternal employment status. Data on maternal and paternal education level, maternal and paternal employment status were obtained from baseline parental questionnaires at the child's age of 2-4 weeks. Following the standard definition of Statistics Netherlands [24] the maternal highest attained education level was categorized as high (higher vocational training, university degree), middle (>4 years general secondary school or intermediate vocational training), or low (no education, primary school, or 4 years or less general secondary school).

Child growth assessments

Data on weight (and height) of the child were acquired from the YHC registration files. At each YHC routing visit (at child age of circa 0, 1, 2, 3, 4, 6, 9, 12 month), child weight and height was measured using standardized methods by YHC nurses [25]. We used child weight measurement at child age of circa 0, 3, 6, and 9 months. To adjust weight for physiological growth and gender differences, the weight-for-age -scores (WAZ) were calculated using the Dutch 1997 age- and gender-specific reference values [26]. Infant weight gain in different time windows (0-3 months, 0-6 months, and 6-12 months) was assessed by changes in WAZ between the two time-points. An increase in WAZ of greater than 0.67 in each time window was defined as rapid weight gain [7, 27].

Potential mediators

Potential mediators for the association between SES and infant weight gain were selected based on previous researches linking them with infant weight gain [17-22] and the rational plausibility that SES may influence these factors.

Infant characteristics

Infant characteristics at birth including gestational age at birth (weeks) and birth weight are highly related to the velocity of infant weight gain. Gestational age at child birth was obtained by baseline questionnaire. We created gestational age- and gender-adjusted infant birth weight (weight for gestational age z- score) within our study population based on North European growth charts [28].

Prenatal factors

Prenatal factors included maternal age at child birth, maternal pre-pregnancy BMI, paternal BMI, maternal and paternal height (meters), maternal gestational weight gain (kilogram), maternal diabetes (Yes/No), maternal hypertension (Yes/No), and parity [17, 19]. Maternal pre-

pregnancy BMI and paternal BMI was calculated by weight(kilogram)/ height^2(meter). These variables were self-reported by parents in baseline questionnaire at child age 2-4 weeks.

Infant feeding practices

Infant feeding factors that may influence infant growth included duration of breastfeeding, and timing of introduction of complementary feeding. In the questionnaire at child age 6 months, parents were asked to report whether they have initiated breastfeeding, and how old the child was when they stopped giving breastfeeding. Parents were also asked to report how old the child was when they started to give the child foods or liquids besides breast milk or formula. The coding of breastfeeding duration and age at introduction of complementary feeding are shown in Table S1.

Potential confounders

Child gender and exact age at measurement, child ethnic background (non-native VS native) were considered as potential confounders, since they can bias the association, but are not on the causal pathway between SES and infant weight gain. The child's ethnic background was defined as native only if both parents had been born in the Netherlands [29].

Statistical analysis

Descriptive statistics were calculated to present sample characteristics. We plotted the average weight for age z-score trajectories between child birth and 12 months of age according to maternal education level (by R package 'ggplot'), using all the available weight measurements in the period of 0-12 months.

Linear regression models were used to examine the association between maternal education level and infant weight gain (represented by changes in WAZ) at different times windows of infant growth (0 to 3, 0 to 6, and 6 to 12 months). Logistic regression models were used to examine the association between maternal education level and rapid weight gain (Yes vs No). The models were adjusted for potential confounders including child gender, ethnic background, and age at weight measurement. To handle the multiple testing problem, Bonferroni correction was adopted, which sets the significance level at $\alpha/n = 0.05/3 = 0.017$.

We examined the independent association of the potential mediators with infant weight gain using multivariate linear regression models, adjusting for maternal educational level and potential confounders. Factors associated with both infant weight gain and maternal education level were considered as potential mediators in the following path analysis ($p<0.10$) [30]. including: gestational age at child birth, weight for gestational age z-score, duration of breastfeeding, age at introduction of complementary feeding, parental heights, maternal BMI. A path analysis mediation model was used to examine the mediating pathways between maternal education level and infant weight gain (Proc Calis procedure in SAS). The path analysis model consisted of regressions models which a) regressed the infant weight gain on maternal education level and the potential mediators, and b) regressed the potential mediators on maternal education level. The goodness of fit index (GFI) for the path analysis model was 0.94, and the Root Mean Square Error of Approximation (RMSEA) was 0.07, suggesting a favorable model fit [31]. The indirect effect of maternal education level for each of the pathways was calculated as the product of regression coefficients on that pathway [30, 32]. The proportion of the effect of SES on infant weight gain mediated by each mediator was determined by dividing the corresponding absolute indirect effect by the total effect [33].

Some of the potential mediators had missing values, ranging from 0.03% missing (maternal height) to 23% missing (age at introduction of complementary feeding). To reduce potential bias associated with missing data, a multiple imputation procedure was performed. As the variables with missing values included both continuous (e.g. gestational age) and categorical variables (e.g. maternal hypertension), a multiple imputation procedure by fully conditional specification (FCS) was used [34, 35]. Twenty imputed datasets were generated to represent a plausible range of values that approximate the missing values. All the potential mediators and confounders, maternal education level, and infant WAZ were used as predictors for the missing data imputation. Pooled regression coefficients are shown in the results for the multiple linear regression analyses and path analyses. To check the quality of the imputation, we inspected the distribution of the imputed variables in the completed dataset and in the original dataset (Table S2.). There were no apparent differences between the completed data and original data.

We repeated the analysis by using other SES indicators including paternal education level, paternal and maternal employment status to assess the SES gradient in infant weight gain (Table S4.). Also, we repeated the analysis using gain in weight for height z-scores, and BMI z-scores in different time windows as outcomes, the results are shown in Table S4. We performed a sensitivity analysis using data from subjects who did not receive any intervention (the parent-child dyads who were allocated to the control group and 'E-Health' group), the results were comparable (Tables S5. And Table S6.). In addition, we performed sensitivity analysis using the complete cases with no missing values on the potential mediators, the results were comparable (Table S7.).

Results

Sample characteristics according to maternal educational level

Table 1 shows the general characteristics of the study participants in the total study population, and by maternal education. The percentage of low-, middle-, and high-educated mothers was 13.5%, 35.4%, and 51.1% respectively. Infants with low-educated mothers had shorter gestational age, and a smaller birth weight (p<0.05). Numbers of male and female infants were equal. A percentage of 16.3 of the infants have a non-Dutch ethnic background. Low-educated mothers were younger at infant birth, had a shorter height, and higher pre-pregnancy BMI. With regard to infant feeding practices, lower educated mothers gave breastfeeding for a shorter duration and introduced complementary food earlier.

Table 1. Characteristics of the infants and parents according to maternal educational level

	Missing	Total	Maternal educational level			*p-value*
			Low	Middle	High	
		2513	339	890	1284	
Infant characteristics						
Gender, male (%)	0	50.8	55.1	48.6	51.2	0.12
Ethnic background, non-Dutch (%)	0	16.3	19.2	14.9	16.4	0.01
Gestational age (weeks)	31	39.7(1.3)	39.5(1.4)	39.6(1.3)	39.7(1.3)	0.01
Weight for gestational age z-score at birth	31	0.1(1.0)	-0.1(1.1)	0.1(1.0)	0.2(1.0)	<0.001
Prenatal factors						
Maternal age at child birth (years)	20	30.9(4.3)	29.0(5.3)	30.2(4.3)	31.9(3.7)	<0.001
Maternal pre-pregnancy BMI (kg/m^2)	102	24.2(4.5)	24.8(5.3)	24.8(4.7)	23.7(4.0)	<0.001
Paternal BMI (kg/m^2)	254	25.3(3.3)	25.4(4.3)	25.5(3.5)	25.0(2.9)	0.002
Maternal height (meters)	9	1.7(0.1)	1.7(0.1)	1.7(0.1)	1.7(0.1)	<0.001
Paternal height (meters)	48	1.8(0.1)	1.8(0.1)	1.8(0.1)	1.8(0.1)	<0.001
Gestational weight gain mother (kg)	139	14.2(5.2)	13.7(5.8)	14.2(5.7)	14.2(4.8)	0.21
Maternal hypertension[1](%)	32	9.5	8.5	11.3	8.5	0.08
Maternal diabetes (%)	32	1.6	2.1	1.7	1.4	0.56
Parity, primipara (%)	0	46.7	50.5	44.6	47.1	0.17
Infant feeding practices						
Started breastfeeding after birth (%)	172	81.2	72.6	80.7	89.1	<0.001
Breastfeeding duration (months)	223	2.8(2.8)	1.4 (2.3)	2.4(2.7)	3.5(2.7)	<0.001
Age at introduction of complementary foods (months)	578	4.6(1.0)	4.1(1.1)	4.5(0.9)	4.8(0.9)	<0.001

Note: Continuous variables are presented as means (SD), and categorical variables are presented as percentage. Differences were tested with One way ANOVA analysis and Chi-square tests.

[1]: maternal hypertension disorders included maternal hypertension and eclampsia

Maternal education level and weight gain/rapid weight gain.

Fig 1 shows the patterns of average WAZ over time according to maternal education level. Infants of lower educated mothers had lower weight at birth, and gained weight more rapidly in the first half of infancy. After infant age 6 months, there was no difference in WAZ between maternal education subgroups.

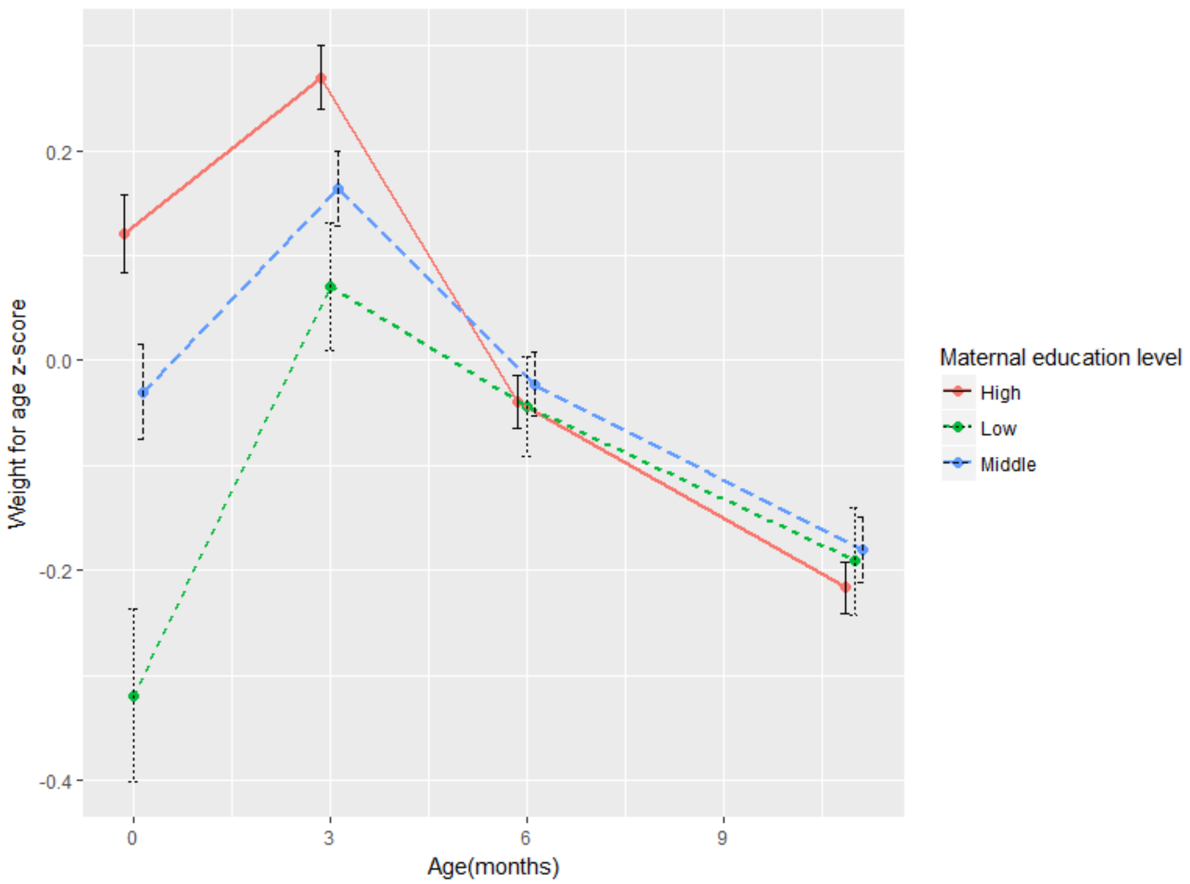

Figure 1. The average weight for age z-score over time from birth to child 12 months according to maternal education level.

Table 2 shows that infants with low- and middle-educated mothers had greater increase in WAZ in the period of 0-3 months, and 0-6 months compared to infants with high-educated mothers. The differences in WAZ changes between infants of low-educated mothers and those of high-educated mothers in the period of 0-3 months and 0-6 months were 0.24 (95% confidence interval (CI) 0.09–0.38), 0.41 (95% CI 0.27–0.57) respectively. Infants with low-educated mothers also had a higher ratio of rapid weight gain during the period 0-3 months, and

0-6 months. We repeated the analysis by using paternal education level, paternal and maternal employment status as indicators of SES, the results were comparable (Table S2).

Table 2. The association of mother education level with infant weight gain and rapid growth at different time windows

	0-3 months	0-6 months	6-12 months
	n=1661	n=2002	n=1848
Gain in WAZ [1]	β (95% CI)	β (95% CI)	β (95% CI)
Mother educational level			
Low vs High	0.24(0.09,0.38) ***	0.42(0.27,0.57) ***	0.03(-0.04,0.09)
Middle vs High	0.08(-0.02,0.18)	0.18(0.07,0.28) **	0.03(-0.02,0.07)
Rapid weight gain (Yes vs No)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Mother educational level			
Low vs High	1.62(1.21,2.16) **	1.87(1.43,2.44) **	1.10(0.64,1.89)
Middle vs High	1.26(1.02,1.55)	1.52(1.25,1.86)	1.14(0.78,1.66)

Note: Models adjusted for exact age at measurements, gender and ethnic background of infants.
$^{*}p < 0.017$, $^{**}p < 0.01$, $^{***}p < 0.001$.
[1]: Weight for age z-score.

Potential mediators

Table 3 shows the results of multivariate linear regression models for factors associated with weight gain at 0-6 months, factors associated with infant weight gain included infant gender, ethnic background, birth weight, gestational age, maternal gestational weight gain, maternal diabetes, parity, maternal and paternal height, maternal pre-pregnancy BMI, duration of breastfeeding, and age at introduction of complementary foods.

Table 3. Factors associated with infant weight gain at different time windows: results from multivariate linear regression models.

Age windows	0-6 months β (95%CI)
Infant characteristics	
Weight for gestational age z-score	-0.77(-0.81, -0.73) ***
Gestational age at birth (weeks)	-0.37(-0.40, -0.35) ***
Prenatal factors	
Maternal age at child birth (years)	-0.01(-0.02, 0.00)
Maternal pre-pregnancy BMI (kg/m2)	0.01(0.00, 0.01) *
Paternal BMI (kg/m2)	0.01(0.00, 0.02)
Maternal height (meters)	0.64(0.12, 1.16) *
Paternal height (meters)	1.16(0.68, 1.64) ***
Gestational weight gain mother (kg)	0.00(0.00, 0.01)
Maternal hypertension	-0.04(-0.15, 0.07)
Maternal diabetes	0.17(-0.09, 0.42)
Parity, primipara	-0.05(-0.13, 0.02)
Infant feeding practices	
Breastfeeding duration, (months)	-0.05(-0.06, -0.03) ***
Age at introduction of complementary feeding, (months)	-0.08(-0.12, -0.04) ***

Note: The models included all the potential explanatory variables, and exact age at weight measurement. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

In the path analysis, we focused on explaining the difference in infant weight gain between low and high maternal education level in the period of 0-6 months. Analyses revealed that a low-maternal education level, compared to a high-maternal education level, was associated with increased weight gain in the first 6 months of infancy indirectly through infant birth weight, infant gestational age, maternal pre-pregnancy BMI, maternal and paternal heights, duration of breastfeeding, and age at introduction of complementary food (Fig 2). Low maternal educational level had no direct effect on infant weight gain in the period of 0-6 months (Table 4). Infants of mothers with low educational level have increases in WAZ in the period of 0-6 months of 0.23 via weight for gestational age z-score, 0.07 via gestational age, 0.16 via breastfeeding duration and age at introduction of complementary feeding in total. In addition, parental heights have a counter effect (-0.05) on the association between lower maternal educational level and gains in WAZ.

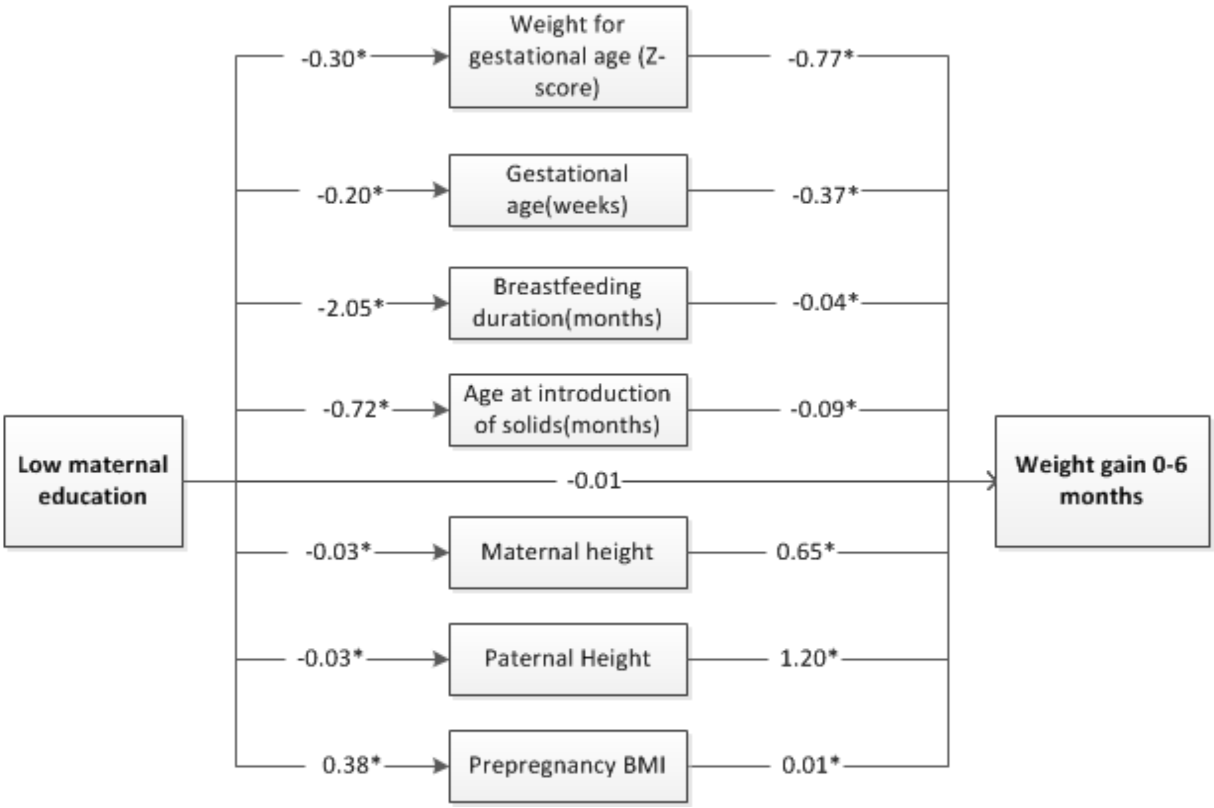

Figure 2. Path analysis model for maternal education and weight gain 0-6 months.

Note: *p<0.05.

Table 4. The pathways linking maternal educational level and infant weight gain in the period of 0-6 months.

	Low vs High maternal educational level	
	Effects	Proportion mediated
Direct effect	-0.01	-1%
Indirect effect through potential mediators		
Weight for gestational z-score	0.23*	57%
Gestational age	0.07*	18%
Breastfeeding duration	0.09*	22%
Age at introduction of complementary foods	0.07*	17%
Maternal Height	-0.02*	-4%
Paternal Height	-0.03*	-8%
Maternal pre-pregnancy BMI	0.00	1%
Total effect	0.41	

Note : The model adjusted for exact age of the infant, and child ethnic background.
*The effect was statistically significant (p<0.05)

Discussion

Overall, we found clear evidence of a SES gradient in infant weight gain in the period of 0-6 months in this population based sample from the Netherlands. The main mediating factors explaining the association between family SES and infancy weight gain included birth weight, gestational age, and infant feeding practices. After adjusting for all the potential mediators, maternal education level was no longer associated with infant weight gain.

In our study population, infants with lower educated mother had lower birthweight, and gain weight more rapidly in the first 6 months. The associations between low maternal education level and more rapid infant weight gain in the first 6 months could largely be explained by shorter gestational age, and smaller weight for gestational age z-score. In line with previous studies [36-39], our study found that infants with lower educated mothers had shorter gestational age, and had smaller weight for gestational age -score. Weight gain during the first few months after birth is highly dependent on birth weight, since babies born with a smaller size tend to catch-up, while heavier babies tend to catch-down [19]. Increased weight gain during infancy following low birthweight have been independently related to increased risk of obesity, and cardiovascular risk factors such as hypertension, and diabetes/insulin resistance [11, 12, 40-43]. In addition, studies have also suggested that increased weight gain during infancy is associated with cardiovascular risk factors in later life independent of birthweight [44]. Therefore, the increased weight gain following lower birth weight in the low maternal educational group deserves further attention. However, it should be noted that infant weight in the lower maternal educational group did not exceed that in the higher educational group during infancy. It is possible the increased weight gain in the lower SES group is due to a nature convergence of the infant weight to the average level after birth. Whether the SES divergence in weight gain during infancy can explain the SES inequalities in obesity and cardiovascular risk factors in later life requires further investigation.

In addition to infant birth weight, infant feeding practices including breastfeeding duration and age at introduction of complementary food explained the remaining associations between low maternal education level and increased infant weight gain. The effect explained by infant feeding practices was 40% in total. In previous studies, infant feeding practices explained 62% of the effect in the first 3 months [15]. and 27% of the effect in the first year [16]. Consistent with previous studies [45-48], we found that lower educated mothers were less likely to initiate breastfeeding, breastfed for a shorter period, and introduced complementary food at an earlier age. Both formula feeding [49, 50] and early introduction of complementary foods [51] have been associated with increased weight gain during infancy. Higher protein and energy content from formula and complementary food [52] may stimulate the secretion of insulin-like growth factor which enhances growth in the first 6 months of infancy [53]. In addition, breastfed infants may learn to self-regulate their intake better than formula fed infants [54]. It should be noted that reverse causalities might exist for the associations of breastfeeding duration and age at introduction of complementary feeding with infant weigh gain. Parents of infants experiencing more rapid growth may stop breastfeeding early and introduce complementary feeding early, because they think their child may need more energy. If a such a reverse causality exists, we may have overestimated the real effect of breastfeeding duration and age at introduction of complementary feeding on infant weight gain. And therefore, the indirect effect of maternal educational level on infant weight gain mediated by breastfeeding duration and age at introduction of complementary feeding may have been overestimated.

Parental heights have counter effects on the association between low maternal education level and weight gain during 0-6 months. On average, parents of higher SES have higher statue. Parental statues can influence growth rate during infancy- infant with taller parents tend to have higher weight and length gain [20].

Maternal educational level was chosen as the main indicator of family SES in the present study, as healthy infant weight development is mainly related to maternal related factors, such as child birthweight, maternal BMI, and infant feeding. In addition, educational level is a stable variable accomplished in early adult life, and is relevant to people regardless of age and working circumstances. We repeated our analysis using other family SES indicators, including paternal educational level, maternal employment status and paternal employment status. In addition, we combined maternal and paternal educational level as parental educational level, which was defined as the highest attained educational level of both parents. As we expected, paternal educational level had similar (yet weaker) graded association with infant weight gain than low maternal educational level (Table S3.). The association of parental educational level with infant weight gain was similar to maternal educational level and tend to be stronger. This might indicate that the more unfavorable socioeconomic conditions a family have, the stronger the effect on infant weight gain. The association between maternal unemployment and infant weight gain could be partly explained by maternal educational level. Also, unemployed mothers may have more time to feed their children and therefore contribute to higher BMI of children. The absence of association between paternal employment status and infant weight gain might be due to the low percentage of paternal unemployment (3%), and the instability of employment status.

In addition of infant weight for age z-scores, weight-for-length z-scores and BMI for age z scores have also been relevant to the development of body composition. We tested the association between family SES and the development of weight-for-length z-scores and BMI z-scores of the children in their first year of life. Maternal educational level was associated with higher increases in BMI z-scores between age 0 to 6 months, while was not significantly associated with changes in weight for length z-scores. This might be because weight for length z-scores are not age adjusted, and may be not sensitive to changes in infant weight gain in a short period. Previous studies indicated that weight for length z-scores may lack reliability in younger children.

The present study has a number of strengths. Firstly, the repeated measurements of infant weight allowed us to track the trajectory of infant weight gain. Secondly, we used a literature and hypothesis driven approach to select relevant variables. All mediating variables were selected based on a priori association with infant weight changes. The association between SES and increased infant weight gain was fully explained by the selected potential confounding factors. Thirdly, by using path analysis, correlations between mediators were taken into account, and we were able to calculate the independent effect mediated by multiple mediators' [33]. Some limitations have to be mentioned as well. Firstly, selective participation and loss to follow-up is possible, especially among the lower-educated groups. However, this may not bias our finding, as the association between exposure and the outcome will only be biased when participation is associated with both exposure and outcome. Secondly, we were not able to assess the effect of maternal smoking on infant weight gain which may have explained the association between maternal education and infant weight gain [16]. Thirdly, we used data from a cluster randomized controlled trial for childhood overweight prevention. It is possible that interventions are more effective when maternal educational levels are higher, as high educated mothers have higher receptiveness to healthy education messages. Therefore, intervention might strengthen the maternal educational gradients in infant weight gain. However, our interaction analyses suggested that the SES difference does not differ by the intervention groups. Also, sensitivity analysis using data from children who did not received any interventions suggested that the association between maternal educational level and infant weight gain was comparable to the results using all the available subjects [55].

In conclusion, our findings indicate that infants from lower SES families have more rapid weight gain during the first half of infancy than those from higher SES families. The association between lower SES and more rapid weight gain can be explained by lower birthweight, shorter gestational age, shorter duration of breastfeeding, and earlier introduction of complementary foods. Promotion of a healthy pregnancy, optimizing duration of breastfeeding and timing of complementary feeding, in particular among low educated women, may contribute to normalizing infant growth and reduce adverse consequences of increased infant weight gain.

References

1. Nguyen, D.M. and H.B. El-Serag, *The Epidemiology of Obesity.* Gastroenterol Clin North Am, 2010. **39**(1): p. 1-7.
2. Shrewsbury, V. and J. Wardle, *Socioeconomic status and adiposity in childhood: a systematic review of cross-sectional studies 1990-2005.* Obesity (Silver Spring), 2008. **16**(2): p. 275-84.
3. Bouthoorn, S.H., et al., *Development of socioeconomic inequalities in obesity among Dutch pre-school and school-aged children.* Obesity (Silver Spring), 2014. **22**(10): p. 2230-7.
4. Boone-Heinonen, J., et al., *Connecting the Dots in Childhood Obesity Disparities: A Review of Growth Patterns from Birth to Pre-Adolescence.* Curr Epidemiol Rep, 2016. **3**(1): p. 113-124.
5. Massion, S., et al., *Exploring the impact of early life factors on inequalities in risk of overweight in UK children: findings from the UK Millennium Cohort Study.* Arch Dis Child, 2016. **101**(8): p. 724-30.
6. Baird, J., et al., *Being big or growing fast: systematic review of size and growth in infancy and later obesity.* Bmj, 2005. **331**(7522): p. 929.
7. Monteiro, P.O. and C.G. Victora, *Rapid growth in infancy and childhood and obesity in later life--a systematic review.* Obes Rev, 2005. **6**(2): p. 143-54.
8. Salgin, B., et al., *Even transient rapid infancy weight gain is associated with higher BMI in young adults and earlier menarche.* Int J Obes (Lond), 2015. **39**(6): p. 939-44.
9. Singhal, A., et al., *Promotion of faster weight gain in infants born small for gestational age is there an adverse effect on later blood pressure?* Circulation, 2007. **115**(2): p. 213-220.
10. Singhal, A., et al., *Is slower early growth beneficial for long-term cardiovascular health?* Circulation, 2004. **109**(9): p. 1108-13.
11. Taine, M., et al., *Rapid Early Growth May Modulate the Association Between Birth Weight and Blood Pressure at 5 Years in the EDEN Cohort StudyNovelty and Significance.* Hypertension, 2016. **68**(4): p. 859-865.
12. Leunissen, R.W., et al., *Timing and tempo of first-year rapid growth in relation to cardiovascular and metabolic risk profile in early adulthood.* Jama, 2009. **301**(21): p. 2234-42.
13. Voerman, E., et al., *Critical periods and growth patterns from fetal life onwards associated with childhood insulin levels.* Diabetologia, 2017. **60**(1): p. 81-88.
14. Marinkovic, T., et al., *Early Infant Growth Velocity Patterns and Cardiovascular and Metabolic Outcomes in Childhood.* J Pediatr, 2017. **186**: p. 57-63 e4.
15. Wijlaars, L.P., et al., *Socioeconomic status and weight gain in early infancy.* Int J Obes (Lond), 2011. **35**(7): p. 963-70.
16. Van Den Berg, G., et al., *Low maternal education is associated with increased growth velocity in the first year of life and in early childhood: the ABCD study.* Eur J Pediatr, 2013. **172**(11): p. 1451-7.

17. Woo Baidal, J.A., et al., *Risk Factors for Childhood Obesity in the First 1,000 Days: A Systematic Review.* Am J Prev Med, 2016. **50**(6): p. 761-79.
18. Mihrshahi, S., et al., *Determinants of rapid weight gain during infancy: baseline results from the NOURISH randomised controlled trial.* BMC Pediatr, 2011. **11**: p. 99.
19. Kupers, L.K., et al., *Determinants of Weight Gain during the First Two Years of Life--The GECKO Drenthe Birth Cohort.* PLoS One, 2015. **10**(7): p. e0133326.
20. Hindmarsh, P.C., et al., *Factors predicting ante- and postnatal growth.* Pediatr Res, 2008. **63**(1): p. 99-102.
21. Touwslager, R.N., et al., *Determinants of infant growth in four age windows: a twin study.* J Pediatr, 2011. **158**(4): p. 566-572 e2.
22. Baker, J.L., et al., *Maternal prepregnant body mass index, duration of breastfeeding, and timing of complementary food introduction are associated with infant weight gain.* Am J Clin Nutr, 2004. **80**(6): p. 1579-88.
23. Raat, H., et al., *Primary prevention of overweight in preschool children, the BeeBOFT study (breastfeeding, breakfast daily, outside playing, few sweet drinks, less TV viewing): design of a cluster randomized controlled trial.* BMC Public Health, 2013. **13**: p. 974.
24. Netherlands, S., *Dutch standard classification of education 2003.* Voorburg/Heerlen, Netherlands: Statistics Netherlands, 2004.
25. Bulk-Bunschoten AMW, R.C., Leerdam FJM, Hirasing RA: , *Youth health care overweight detection protocol. .* Woerden: Platform Jeugdgezondheidszorg 2004. **12-1**.
26. Fredriks, A.M., et al., *Continuing positive secular growth change in The Netherlands 1955–1997.* Pediatric research, 2000. **47**(3): p. 316-323.
27. Ong, K.K.L., et al., *Association between postnatal catch-up growth and obesity in childhood: prospective cohort study.* Bmj, 2000. **320**(7240): p. 967-971.
28. Niklasson, A., et al., *An Update of the Swedish Reference Standards for Weight, Length and Head Circumference at Birth for Given Gestational Age (1977 ‐ 1981).* Acta Paediatrica, 1991. **80**(8 ‐ 9): p. 756-762.
29. Swertz O, D.P., Thijssen J. , *Statistics Netherlands. Migrants in the Netherlands 2004.* Voorburg/Heerlen, Netherlands: Statistics Netherlands, 2004.
30. Baron, R.M. and D.A. Kenny, *The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations.* Journal of personality and social psychology, 1986. **51**(6): p. 1173.
31. Jenatabadi, H.S. *An Overview of Path Analysis: Mediation Analysis Concept in Structural Equation Modeling*. 2015 [cited 2018; Available from: https://arxiv.org/abs/1504.03441.
32. MacKinnon, D., *Introduction to Statistical Mediation Analysis* 2008: Lawrence Erlbaum Associates.
33. Ditlevsen, S., et al., *The mediation proportion: a structural equation approach for estimating the proportion of exposure effect on outcome explained by an intermediate variable.* Epidemiology, 2005. **16**(1): p. 114-120.
34. Yuan, Y., *Multiple imputation using SAS software.* Journal of Statistical Software, 2011. **45**(6): p. 1-25.
35. Liu, Y. and A. De, *Multiple Imputation by Fully Conditional Specification for Dealing with Missing Data in a Large Epidemiologic Study.* Int J Stat Med Res, 2015. **4**(3): p. 287-95.
36. Morgen, C.S., et al., *Socioeconomic disparities in birth weight and body mass index during infancy through age 7 years: a study within the Danish National Birth Cohort.* BMJ Open, 2017. **7**(1): p. e011781.
37. Jansen, P.W., et al., *Explaining educational inequalities in birthweight: the Generation R Study.* Paediatr Perinat Epidemiol, 2009. **23**(3): p. 216-28.
38. Mortensen, L.H., et al., *Social inequality in fetal growth: a comparative study of Denmark, Finland, Norway and Sweden in the period 1981-2000.* J Epidemiol Community Health, 2008. **62**(4): p. 325-31.

39. Mortensen, L.H., et al., *Income-related and educational inequality in small-for-gestational age and preterm birth in Denmark and Finland 1987-2003.* Scand J Public Health, 2010. **38**(1): p. 40-5.
40. Jornayvaz, F.R., et al., *Low birth weight leads to obesity, diabetes and increased leptin levels in adults: the CoLaus study.* Cardiovasc Diabetol, 2016. **15**.
41. Curhan, G.C., et al., *Birth weight and adult hypertension, diabetes mellitus, and obesity in US men.* Circulation, 1996. **94**(12): p. 3246-50.
42. Eriksson, J.G., et al., *Catch-up growth in childhood and death from coronary heart disease: longitudinal study.* Bmj, 1999. **318**(7181): p. 427-31.
43. Dulloo, A.G., et al., *The thrifty 'catch-up fat' phenotype: its impact on insulin sensitivity during growth trajectories to obesity and metabolic syndrome.* Int J Obes (Lond), 2006. **30 Suppl 4**: p. S23-35.
44. Singhal, A., *Long-Term Adverse Effects of Early Growth Acceleration or Catch-Up Growth.* Ann Nutr Metab, 2017.
45. Gibbs, B.G. and R. Forste, *Socioeconomic status, infant feeding practices and early childhood obesity.* Pediatr Obes, 2014. **9**(2): p. 135-46.
46. van Rossem, L., et al., *Are starting and continuing breastfeeding related to educational background? The generation R study.* Pediatrics, 2009. **123**(6): p. e1017-27.
47. Lin, S.L., et al., *Timing of solid food introduction and obesity: Hong Kong's "children of 1997" birth cohort.* Pediatrics, 2013. **131**(5): p. e1459-67.
48. van Rossem, L., et al., *Weight change before and after the introduction of solids: results from a longitudinal birth cohort.* Br J Nutr, 2013. **109**(2): p. 370-5.
49. van Rossem, L., et al., *Is the association of breastfeeding with child obesity explained by infant weight change?* Int J Pediatr Obes, 2011. **6**(2-2): p. e415-22.
50. Klag, E.A., et al., *Associations Between Breast Milk Feeding, Introduction of Solid Foods, and Weight Gain in the First 12 Months of Life.* Clin Pediatr (Phila), 2015. **54**(11): p. 1059-67.
51. Grote, V., et al., *The introduction of solid food and growth in the first 2 y of life in formula-fed children: analysis of data from a European cohort study.* Am J Clin Nutr, 2011. **94**(6 Suppl): p. 1785S-1793S.
52. Inostroza, J., et al., *Low-Protein Formula Slows Weight Gain in Infants of Overweight Mothers.* J Pediatr Gastroenterol Nutr, 2014. **59**(1): p. 70-7.
53. Socha, P., et al., *Milk protein intake, the metabolic-endocrine response, and growth in infancy: data from a randomized clinical trial.* Am J Clin Nutr, 2011. **94**(6 Suppl): p. 1776s-1784s.
54. Singhal, A. and J. Lanigan, *Breastfeeding, early growth and later obesity.* Obes Rev, 2007. **8 Suppl 1**: p. 51-4.
55. Mwangome, M.K. and J.A. Berkley, *The reliability of weight ‐for ‐length/height Z scores in children.* Maternal & child nutrition, 2014. **10**(4): p. 474-480.

Supplemental table

Table S1. The measurement and recoding method for breastfeeding duration and age at introduction of complementary feeding

Variables	Questions	Answering categories and Recoding
Breastfeeding duration (months)		
	Did you started breastfeeding after child birth	No➔ 0 Yes➔ recoding according to the following questions
	How old was your child when you stopped breastfeeding totally?	1 I am still giving breastfeeding ➔6.5 2 within 1 week ➔ 0.2 3 In week 2➔0.5 4 In week 3➔0.8 5 In week 4➔ 1 6 1~2 months➔ 1.5 7 2~3 months➔ 2.5 9 3~4 months➔ 3.5 10 4~5 months➔ 4.5 11 >5 months ➔ 5.5
Age at introduction of complementary feeding (months)		
	Please indicate how old was your child when you gave each of the following product for the first time respectively? A list of food were provided, including (syrup or instant lemonade, diet soda, sweet dairy drinks, milk/buttermilk, custard/yogurt/curd, pap in a bottle, pap from a plate, bread without toppings, bread with toppings, baby biscuits, chocolate or candy, crackers or grissini, fruit from jars, fresh fruit, vegetable jars without fish or meat, vegetables jars with fish or meat, pasta/rice/potato, fresh vegetable, fish/meat/meat substitutes.)	1~2 months➔ 1.5 2~3 months➔ 2.5 3~4 months➔ 3.5 4~5 months➔ 4.5 >5 months ➔ 5.5 Never➔ 6.5 The timing of introduction of complementary feeding was defined as the youngest age of the infant when any of the above mentioned complementary food were introduced to the infant.

Table S2. The distribution of the potential mediators in the observed dataset and in one of the 20 imputed datasets.

	Observed data		Imputed data	
	Mean	SD	Mean	SD
Gestational age at birth (weeks)	39.66	1.30	39.66	1.29
Weight for gestational age z-score	0.05	1.01	0.05	1.01
Maternal age at child birth (years)	30.90	4.29	30.89	4.29
Maternal height (meters)	1.70	0.07	1.70	0.07
Paternal height (meters)	1.83	0.07	1.83	0.07
Maternal pre-pregnancy BMI (kg/m2)	24.27	4.53	24.28	4.53
Paternal BMI (kg/m2)	25.24	3.31	25.23	3.31
Breastfeeding duration, (months)	2.82	2.78	2.85	2.77
Age at introduction of complementary feeding, (months)	4.61	0.95	4.58	0.94
Gestational weight gain mother (kg)	14.14	5.29	14.09	5.28

Note: we imputed factors associated with infant weight gain in the period of 0-6 months.

Table S3. The association of different indicators of socioeconomic status with infant weight gain at different time windows.

	0-3 months n=1661	0-6 months n=2002	6-12 months n=1848
Gain in weight for age SDS	β (95% CI)	β (95% CI)	β (95% CI)
Paternal education level			
Low vs High	0.20(0.07,0.33) **	0.34(0.20,0.48)***	0.05(-0.01,0.11)
Middle vs High	0.12(0.01,0.22) *	0.18(0.07,0.29) **	0.02(-0.03,0.07)
Maternal employment status			
Without paid job vs with paid job	0.20(0.07,0.33) **	0.27(0.13,0.40) ***	-0.02(-0.08,0.04)
Paternal employment status			
Without paid job vs with paid job	0.18(-0.07,0.44)	0.11(-0.18,0.40)	0.00(-0.12,0.13)
Parental educational level			
Low vs High	0.23(0.06,0.39)	0.45(0.27,0.63) ***	0.08(0.01,0.16)
Middle vs High	0.12(0.02,0.22)	0.25(0.14,0.36) **	0.03(-0.02,0.08)

Note: The models were adjusted for child gender, ethnic background, age at weight measurement, and intervention group.
.$^{*}p < 0.017$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table S4. The association of maternal educational level with gains in weight for height z-score (WHZ) and gains in BMI for age z-score (BMIZ) at different time windows.

Age windows	0-3 months	0-6 months	6-12 months
Outcome: Gain in WHZ	β (95% CI)	β (95% CI)	β (95% CI)
Mother educational level			
Low vs High	-0.01(-0.19,0.18)	0.02(-0.15,0.19)	-0.05(-0.13,0.03)
Middle vs High	-0.06(-0.19,0.07)	-0.01(-0.13,0.11)	-0.03(-0.09,0.02)
Outcome: Gain in BMIZ			
Mother educational level			
Low vs High	0.17(-0.06,0.40)	0.29(0.07,0.50) *	-0.06(-0.14,0.03)
Middle vs High	0.00(-0.16,0.16)	0.11(-0.04,0.26)	-0.04(-0.10,0.02)

Note: The models were adjusted for child gender, ethnic background, age at weight measurement, and intervention group.
$^{*}p < 0.05$

Table S5. The association of maternal educational level with infant weight gain at different time windows in children received no interventions.

Gain in WAZ [1]	0-3 months		0-6 months		6-12 months	
	β (95% CI)[1]	*p*-value[2]	*β* (95% CI) [1]	*p*-*value*[2]	*β* (95% CI) [1]	*p*-*value*[2]
Mother education level						
Low vs High	0.21(0.03,0.39)	0.57	0.42(0.23,0.60)	0.71	0.02(-0.06,0.10)	0.66
Middle vs High	0.11(-0.01,0.23)	0.54	0.23(0.10,0.36)	0.26	0.01(-0.05,0.07)	0.31

[1] :The models were adjusted for child gender, ethnic background, and age at weight measurement.

[2] : The *p-value* for the interaction terms of SES indicators and intervention group in the models predicting infant weight gain at different time windows

Table S6. Results of multivariate linear regression models for factors associated with infant weight gain in the period of 0-6 months: complete case analysis.

Age windows	0-6 months β (95%CI)
Infant characteristics	
Weight for gestational age z-score	-0.76(-0.80,-0.72) ***
Gestational age at birth (weeks)	-0.37(-0.40,-0.34) ***
Prenatal factors	
Maternal age at child birth (years)	0.00(-0.01,0.01)
Maternal pre-pregnancy BMI (kg/m2)	0.01(0.00,0.01) *
Paternal BMI (kg/m2)	0.01(0.00,0.02)
Maternal height (meters)	0.74(0.13,1.36) *
Paternal height (meters)	1.26(0.70,1.82) ***
Gestational weight gain mother (kg)	0.01(0.00,0.02)
Maternal hypertension	-0.03(-0.16,0.10)
Maternal diabetes	0.17(-0.19,0.52)
Parity, primipara	-0.07(-0.15,0.01)
Infant feeding practices	
Breastfeeding duration, (months)	-0.05(-0.07,-0.04) ***
Age at introduction of complementary feeding, (months)	-0.07(-0.11,-0.02) **

Note: The models were adjusted for maternal educational level, child gender, ethnic background, age at weight measurement, and intervention group. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table S7. The pathways linking maternal education level and infant weight gain in the period of 0-6 months- complete case analysis.

	Low vs High maternal educational level	
	effect	Proportion mediated
Direct effect	0.01	2%
Indirect effect through potential mediators		
Weight for gestational Z-score	0.22*	57%
Gestational age	0.05*	14%
Breastfeeding duration	0.08*	20%
Age at introduction of complementary foods	0.07*	17%
Maternal Height	-0.02*	-5%
Paternal Height	-0.03*	-9%
Maternal pre-pregnancy BMI	0.01	4%
Total effect	0.39	

Note : The model adjusted for exact age of the infant, and child ethnic background.
*The effect was statistically significant (p<0.05).

PART II

Health behaviors and childhood overweight

CHAPTER 3

Sleep and BMI in infancy and early childhood (6-36 months): A longitudinal study

Pediatric obesity, 2019; e12506.

Lu Wang, Wilma Jansen, Magda M Boere-Boonekamp, Eline Vlasblom, Monique P L'Hoir, Maaike Beltman, Amy van Grieken, Hein Raat

Abstract

Background

Relatively few longitudinal studies have evaluated the association between sleep and BMI among younger children. In addition, few studies have evaluated the bidirectional longitudinal association between sleep duration and child BMI.

Objective

To determine in children aged 6-36 months: 1) the cross-sectional association of sleep duration and sleep problems with child BMI z-score; 2) whether sleep duration predict changes in child BMI z-score, 3) and whether BMI z-score can predict changes in child sleep duration.

Methods

This study used longitudinal data from the BeeBOFT study (n=2308). Child sleep duration, and sleep problems (indicated by night awakenings and sleep onset latency) were parent reported and child BMI was measured using a standardized protocol by trained health care professionals at approximately 6, 14, and 36 months of age. Linear mixed models and linear regression models were applied to assess the cross-sectional, and bidirectional longitudinal associations between sleep and BMI z-scores.

Results

Cross-sectionally, shorter sleep duration was associated with higher BMI z-scores at 14 months ($\beta=-0.034$, $p<0.05$) and 36 months ($\beta=-0.045$, $p<0.05$). Sleep duration at 6 or 14 months did not predict BMI z-score at either 14 or 36 months. Higher BMI z-scores at 6 months predicted shorter sleep duration (hours) at 14 months ($\beta=-0.129$, $p<0.001$). No association was found between sleep problems and child BMI z-scores.

Conclusion

Cross-sectional associations between shorter sleep duration and higher BMI z-score emerged in early childhood (age 14 and 36 months). Higher BMI z-scores may precede shorter sleep duration but not vice versa.

Introduction

There is increasing evidence that shorter sleep duration is associated with increased risk of overweight among children [1-5]. However, the available evidence is largely from school-aged children and adolescents. Only a few studies have investigated the relationship between sleep duration and BMI standardized for age and sex (BMI z-score) during infancy and early childhood (0-4 years), the findings are mixed [6-11]. For instance, in a longitudinal study of 915 children from the US, Taveras et al found that sleep duration <12 hours during infancy (6-24 months) was associated with higher BMI z-score at 3 years [6]. In contrast, in prospective cohort study of 3857 children from Australia, Hiscock et al reported no associations between sleep duration at 0-1 years and BMI z-score measured at 2-3 years [7]. In a cohort of 311 children from Denmark, Klingenberg et al found no longitudinal association between sleep duration at 9 months and 18 months (parent reported as well as objectively measured) and BMI z-score at 3 years[8]. Furthermore, recent studies have found indications that beyond sleep duration, sleep problems (e.g. excessive night awakenings, sleep onset difficulties) might contribute to increased risk of overweight in children [12-14]. Few studies have evaluated the association between both sleep duration and sleep problems with BMI z-score in infancy and early childhood. Given that infancy and early childhood is a critical period for the development of overweight [15], further research is warranted to confirm whether sleep duration and sleep problems constitute modifiable risk factors for weight gain in infancy and early childhood.

In addition, a few recent studies have pointed out a potential bi-directional association between shorter sleep duration and higher BMI z-score in young children [10, 11]. Therefore, overweight might precede shorter sleep duration and vice versa. Inadequate sleep is associated with poorer cognitive, physical, and socioemotional development [16]. As there has been an increasing trend of insufficient sleep duration and sleep problems among children [17], and short sleep duration and sleep problems in infancy and early childhood may persist to later ages [18], research is needed to investigate whether overweight contributes to shorter sleep duration and sleep problems in infancy and early childhood.

The present study, with the availability of repeated measured data on sleep duration, sleep problems, and BMI z-score across age 6 to 36 months in a large population based sample of children from the Netherlands, will add further evidence to elucidate the relationship between sleep and BMI z-score in younger children. We examined the cross-sectional associations of sleep duration and sleep problems (i.e. frequent night awakenings and longer sleep onset latency) with BMI z-score during infancy and early childhood. In addition, we examined whether bidirectional longitudinal association existed between sleep duration and BMI z-score, i.e., whether shorter sleep duration predicts higher BMI z-score at a later age or higher BMI z-score predicts shorter sleep duration at a later age. We hypothesized that both sleep duration and sleep problems are cross-sectionally associated with BMI z-score, and that bidirectional longitudinal association exist between sleep duration and BMI z-score during infancy and early childhood (age 6-36 months).

Methods

Study design and population

This study is a secondary data analysis using data from the 'BeeBOFT' study, which is a population-based cluster randomized controlled trial for the primary prevention of overweight among infants and toddlers (0-3 years) conducted in the Netherlands [19, 20]. The study participants were randomly allocated to one of the two intervention conditions, i.e. the 'BBOFT+' intervention and the 'E-health4Uth' intervention, or the control condition. Both interventions were targeted on parents and aimed at promoting health behaviors of children (i.e. breast feeding, daily exercise/outdoor playing, daily breakfast, fewer sweet drinks and less TV viewing). The 'BBOFT+' intervention also aimed to improve children's sleep behaviors in addition to the above health behaviors. In the 'BBOFT+' intervention group, parents received advice on child rearing skills to promote children's health behaviors at each Youth Health Care routine visit (scheduled at child age 0.5, 1, 2, 3, 4, 6, 9, 11, 14, 18, 24 and 36 months). In the 'E-health4Uth' intervention group, parents received tailored advice on children's health behaviors after they finished an online survey at child age 18 and 24 months, respectively. In the control condition, children received preventive youth health care as usual. The Medical Ethics Committee of the Erasmus Medical Centre has reviewed the research proposal of the BeeBOFT study and concluded that the Dutch Medical Research Involving Human Subjects Act (in Dutch: Wet medisch-wetenschappelijk onderzoek met mensen) did not apply to this research proposal. The Medical Ethics Committee therefore had no objection to the execution of this study (proposal number MEC-2008-250).

From January 2009 through September 2010, parents were informed about the BeeBOFT intervention study when the Youth Health Care nurse visited them in the second week after child birth. Parents were also invited to fill in a written informed consent form to participate in the 3-year study, and a baseline questionnaire regarding social demographic characteristics and perinatal factors. In total, parents of 3003 children returned the written informed consent to participation and the baseline questionnaire. At child age 6, 14 and 36 months, the parents were invited to complete questionnaires on children's health behaviors and determinants of these behaviors. Children' weight and height were measured at each Youth Health Care routine visit scheduled at child age 0.5, 1, 2, 3, 4, 6, 9, 11, 14, 18, 24 and 36 months repeatedly. Children with missing information on BMI or sleep duration at all three time points (i.e. age 6, 14 and 36 months) were excluded (n=695). Finally, 2308 subjects were included in the study.

Measurements

Sleep related variables

Children's sleep characteristics were assessed by parental questionnaire at child age circa 6, 14, and 36 months. The exact ages of the children at the three measurement waves were 6.34 (Standard Deviation (SD) =0.61), 14.25 (SD=1.06), and 37.44 (SD=1.54) respectively. At all three time-points, the respondents were asked to report children's average sleep duration, number of night awakenings and sleep onset latency during the past 4 weeks. For sleep duration, parents were asked to report the average number of hours their child slept between 6:00 p.m. and 8:00 a.m. and between 8:00 a.m. and 6:00 p.m. These data were added to get total average sleep duration in a 24-hours period. For number of night awakenings, parents were asked to report how often their child woke up during the night on average (answering categories are 0, 1, 2, 3, 4, and 5 times or more times per night). For sleep onset latency, parents reported on how long it took the child to fall asleep on average (answering categories are <10 min, 10-30 min, 30min-1 hour, 1-2 hours, and more than 2 hours). Sleep onset latency in the questionnaire refer to both night-time and day-time sleep. We defined sleep problems as the presence of night awakenings ≥3 time per night or sleep onset latency >30 min in our main analysis [21-23].

Child anthropometrics

Data on weight and height of the participating children were acquired from the Youth Health Care registration files. Children's height and weight were measured in accordance with standardized protocols at each Youth Health Care routine visit (set at child age 0.5, 1, 2, 3, 4, 6, 9, 11, 14, 18, 24, and 36 months) by trained Youth Health Care professionals [24]. Children's height and weight were measured without clothes (at 36 months only underwear), using calibrated weight scales and length meters; height was measured to the nearest 0.1 cm, and weight was measured to the nearest 0.01 kg (infants) and 0.1 kg (toddlers). Children's BMI were calculated by the weight in kilograms divided by squared body length in meters. Age and gender adjusted BMI z-scores were calculated using the World Health Organization Growth Standard (2006) [25]. For analysis of the present study, we only used children's BMI z-scores measured at age circa 6, 14 and 36 months. As children's BMI z-scores were not always measured at the exact time points, we interpolated children's BMI z-scores at 6, 14, and 36 months by the nearest BMI z-score measured within the age range of respectively 4-8 months, 12-16 months, and 33-45 months. The average exact ages of the children at BMI measurement were 6.13 (SD=0.48), 14.23 (SD=0.50), and 36.44(SD=0.83) months respectively for the 3 measurement waves.

Covariates

Potential confounding factors were chosen based on biological plausibility and previous evidence linking them with BMI [26, 27] and sleep duration [28, 29] in early childhood, including maternal age, maternal educational level, maternal pre-pregnancy BMI, parity, and child gender, child ethnic background, child birth weight, gestational age, duration of breastfeeding, child screen time and intervention groups. The following characteristics were assessed by the baseline questionnaire: maternal age, maternal educational level, and maternal pre-pregnancy BMI, parity; and child gender, child ethnic background, and child gestational age. The highest attained educational level of mother was categorized as high (higher vocational training, university degree or higher), middle (>4 years general secondary school or intermediate vocational training), and low (no education, primary school, or 4 years or less general secondary school) [30]. Mothers reported their pre-pregnancy body weight and height in the baseline questionnaire which were used to calculate maternal pre-pregnancy BMI. The child's ethnic background was defined as Dutch if both of his/her parents were classified as Dutch; a parent was classified as Dutch if both of his/her own parents were born in the Netherlands [24]. Child birthweight (in grams) and date of birth was acquired from Youth

Health Care registration files. The expected due date was reported in the baseline questionnaire, using which we calculated the date of conception (based on 280 days of pregnancy). Gestational age in days was then calculated using the calculated date of conception and date of birth of the child. The duration of breastfeeding was assessed in the questionnaire at 6 months (detailed information shown in Table S1). In addition, the 'intervention group' was considered as a potential confounding factor, as both the two intervention groups received interventions on children's lifestyle behaviors, and the 'Beeboft' group received additional interventions on children's sleep [19]. Finally, at all three time points, parents reported the average number of hours their child spent on watching TV/video/DVD (and computer use at 36 month) per day (detailed information shown in Table S1).

Statistical analyses

Cross-sectional analyses

We applied linear regression models to assess the cross-sectional associations of sleep duration and sleep problems with BMI z-score at 6, 14 and 36 months respectively. The models were adjusted for the exact age at sleep measurement, the exact age at BMI measurement, and maternal age, maternal educational level, maternal pre-pregnancy BMI, parity, and child gender, child ethnic background, child birth weight, gestational age, duration of breastfeeding, child screen time and intervention groups.

Linear mixed models were fitted to assess the overall cross-sectional association of sleep duration and sleep problems with BMI z-score across the age of 6, 14 and 36 months, using the repeated measured sleep variables and BMI z-score at all three measurement waves. Using a linear mixed model, we were able to take into account the interdependency between observations of the same child. The models were adjusted for age at measurement (6, 14, or 36 months), maternal age, maternal educational level, maternal pre-pregnancy BMI, parity, and child gender, child ethnic background, child birth weight, gestational age, duration of breastfeeding, child screen time and intervention groups. The interaction terms of age at measurement with sleep variables (duration, problems) were then added to the models to determine whether the association between sleep duration/sleep problems and BMI z-score differed by age. In addition, to determine whether the associations of sleep duration and sleep problems with BMI z-score differed by child gender [12], ethnic background [11], intervention groups, and maternal educational level, the interaction terms of these variables with sleep duration or sleep problems were added to the linear mixed models. The interaction term was considered as significant at $p< 0.10$ [31]. The results (additional files Table S2) suggested that only the interaction term of sleep duration with ethnic background was significant ($p<0.001$). Stratified analysis was further performed for the association between sleep duration and BMI according to ethnic background (Results for stratified analyses are shown in additional file Table S3).

Longitudinal analyses

Linear regression models were applied to determine whether a bidirectional longitudinal association exists between sleep duration and BMI z-score. We used sleep duration at earlier age points to predict BMI z-score at later age points (i.e., 6 m sleep → 14 m BMI z-score, 6 m sleep → 36 m BMI z-score, 14 m sleep → 36 m BMI z-score); and then BMI z-score at earlier age points to predict sleep duration at later age points (i.e., 6 m BMI z-score → 14 m sleep, 6 m BMI z-score → 36 m sleep, 14 m BMI z-score → 36 m sleep). The models were progressively adjusted for the potential confounding factors including the exact ages at sleep measurement and at BMI measurement, maternal age, maternal educational level, maternal pre-pregnancy BMI, parity, and child gender, child ethnic background, child birth weight, gestational age, duration of breastfeeding, child screen time at baseline and intervention groups (model 1), and BMI z-score or sleep duration at baseline (model 2). Finally, the interaction terms of child ethnic background and sleep duration/BMI z-score were added to the above models to determine whether the potential differences in the longitudinal associations between sleep and BMI differs by child ethnic background.

Sensitivity analysis

For sleep problems, we repeated our cross-sectional analyses using different cut-offs of night awakenings (2 night awakenings vs < 2 awakenings) and sleep onset latency (>1 hour vs <1 hour) in the linear regression models. The results are presented in Table S4.

Results

Study population

Table 1 provides a summary of the characteristics of the study population. As age increased, children's sleep duration (p<0.001) and number of night awakenings per night (p<0.001) decreased, while the percentages of children with sleep onset latency >30 minutes increased (p<0.001).

Cross-sectional association

The results of the linear regression models for the cross-sectional association of sleep duration and sleep problems with BMI z-score at child age circa 6, 14, and 36 months respectively (Table 2) showed that sleep duration was inversely associated with BMI z-score at 14 months (β=-0.034, p=0.03) and 36 months (β=-0.045, p=0.03), after adjusting for potential confounding factors. No significant association was found between sleep problems and BMI z-score at any ages.

The results of the linear mixed models (Table 3) showed that sleep duration was negatively associated with BMI z-score across 6 to 36 months (overall effect, β=-0.023, p=0.01), after adjusting for potential confounding factors. The interaction term of sleep duration and age (6, 14, or 36 months) suggested that the cross-sectional association of sleep duration with BMI z-score differed by age, with the strength of association between sleep duration and BMI z-score at age 6 months lower compared to age 36 months (p<0.10).

Interaction analyses (shown in additional file Table S2) suggested that the association between sleep duration and BMI z-score differs by child ethnic background (p<0.001). Stratified analysis (shown in additional file Table S3) showed that the cross-sectional association between sleep duration and BMI z-score was stronger among children with a Dutch ethnic background (overall effect, β=-0.033, p=0.001). There was no significant association between sleep duration and BMI z-score in children with non-Dutch ethnic background (overall effect, β=0.021, p=0.34).

Longitudinal association

Table 4 shows the results of the linear regression models examining the bidirectional longitudinal association between sleep duration and BMI z-score. The results revealed that sleep duration at 6 or 14 months did not significantly predict changes BMI z-score at 14 or 36 months. Higher BMI z-score at 6 months was significantly associated with shorter sleep duration at 14 months (β=-0.132, p<0.001), after adjusting for potential confounding factors, and baseline sleep duration. Interaction analyses showed no significant ethnic differences in all these above longitudinal associations (all $p>0.20$).

Sensitivity analysis

Sensitivity analysis (shown in additional file Table S4) suggested that sleep problems were not cross-sectionally associated with BMI z-score when applying different cut-off values for frequency of night awakenings and sleep latency for defining sleep problems.

Discussion

Overall, our study findings demonstrate that a negative cross-sectional association between sleep duration and BMI z-score already occurred during early childhood (i.e. age 14 and 36 months). Prospectively, shorter sleep duration at the age of 6 or 14 months did not predict BMI z-score at later ages (i.e. at 14 and 36 months). A higher BMI z-score at the age of 6 months did predict shorter sleep duration at the age of 14 months after adjusting for baseline sleep. We did not find significant cross-sectional or longitudinal associations between sleep problems and child BMI z-score.

Our results suggest that there were modest cross-sectional associations between shorter sleep duration and higher BMI z-score at child age 14 and 36 months, but not at 6 months. The magnitude of the associations was modest (e.g., the BMI z-score was 0.045 higher per 1 hour longer sleep duration at the age of 36 months), and is comparable to a few previous studies [10, 32]. Although the effect size we found might not be clinically significant, any potential influences on adiposity levels in early life may be important given that adiposity levels may persist into later life. It has been proposed that the association between short sleep duration and increased BMI could be mediated or confounded by increased energy intake [33, 34], and increased television viewing [35], and decreased physical activities in children [35]. However, in the present study, the cross-sectional association between sleep duration and BMI z-score was not attenuated after adjusting for TV viewing hours. A previous study which assessed the cross-sectional association between sleep duration and BMI z-score also suggest that the association was not attenuated after adjusting for TV viewing, and dietary factors [11].

Our interaction analysis and stratified analysis suggested that the cross-sectional association between sleep duration and BMI z-score only existed among children with a Dutch ethnic background. This result is in contrast with a previous study conducted in the UK in which a significant association was found in a South Asian population and not in Caucasian children [11]. It is possible that the lack of association in the non-Dutch group is due to the mixed ethnic background of this group. Sleep duration may cluster differently with obesogenic factors among children with different ethnic backgrounds.

We did not find a longitudinal association between sleep at 6 or 14 months and BMI z-score at the age of 14 or 36 months. Therefore, our results do not support a causal relationship between shorter sleep duration and weight gain in infancy and early childhood. The observed cross-sectional association between sleep duration and child BMI in the present study could be a result of residual confounding factors. For example, lack of parental vigilance or sensitivity, which were not measured in our study, might be associated with both inadequate sleep and increased BMI of children [36-38]. Two other previous studies also did not find longitudinal associations between sleep duration and BMI among children aged 3 years and younger: Klingenberg et al found no association between sleep duration at 9 and 18 months and BMI at 3 years among 313 Danish children [8]; Hiscock et al found no association between sleep duration at 0-1 years and BMI at 2-3 years among 3857 Australian children [7]. However, in contrast, Taveras et al found that sleep duration of less than 12 hours/day in the first 2 year of life was associated with higher adiposity level at age 3 years among 915 US children [6]. Compared to the study of Taveras et al [6], children in our study population and in the study of Klingenberg et al and Hiscock et al have a relatively long average sleep durations per day (i.e. 14.9 (SD=1.6) hours/day at age 6 months in the present study, 13.8 (SD=1.0) hours/day at age 9 months in the study of Klingenberg el al, and 13.4 (SD=1.9) hours/day between 0-1 years in the study of Hiscock et al, compared to 12.3 (SD=1.9) hours/day at age 6 months in the study of Taveras et al). Therefore, the lack of a longitudinal association between sleep duration and child BMI could be due to a longer total sleep duration of children in our population. Sleep duration might have minimal effect on child's weight development when the child gets longer sleep. Another possible explanation for the lack of a longitudinal association is a low intraindividual stability of sleep duration in early childhood [39], which may have reduced the predictive value of sleep duration. Variability in sleep duration might be induced by, for instance developmental spurts, illnesses or seasonal effects and changes in parental rearing attitudes [39].

We found some evidence that higher BMI z-score may precede shorter sleep duration: that higher BMI z-score at age 6 months significantly predicted shorter sleep duration at age

14 months, after adjusting for baseline sleep duration and BMI z-score at 14 months. Our finding is in line with the study of Ivonne et al [10], in which a higher BMI z-score at the ages of 2 and 24 months predicted shorter sleep duration at the ages of 6 and 36 months, respectively. In the present study, there was no significant association between BMI z-score at 6 months or 14 months with sleep duration at 36 months. It is possible that BMI z-score only has a short-term effect on sleep duration. The mechanism for the observed longitudinal association between higher BMI z-score and shorter sleep duration is not clear. It is possible that children with higher BMI z-score were less active [40], and therefore need less sleep [41]. It has also been proposed that the association between higher BMI and curtailed sleep may be mediated by poorer general health and physiological disorders such as sleep apnea [11, 42, 43]. However, the observed longitudinal association could be a result of social or lifestyle factors that were not included as potential confounders. The models were adjusted for TV viewing time, but the residual confounding may be present with regard to other factors reflecting unhealthy lifestyles and behaviors (e.g. unhealthy dietary intake or lack of healthy sleeping habits or early bedtime). Due to the limited number of studies, further research is warranted to confirm and to understand the mechanism for the longitudinal association between BMI and sleep duration.

Sleep problems, which were assessed by night awakenings and sleep onset latency, have no significant association with child BMI z-score. Arsham et.al.[14] suggested that infant sleep problems have differential effect on childhood overweight at around 11 years per different definitions of sleep problems. However, due to different aspects of sleep behavior assessed in the present study, comparison with the previous study [14] is difficult. In the present study, we did not collect information on duration of the waking episodes. It is possible that night awakening contributes to overweight only when the waking episode is too long. Another possible reason for the null association between sleep problems and child BMI z-score is the younger age group of our population. Two previous studies which investigated the association between frequent night awakenings with BMI z-score in infants also found no association [12, 23].

Strengths of this study included the relatively large sample size, repeated assessments of sleep indicators and anthropometrics at 6, 14 and 36 months, and the careful assessment of potential confounding factors. Our data allowed us to assess the longitudinal association between sleep duration as well as sleep problems with child BMI z-score. In addition, the reverse causality between BMI z-score and sleep was assessed by using BMI z-score to predict later sleep duration.

A first limitation of our study is that children's sleep indicators, including sleep duration, number of night awakenings, and sleep onset latency were assessed by parent reported questionnaire. It has been suggested parents tend to overestimate children's sleep duration[44, 45], while underestimate children's night awakenings and sleep onset latency [44]. However, despite the potential bias, previous research also suggested that parent-reported sleep data are well correlated with objectively measured sleep data for preschool aged children, suggesting that parent-reported data are still useful [44]. In addition, parents may even provide a better representation of habitual sleep behavior than a brief period of objective recording [46]. Secondly, due to the limitation of observational studies, a causal relationship cannot be inferred. Although we have assessed the potential confounding factors extensively, un-observed confounding factors may exist, such as non-responsive parenting which may contribute to both higher BMI z-score and shorter sleep duration [36-38]. Thirdly, we used data from a cluster randomized controlled trial with two interventions aimed at promoting healthy lifestyle behaviors of young children. However, we have adjusted intervention group as a covariate in all the analyses. In addition, the interaction analysis suggested that the association between sleep duration and BMI z-score did not differ by intervention group (additional file Table S2). Finally, our population is relatively highly educated, containing predominantly Caucasian population. Therefore, generalization of our findings should be made carefully.

In conclusion, shorter sleep duration is associated with higher BMI z-score at the age of 14 and 36 months. We found no evidence that shorter sleep duration predicts changes in BMI z-score, and some evidence that a higher BMI z-score may predict a shorter sleep duration.

References

1. Felső, R., et al., *Relationship between sleep duration and childhood obesity: Systematic review including the potential underlying mechanisms.* Nutrition, Metabolism and Cardiovascular Diseases, 2017. **27**(9): p. 751-761.
2. Ruan, H., et al., *Habitual Sleep Duration and Risk of Childhood Obesity: Systematic Review and Dose-response Meta-analysis of Prospective Cohort Studies.* Sci Rep, 2015. **5**: p. 16160.
3. Fatima, Y., S.A. Doi, and A.A. Mamun, *Longitudinal impact of sleep on overweight and obesity in children and adolescents: a systematic review and bias-adjusted meta-analysis.* Obes Rev, 2015. **16**(2): p. 137-49.
4. Liu, J., A. Zhang, and L. Li, *Sleep duration and overweight/obesity in children: review and implications for pediatric nursing.* J Spec Pediatr Nurs, 2012. **17**(3): p. 193-204.

5. Miller, M.A., et al., *Sleep duration and incidence of obesity in infants, children, and adolescents: a systematic review and meta-analysis of prospective studies.* Sleep, 2018. **41**(4): p. zsy018.
6. Taveras, E.M., et al., *Short sleep duration in infancy and risk of childhood overweight.* Arch Pediatr Adolesc Med, 2008. **162**(4): p. 305-11.
7. Hiscock, H., et al., *Sleep duration and body mass index in 0-7-year olds.* Arch Dis Child, 2011. **96**(8): p. 735-9.
8. Klingenberg, L., et al., *No relation between sleep duration and adiposity indicators in 9-36 months old children: the SKOT cohort.* Pediatr Obes, 2013. **8**(1): p. e14-8.
9. Bolijn, R., et al., *Daytime sleep duration and the development of childhood overweight: the KOALA B irth C ohort S tudy.* Pediatric obesity, 2016. **11**(5): p. e1-e5 %@ 2047-6302.
10. Derks, I.P.M., et al., *Longitudinal Associations of Sleep Duration in Infancy and Early Childhood with Body Composition and Cardiometabolic Health at the Age of 6 Years: The Generation R Study.* Child Obes, 2017. **13**(5): p. 400-408.
11. Collings, P.J., et al., *Sleep Duration and Adiposity in Early Childhood: Evidence for Bidirectional Associations from the Born in Bradford Study.* Sleep, 2017. **40**(2).
12. Tikotzky, L., et al., *Sleep and physical growth in infants during the first 6 months.* J Sleep Res, 2010. **19**(1 Pt 1): p. 103-10.
13. Jarrin, D.C., J.J. McGrath, and C.L. Drake, *Beyond sleep duration: distinct sleep dimensions are associated with obesity in children and adolescents.* Int J Obes (Lond), 2013. **37**(4): p. 552-8.
14. Alamian, A., et al., *Infant sleep problems and childhood overweight: Effects of three definitions of sleep problems.* Prev Med Rep, 2016. **4**: p. 463-8.
15. Lucas, K., et al., *The positive association of infant weight gain with adulthood body mass index has strengthened over time in the Fels Longitudinal Study.* Pediatr Obes, 2018.
16. Chaput, J.P., et al., *Systematic review of the relationships between sleep duration and health indicators in the early years (0-4 years).* BMC Public Health, 2017. **17**(Suppl 5): p. 855.
17. Matricciani, L.A., et al., *Never enough sleep: a brief history of sleep recommendations for children.* Pediatrics, 2012. **129**(3): p. 548-56.
18. Hysing, M., et al., *Trajectories and predictors of nocturnal awakenings and sleep duration in infants.* J Dev Behav Pediatr, 2014. **35**(5): p. 309-16.
19. Raat, H., et al., *Primary prevention of overweight in preschool children, the BeeBOFT study (breastfeeding, breakfast daily, outside playing, few sweet drinks, less TV viewing): design of a cluster randomized controlled trial.* BMC Public Health, 2013. **13**: p. 974.
20. van Grieken, A., et al., *Personalized Web-Based Advice in Combination With Well-Child Visits to Prevent Overweight in Young Children: Cluster Randomized Controlled Trial.* J Med Internet Res, 2017. **19**(7): p. e268.
21. Sadeh, A. and T.F. Anders, *Infant Sleep Problems - Origins, Assessment, Interventions.* Infant Mental Health Journal, 1993. **14**(1): p. 17-34.
22. Zuckerman, B., J. Stevenson, and V. Bailey, *Sleep problems in early childhood: continuities, predictive factors, and behavioral correlates.* Pediatrics, 1987. **80**(5): p. 664-71.
23. Sha, T., et al., *Association between Sleep and Body Weight: A Panel Data Model Based on a Retrospective Longitudinal Cohort of Chinese Infants.* Int J Environ Res Public Health, 2017. **14**(5).
24. A., B.-B. *Signaleringsprotocol overgewicht in de jeugdsgezondheidszorg Youth health care overweight-detection-protocol*. 2005; Available from: http://www.twenteinbalans.nl/images/stories/070917_sigaleringsprotocol_overgewicht_JGZ.pdf.
25. World Health, O., *WHO child growth standards: length/height for age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age, methods and development*. 2006: World Health Organization.

26. Kupers, L.K., et al., *Determinants of Weight Gain during the First Two Years of Life--The GECKO Drenthe Birth Cohort.* PLoS One, 2015. **10**(7): p. e0133326.
27. Woo Baidal, J.A., et al., *Risk Factors for Childhood Obesity in the First 1,000 Days: A Systematic Review.* Am J Prev Med, 2016. **50**(6): p. 761-79.
28. Nevarez, M.D., et al., *Associations of early life risk factors with infant sleep duration.* Acad Pediatr, 2010. **10**(3): p. 187-93.
29. McDonald, L., et al., *Predictors of shorter sleep in early childhood.* Sleep medicine, 2014. **15**(5): p. 536-540.
30. Netherlands, S., *Dutch standard classification of education 2003.* Voorburg/Heerlen, Netherlands: Statistics Netherlands, 2004.
31. Sun, X., et al., *Is a subgroup effect believable? Updating criteria to evaluate the credibility of subgroup analyses.* Bmj, 2010. **340**: p. c117.
32. Zhou, Y., et al., *Sleep duration and growth outcomes across the first two years of life in the GUSTO study.* Sleep Med, 2015. **16**(10): p. 1281-6.
33. Nedeltcheva, A.V., et al., *Sleep curtailment is accompanied by increased intake of calories from snacks.* Am J Clin Nutr, 2009. **89**(1): p. 126-33.
34. Kjeldsen, J.S., et al., *Short sleep duration and large variability in sleep duration are independently associated with dietary risk factors for obesity in Danish school children.* Int J Obes (Lond), 2014. **38**(1): p. 32-9.
35. Hart, C.N., et al., *Effect of experimental change in children's sleep duration on television viewing and physical activity.* Pediatr Obes, 2017. **12**(6): p. 462-467.
36. Glaser, N. and D. Styne, *Weighing the Causal Evidence That Associates Short Sleep Duration With Obesity.* Pediatrics, 2017. **140**(3): p. e20172015.
37. Brand, S., et al., *Perceived parenting styles, personality traits and sleep patterns in adolescents.* Journal of adolescence, 2009. **32**(5): p. 1189-1207.
38. Kakinami, L., et al., *Parenting style and obesity risk in children.* Preventive Medicine, 2015. **75**: p. 18-22.
39. Jenni, O.G., et al., *Sleep duration from ages 1 to 10 years: variability and stability in comparison with growth.* Pediatrics, 2007. **120**(4): p. e769-76.
40. Trost, S.G., et al., *Physical activity in overweight and nonoverweight preschool children.* Int J Obes Relat Metab Disord, 2003. **27**(7): p. 834-9.
41. Wu, Y., et al., *Effect of leisure-time aerobic exercise and muscle strength activity on sleep duration: results from the 2012 National Health Interview Survey.* Journal of Public Health, 2016. **24**(2): p. 117-124.
42. Katz, E.S., R.B. Mitchell, and C.M. D'ambrosio, *Obstructive sleep apnea in infants.* American journal of respiratory and critical care medicine, 2012. **185**(8): p. 805-816.
43. Lumeng, J.C. and R.D. Chervin, *Epidemiology of pediatric obstructive sleep apnea.* Proceedings of the American Thoracic Society, 2008. **5**(2): p. 242-252.
44. Iwasaki, M., et al., *Utility of subjective sleep assessment tools for healthy preschool children: a comparative study between sleep logs, questionnaires, and actigraphy.* J Epidemiol, 2010. **20**(2): p. 143-9.
45. Dayyat, E.A., et al., *Sleep estimates in children: parental versus actigraphic assessments.* Nat Sci Sleep, 2011. **3**: p. 115-23.
46. Sadeh, A., *A brief screening questionnaire for infant sleep problems: validation and findings for an Internet sample.* Pediatrics, 2004. **113**(6): p. e570-e577.

Table 1. Characteristics of the study sample (n=2308).

	N	N (%) or Mean ± SD
Child gender, boys, n(%)	2308	1185 (51.3)
Child ethnic background, Dutch, n(%)	2308	1933 (83.8)
Child birth weight, Kilograms	2308	3.47 ± 0.53
Child gestational age, weeks	2283	39.66 ± 1.36
Maternal age, years	2284	31.04 ± 4.22
Maternal pre-pregnancy BMI, kg/m^2	2295	24.19 ± 4.10
Maternal education level, n(%)	2290	
Low		274 (12.0)
Middle		802 (35.0)
High		1214 (53.0)
Parity, primipara, n(%)	2308	1065 (46.1)
Duration of breastfeeding, n(%)	2308	
No breastfeeding		617 (26.7)
Breastfeeding <2 months		400 (17.3)
Breastfeeding 2-4 months		290 (12.6)
Breastfeeding >4 months		867 (37.8)
Missing		134 (5.8)
Sleep duration, h/day		
At age 6 months	1870	14.89 ± 1.59
At age 14 months	1781	14.15 ± 1.36
At age 36 months	1270	11.97 ± 1.24
Number of Night awakenings, times/day		
At age 6 months	1870	1.04 ± 0.99
At age 14 months	1781	0.85 ± 0.91
At age 36 months	1270	0.69 ± 0.81
Sleep onset latency > 30 min, n(%)		
At age 6 months	1870	50 (2.6)
At age 14 months	1781	64 (3.6)
At age 36 months	1270	117 (9.9)

Table 2. Results from linear regression models for the cross-sectional association between sleep (independent variable) and child BMI z-score (dependent variable) at age 6, 14 and 36 months respectively.

Predictors	6 months (n=1816) β (SE)	*p-value*	14 months (n=1741) β (SE)	*p-value*	36 months (n=1240) β (SE)	*p-value*
Total sleep duration (continuous)						
Model 1	-0.004 (0.014)	0.79	**-0.035 (0.015)**	**0.02**	**-0.047 (0.021)**	**0.03**
Model 2	-0.003 (0.014)	0.83	**-0.034 (0.015)**	**0.03**	**-0.045 (0.021)**	**0.03**
Sleep problems (Yes vs No)[1]						
Model 1	0.104 (0.064)	0.11	-0.025 (0.050)	0.62	0.006 (0.065)	0.93
Model 2	0.099 (0.064)	0.12	-0.030 (0.050)	0.55	0.008 (0.065)	0.90
Separate items of sleep problems						
Night awakenings (≥3 vs <3 times)						
Model 1	0.079 (0.068)	0.25	-0.042 (0.078)	0.59	-0.022 (0.133)	0.87
Model 2	0.075 (0.068)	0.27	-0.048 (0.079)	0.54	0.001 (0.134)	0.99
Sleep onset latency (>30 min vs <30min)						
Model 1	0.271 (0.138)	0.05	-0.072 (0.112)	0.52	0.062 (0.092)	0.50
Model 2	0.268 (0.138)	0.06	-0.085 (0.112)	0.45	0.058 (0.093)	0.53

Note: Numbers in **bold** are significant at $p<0.05$.
All the models were adjusted for exact age of the child at sleep measurement, exact age of the child at BMI measurement, maternal age, maternal educational level, maternal pre-pregnancy BMI, parity, and child gender, child ethnic background, child birth weight, gestational age, duration of breastfeeding, and intervention groups; Model 2 further adjusted for child screen time.
[1] Sleep problem is defined as the presence of night waking≥3 per night or sleep latency>30min.

Table 3. Results from linear mixed models for the overall cross-sectional associations between sleep (independent variable) and child BMI z-score (dependent variable) across the age of 6 to 36 months (n=2257).

Predictor	β	SE	*p-value*
Sleep duration (hours/day)			
Model 1			
Overall effect 6-36 months	**-0.023**	**0.009**	**0.01**
Model 2			
Effect on 36 months	**-0.046**	**0.021**	**0.02**
Interaction term with age			
6 vs 36 months	0.043	0.024	0.08
14 vs 36 months	0.010	0.026	0.71
Sleep problems (Yes vs No)[1]			
Model 1			
Overall effect 6-36 months	0.015	0.033	0.66
Model 2			
Effect on 36m	-0.018	0.061	0.77
Interaction term with age			
6 vs 36 months	0.114	0.086	0.19
14 vs 36 months	0.009	0.079	0.91
Separate items of sleep problems			
Night awakenings (≥3 vs <3 times)			
Model 1			
Overall effect 6-36 months	0.019	0.047	0.69
Model 2			
Effect 36 months	-0.093	0.122	0.44
Interaction term with age			
6 vs 36 months	0.173	0.139	0.21
14 vs 36 months	0.090	0.146	0.63
Sleep onset latency (>30 vs <30min)			
Model 1			
Overall effect 6-36 months	0.073	0.061	0.24
Model 2			
Effect 36 months	0.060	0.087	0.49
Interaction term with age			
6 vs 36 months	0.227	0.157	0.15
14 vs 36 months	-0.101	0.142	0.48

Note: Numbers printed in **bold** represent significance at $p<0.05$.
Model 1 adjusted for age at measurement (6/14/36 months), maternal age, maternal educational level, maternal pre-pregnancy BMI, parity, and child gender, child ethnic background, child birth weight, gestational age, duration of breastfeeding, child screen time and intervention groups. Model 2 further included the interaction term of age (36 months as reference) and sleep indicators on the basis of model 1.
[1] Sleep problems is defined as the presence of night awakenings ≥3 per night or sleep onset latency>30min.

Table 4. Results from linear regression models for the bidirectional longitudinal association between sleep duration and BMI z-scores.

	Outcome: BMI z-score 14 months			Outcome: BMI z-score 36 months		
Predictor	β	SE	*p-value*	β	SE	*p-value*
Sleep duration 6 months (hours/day)	N=1704			N=1197		
Model 1	-0.007	0.013	0.59	0.001	0.017	0.96
Model 2	-0.005	0.010	0.63	0.000	0.015	1.00
Sleep duration 14 months				N=1169		
Model 1				-0.019	0.020	0.34
Model 2				-0.002	0.015	0.92
	Outcome: sleep duration 14months (hours/day)			Outcome: sleep duration 36 months (hours/day)		
Predictor	β	SE	*p-value*	β	SE	*p-value*
BMI z-score 6 months	N=1549			N=1405		
Model 1	**-0.129**	**0.037**	**0.001**	-0.016	0.035	0.65
Model 2	**-0.132**	**0.034**	**<0.001**	-0.007	0.034	0.85
Model 3	**-0.149**	**0.048**	**0.003**			
BMI z-score 14 months				N=1385		
Model 1				-0.045	0.038	0.24
Model 2				-0.026	0.036	0.48

Note: Numbers printed in **bold** represent significance at $p<0.05$.

Model 1 adjusted for exact age of the child at sleep measurement, exact age of the child at BMI measurement, maternal age, maternal educational level, maternal pre-pregnancy BMI, parity, and child gender, child ethnic background, child birth weight, gestational age, duration of breastfeeding, child screen time at baseline and intervention groups; Model 2 further adjusted for baseline BMI z-scores/Sleep duration; Model 3 further adjusted for current sleep duration/BMI when Model 2 was significant

Table S1. The questions for measuring sleep, and several other covariates.

	Response categories and value assignment
Sleep (assessed at 6, 14 and 36 months respectively, parents were asked to keep in mind the last four weeks when answering the questions)	
Nighttime sleep duration: How many hours does your child sleep on average at night (between 18:00 at night and 8:00 in the morning)	'Less than 7'=7, 8, 9, …, '14 or more' =14
Daytime sleep duration: How many hours does your child sleep on average during the day (between 8:00 am. and 18:00 pm)	0, 1, …, 5, '6 or more'=6
Night awakenings: During the past 4 weeks, how often your child was awake on average each night?	0, 1, 2, 3, 4, '5 times or more'=5
Sleep latency: How long does it take on average before your child falls asleep?	(<10 min, 10~30 min, 30min~1 hour, 1~2 hours, more than 2 hours)
Breastfeeding duration (assessed at 6 months)	
Did you started breastfeeding after child birth?	No➔ No breastfeeding Yes➔ recoding according to the following question
How old was your child when you completely stopped breastfeeding?	(within 1 week; in week 2; in week 3; in week 4;1~2 months)➔ 0-2 months 2~3 months; 3~4 months➔ 2-4 months (4~5 months; >5 months; I am still giving breastfeeding) ➔ >4 months
Screen time 6 months (parents were asked to keep in mind the last four weeks when answering the questions)	
Calculation	If T1a=0 then Screen 6m=0, Else, Screen 6m= T2a*T3a
T1a. Does your child ever watch TV?	NO=0, Yes=1
T2a. How many days a week does your child watch TV/video/DVD?	Less than one day =0.5, One day=1; Two day=2,…,Seven days =7, not applicable=0
T3a. How long does your child watch TV/ video/DVD on average per day?	Less than 30 minutes/day =0.25, 30 minutes to 1 hour/day=0.75, 1 to 2 h/d =1.5, 2 to 3 h/d =2.5, 3 to 4 h/d =3.5, 4 to 5 h/d =4.5, 5to 6 h/d =5.5, not applicable=0
Screen time14 months (parents were asked to keep in mind the last four weeks when answering the questions)	
Calculation	If T1b=0 then Screen14=0, Else, Screen14= T2b*T3b

T1b. Does your child ever watch TV/video/DVD?	NO=0, Yes=1
T2b. On how many days a week does your child watch TV/ video/DVD?	Less than one day =0.5, One day=1; Two day=2,…,Seven days =7, not applicable=0
T3b. How long does your child watch TV/ video/DVD on average per day?	Less than 30 min/day =0.25, 30 min to 1 h/day=0.75, 1 to 2 h/d =1.5, 2 to 3 h/d =2.5, 3 h or more/d =3.5, not applicable=0
Screen time 36 months (parents were asked to keep in mind the last four weeks when answering the questions)	
Calculation	If T1c=0 and T6c=0 then Screen36=0; Else, Screen36=sum of (T2c*S3c, T4c*T5c, T7c*T8c, T9c*T10c).
T1c. Does your child watch TV/video/DVD?	NO=0, Yes=1;
T2c. On how many days does your child watch TV/video/DVD during the weekdays?	Less than one day =0.5, One day=1; Two day=2,…,Seven days =7, not applicable=0
T3c. How long per day does your child watch TV/video/DVD on average during the weekdays?	Less than 30 min/day =0.25, 30 min to 1 h/day=0.75, 1 to 2 h/d =1.5, 2 to 3 h/d =2.5, 3 to 4 h/d =3.5, 4 to 5 h/d =4.5, 5 or more h/d =5.5, not applicable=0
T4c. On how many days does your child watch TV/video/DVD during the weekends?	Less than one day =0.5, One day=1; Two day=2,…,Seven days =7, not applicable=0
T5c. How long per day does your child watch TV /video/DVD on average on weekends?	Less than 30 min/day =0.25, 30 min to 1 h/day=0.75, 1 to 2 h/d =1.5, 2 to 3 h/d =2.5, 3 to 4 h/d =3.5, 4 to 5 h/d =4.5, 5 or more h/d =5.5, not applicable=0
T6c. Does your child play computer games?	NO=0, Yes=1
T7c. On how many days does your child spend time on playing computer games during the weekdays?	Less than one day =0.5, One day=1; Two day=2,…,Seven days =7, not applicable=0
T8c. How long per day does your child spend on playing computer games on average during the weekday?	Less than 30 min/day =0.25, 30 min to 1 h/day=0.75, 1 to 2 h/d =1.5, 2 to 3 h/d =2.5, 3 to 4 h/d =3.5, 4 to 5 h/d =4.5, 5 or more h/d =5.5, not applicable=0
T9c. On how many days does your child spend time on playing computer games during the weekends?	Less than one day =0.5, One day=1; Two day=2,…,Seven days =7, not applicable=0
T10c. How long per day does your child play computer games on average during the weekends?	Less than 30 min/day =0.25, 30 min to 1 h/day=0.75, 1 to 2 h/d =1.5, 2 to 3 h/d =2.5, 3 to 4 h/d =3.5, 4 to 5 h/d =4.5, 5 or more h/d =5.5, not applicable=0

Table S2. The P-values for interaction analyses: results from linear mixed models.

Interaction term	*p-value*
Sleep duration	
Sleep duration * child ethnic background	**<0.001**
Sleep duration * child gender	0.26
Sleep duration * intervention group	0.40
Sleep duration * maternal educational level	0.42
Sleep problems[1]	
Sleep problems * child ethnic background	0.53
Sleep problems * child gender	0.26
Sleep problems * intervention group	0.21
Sleep problems * maternal educational level	0.41

Note: Numbers in **bold** are significant at $p<0.05$.

The interaction terms were added to the linear mixed models for sleep duration or sleep problems simultaneously. All the models were adjusted for age at measurement (6/14/ 36 months), maternal age, maternal educational level, maternal pre-pregnancy BMI, parity, and child gender, child ethnic background, child birth weight, gestational age, duration of breastfeeding, child screen time, intervention groups, and the interaction term of sleep duration or sleep problems with age at measurement.

[1] Sleep problem is defined as the presence of night waking≥3 per night or sleep latency>30min

Table S3. Stratified analysis: results from linear mixed model for the cross-sectional association between sleep duration and child BMI z-score between 6 and 36 months in the Dutch and Non-Dutch group respectively.

	Dutch N=1887			Non-Dutch N=370		
	β	SE	*p-value*	β	SE	*p-value*
Sleep duration predicting BMI						
Model 1						
Overall effect 6-36 months	**-0.033**	**0.010**	**0.001**	**0.021**	**0.021**	**0.34**
Model 2						
Effect on 36 months	**-0.060**	**0.022**	**0.008**	**0.006**	**0.051**	**0.91**
Interaction term with age						
6 vs 36 months	0.053	0.027	0.05	0.015	0.058	0.79
14 vs 36 months	0.008	0.028	0.77	0.023	0.064	0.72

Note: Numbers in **bold** are significant at $p<0.05$.

Model 1 adjusted for age at measurement (6/14/36 months), maternal age, maternal educational level, maternal pre-pregnancy BMI, parity, and child gender, child ethnic background, child birth weight, gestational age, duration of breastfeeding, child screen time and intervention groups. Model 2 further included the interaction term of age (36 months as reference) and sleep indicators on the basis of model 1.

Table S4. The cross-sectional associations between sleep indicators and child BMI z-score at around 6, 14 and 36 months respectively: sensitivity analysis.

Predictors	**6 months[1] (n=1816)** β (SE)	*p-value*	**14 months[1] (n=1741)** β (SE)	*p-value*	**36 months[1] (n=1240)** β (SE)	*p-value*
Number of night awakenings (continuous)						
Model 1	0.035(0.019)	0.06	0.011(0.019)	0.58	0.009(0.029)	0.77
Model 2	0.034(0.019)	0.07	0.009(0.019)	0.63	0.011(0.029)	0.70
Night awakenings (≥2 vs <2 times)						
Model 1	0.060(0.048)	0.21	-0.020(0.052)	0.71	-0.262(0.269)	0.33
Model 2	0.058(0.048)	0.22	-0.024(0.052)	0.65	-0.268(0.281)	0.34
Sleep onset latency (>1 hour vs <1 hour)						
Model 1	0.099(0.289)	0.73	-0.226(0.352)	0.52	0.029(0.078)	0.71
Model 2	0.082(0.289)	0.78	-0.205(0.353)	0.56	0.033(0.078)	0.67

Note: Numbers in **bold** are significant at $p<0.05$.

All the models were adjusted for exact age of the child at sleep measurement, exact age of the child at BMI measurement, maternal age, maternal educational level, maternal pre-pregnancy BMI, parity, and child gender, child ethnic background, child birth weight, gestational age, duration of breastfeeding, and intervention groups; Model 2 further adjusted for child screen time.

[1] For all the models, the sleep indicators were measured at the same measurement wave as BMI z-scores.

CHAPTER 4

Identifying patterns of diet, physical activity, and sedentary behaviors in preschool children

Manuscript submitted

Lu Wang, Wilma Jansen, Amy van Grieken, Magda M Boere-Boonekamp, Eline Vlasblom, Maaike Beltman, Monique P L'Hoir, Hein Raat

Abstract

Objective

To identify the patterns of lifestyle behaviors (including diet, physical activity, and sedentary behaviors) in children aged 3 years, to investigate the parental and child characteristics associated with the lifestyle patterns, and to examine whether the identified lifestyle patterns are associated with child BMI and weight status.

Methods

Cross-sectional data of 2090 children participating in the Dutch BeeBOFT study were used. Data on 3-year old children's diet, physical activity, and sedentary behaviors were parent reported by questionnaire, and children's weight and height were measured by trained professionals according to a standardized protocol. Latent class analysis was applied to identify patterns of lifestyle behaviors among children.

Results

The final latent class model identified three subgroups of children with distinct patterns of lifestyle behaviors: the "unhealthy lifestyle" pattern (36%), the "low snacking and low screen time" pattern (48%), and the "active, high fruit and vegetable, high snacking and high screen time" pattern (16%). Factors associated with the "unhealthy lifestyle" pattern as well as the "active, high fruit and vegetable, high snacking and high screen time" pattern (with the 'low snacking and low sedentary' group as reference group) included low maternal educational level, permissive parenting style, and male gender of the child. No association was found between the identified lifestyle patterns and child BMI z-score at age 3 years.

Conclusion

Three different lifestyle patterns were observed among children aged 3 years and low maternal educational level, permissive parenting style, and male gender of the child were associated with having an unhealthy lifestyle pattern for the child.

Introduction

Childhood obesity is recognized as one of the major public health concerns in the 21st century due to its high prevalence and adverse physical and psychological outcomes [1-4]. Children's lifestyle behaviors, including high intake of energy-dense nutrition low foods (e.g. high intake of sugar-sweetened beverages, unhealthy snacks), high levels of sedentary behavior (e.g., television viewing, computer use), and low levels of physical activity have been shown to contribute to energy imbalance and therefore increase the risk of child overweight and obesity [5-7].

Increasing evidence suggests that certain overweight-related lifestyle behaviors, such as poor dietary behaviors, low levels of physical activity, and high levels of sedentary behaviors tend to co-occur or cluster in some subgroups [8-12]. For example, using cluster analysis, Leech et al (2015) identified three subgroups of children with distinct lifestyle behavior patterns among Australian children 5-6 years (n=362), the "most healthy" group, the "energy-dense consumers who watch TV" group and the "high sedentary behavior/low moderate-to-vigorous PA" group [9]. Miguel-Berges et al (2017) identified six subgroups of children with different lifestyle behavior patterns, one of which was characterized by unhealthy dietary behaviors including high sugar-sweetened beverage consumption and low fruit and vegetable consumption, high level of sedentary behavior, and low physical activity level among children aged 4-6 years from 6 European countries (n=5357) [10]. The co-existence of multiple overweight-related lifestyle behaviors may have a synergic effect on the development of children's overweight and obesity [8, 13]. Understanding the natural co-occurring patterns of multiple overweight-related lifestyle behaviors can inform intervention developers about which behavioral factors need to be targeted simultaneously and on which subgroups the behavior change interventions should be targeted.

Few studies have examined the clustering patterns of lifestyle behaviors among children younger than 5 years [10]. As children's lifestyle behaviors are established in early childhood (0-5 years) and may persist to later life [14], the development of healthy lifestyle behaviors in early childhood should be encouraged to maintain healthy weight. This study therefore aimed to examine the clustering patterns of lifestyle behaviors including sugar-sweetened beverage consumption, unhealthy snack consumption, fruit consumption, vegetable consumption, screen time, and physical activity in preschool children aged 3 years in a population-based sample from the Netherlands. We further examined which parental and child characteristics are associated with different lifestyle behavior patterns. In addition, we examined the association of the identified lifestyle behavior patterns with children's BMI and weight status.

Methods

Study population

Data from the BeeBOFT study were used. The BeeBOFT study is a cluster randomized controlled trial for the primary prevention of overweight among children [15, 16]. In the BeeBOFT study the effect of two intervention conditions, the 'BBOFT+' intervention, and the 'E-Health4Uth' intervention on the prevention of overweight and overweight related behaviors in children 0-3 years were compared to the care as usual condition. A total of 51 regional Youth Health Care (YHC) teams covering both rural and urban regions in the Netherlands participated in the study and were randomly allocated to the three study arms. The research proposal was reviewed by the Medical Ethics Committee of the Erasmus Medical Center. Based on their review, the Committee concluded that the Dutch Medical Research Involving Human Subjects Act (in Dutch: Wet medisch-wetenschappelijk onderzoek met mensen) did not apply to this research proposal (proposal number MEC-2008-250), and therefore had no objection to the execution of this study.

From January 2009 through September 2010, 7985 parent-child dyads were invited to participate in the study by the 51 regional YHC teams during the first home-visit at 2-4 weeks after child birth. Written informed consent for participation in this 3-year study was gained from 3003 parent-child dyads. The parents were also asked to fill in a baseline questionnaire at inclusion, which assessed social demographic characteristics and information regarding pregnancy. At child age 6, 14, and 36 months, the parents were invited to complete a questionnaire on children's health behaviors and determinants of these behaviors. During each YHC routine visit (scheduled at child age 0.5, 1, 2, 3, 4, 6, 9, 11, 14, 18, 24, and 36 months), child's weight and height were measured by YHC professionals according to standardized protocols [17]. For the present study, we used data on the dietary, physical activity, sedentary behaviors of the children at age 36 months. In total, parents of 2253 children returned the questionnaire at child age 36 months. For the current study, children with no missing value on the dietary, physical activity, sedentary behaviors (including sugar-containing drinks consumption, unhealthy snack consumption, fruit consumption, vegetable consumption, screen time, and physical activity) (n=2090) were included for analyses.

Non-response analysis shows that compared to children included in the present study, children excluded from the current study due to non-response for the parental questionnaire and missing values were more likely to have lower maternal educational level, and non-Dutch ethnic background ($p<0.01$, see Table S1 for detailed data).

Measurements

Children's diet, physical activity and sedentary behaviors

Children's diet, physical activity and sedentary behaviors were measured by parental questionnaires at child age 36 months. All questions were adapted from Dutch questionnaires that have been used in previous studies (the questions and answering categories can be found in the supplemental file Table S2) [18, 19]. Each behavior variable was dichotomized into favorable versus unfavorable categories according to current nutrition and physical activity guidelines [20-25].

Dietary behaviors

Parents reported children's consumption of sugar-containing drinks, unhealthy snacks, fresh fruit, and vegetables during the past four weeks in a questionnaire. Parents were asked to report how many cups of sugar-containing drinks their child consumed per weekday and per weekend day on average respectively. The definition and examples for the sugar-containing drinks were provided in the questionnaire: drinks with additional sugar (e.g. soft drinks such as cola, 7-ups, Ice-tea, fruit cordials or syrup; fruit juice, fruit juice beverages; sport and energy drinks with sugar; sweetened dairy drinks; tea or water with sugar). The average amount of sugar-containing drinks consumed by the child per day was computed by averaging the consumption on weekdays and weekends. Children who were reported to consume sugar-containing drinks for > 2 cups per day were classified as having a high consumption of sugar-containing drinks [24]. For the consumption of unhealthy snacks, parents were asked to report how many servings of the following food items their child ate between meals on average per day: candies (e.g. cake, ice cream, chocolate, candies, chocolate bars), and savory snacks (e.g. chips, fries, pizza, hamburger). Children who were reported to eat unhealthy snacks for two servings or more per day were classified as having a high consumption of unhealthy snacks [24].

Parents also reported how many servings of fresh fruit (e.g. apple, orange, pear, kiwi, banana) and how many serving spoons of vegetable (e.g. broccoli, spinach, sweet pepper) their child ate on average per day (answering categories were none, ½, 1, 2, 3, 4, and 5 or more). Children who were reported to have fresh fruit for one serving or less were classified as having a low fruit consumption [24]. Children who were reported to have vegetable for one serving spoon or less were classified as having a low vegetable consumption [24].

Physical activity

Parents reported how many days in a week and how many hours a day their child was engaged in activities in which he/she could move actively (e.g. swimming, toddler gym, movement to music, walking to the store; with the exclusion of playing at home). The answering categories were 0, 1, 2, 3, 4, 5, 6 or 7 days a week, and 0, 0-0.5, 0.5-1, 1-2, 2-3, >3 hours a day. Children who were active for 5 or more days per week and more than 1 hour per day were classified as physically active, while those who did not meet this criterion were classified as having a low level of physical activity [20].

Sedentary behaviors

Parents reported children's screen-based sedentary behaviors including TV viewing time and computer game playing time respectively. Parents were asked to report the average number of weekdays and weekend days their child spent watching TV/video/DVD and playing computer games respectively, and the average hours a day per weekdays/weekend days the child spent watching TV/video/DVD and playing computer games respectively. We calculated the average time the child spent TV viewing per day by the following function: (No. of weekdays * hours per weekday spent on watching TV/video/DVD + No. of weekend days * hours per weekend day spent on watching TV/video/DVD)/7. Similarly, the average time the child spent computer game playing per day was calculated. Children's average screen time per day was calculated by adding up children's average TV viewing time and computer game playing time. Children who were reported to have > 1 hour of screen time on average per day were classified as having excessive screen time [21, 22].

Demographic characteristics

Social demographic characteristics of the parents and children were assessed at baseline, including maternal age and educational level, parity, and child's gender and ethnic background. The highest attained educational level of mother was categorized as high (higher vocational training, university degree), middle (>4 years general secondary school or intermediate vocational training), and low (no education, primary school, or 4 years or less general secondary school) [26]. According to definition established by Statistics Netherlands, the child's ethnic background was defined as Dutch if both of his/her parents were classified as Dutch; a parent was classified as Dutch if both his/her own parents were born in the Netherlands [24]. Mothers reported their body weight and height in baseline questionnaire and in follow-up questionnaire at child age 6 months and 36 months. We used maternal body weight reported at child age 36 months to calculate maternal BMI; and in case of missing, maternal body weight reported at child age 6 months was used instead. The maternal weight status was then classified as 'normal' (BMI <25), or 'overweight'(BMI≥25).

Child anthropometrics

Child's weight and height were measured by Youth Health Care professionals according to standardized protocols [17]. Data on child's weight and height at age circa 36 months acquired from the Youth Health Care registration files were linked to the questionnaire data. Child BMI was calculated by the weight in kilograms divided by squared body length in meters. Age and gender adjusted BMI z-scores were calculated using the World Health Organization Growth Standard (2006) [27]. At the age of 3 years, each child was classified as being 'underweight', 'normal weight', or 'overweight/obese' using international Obesity Task Force (IOTF) age and gender specific cut-off values [28, 29].

Parenting styles

Parenting style was measured at child age 36 months. The questionnaire for measuring parenting style had been used in previous study [30]. Two dimensions of parenting were measured: parental warmth and parental control. Parental warmth addressed the frequency that parents displayed warm affectionate behavior toward their child (six items, e.g. "How often do you have warm, close times together with your child?"). Parental control addressed the frequency with which they set and enforced clear expectations and limits for their children's behavior (e.g. "When you discipline your child, how often does he/she ignore the punishment?", reverse record). Warmth and control scores were dichotomized at median value in the population and combined to approximate the 4 categorical parenting styles. The combination of high warmth and high control was classified as authoritative; low warmth and high control as authoritarian; high warmth and low control as permissive; and low warmth and low control as neglectful [30].

Statistical methods

Latent class analysis was applied to identify patterns of lifestyle behaviors among children. The latent class models identify subgroups (also called latent classes) of children based on their patterns of responses to a set of dichotomized lifestyle behavior indicators, including sugar-containing drinks consumption, unhealthy snack consumption, fruit consumption, vegetable consumption, physical activity, and screen time [31, 32]. Children that were assigned to the same latent class shared similar patterns of lifestyle behaviors. The latent classes were labelled based on the probabilities of children in that latent class reporting a certain value on each lifestyle behavior indicator [31].

To identify the optimal number of latent classes, a series of latent class models with a total number of 1 to 6 classes were evaluated [31]. Table 1 presents the model fit statistics of the 1- to 6-class latent class models, including Loglikelihood values, Akaike's Information Criterion (AIC), and Bayesian Information Criterion (BIC). Both AIC and BIC reached the lowest value at the 3-class model, and the Loglikelihood value decreased only moderately after the 3-class models. With further consideration of the model interpretability, eventually the 3-class latent class model was adopted for subsequent analysis.

Table 2. Model fit statistics of the latent class models according to the number of classes.

Number of latent classes	Loglikelihood	AIC	BIC
1	-8333.36	297.04	311.85
2	-8235.86	116.04	148.12
3	-8215.95	90.21	139.57
4	-8209.36	91.03	157.66
5	-8206.05	98.42	182.33
6	-8202.29	104.89	206.08

Multinomial logistic regression models were applied to examine the associations of the parental and child characteristics with the latent classes that were identified by the 3-class latent class model. Firstly, the univariate associations between the parental and child characteristics with the latent classes were assessed. Then, all the parental and child characteristics were entered in the model simultaneously to examine the independent association between each characteristic and the latent classes. All the models were adjusted for child exact age (in months) at the time of questionnaire measurement.

The associations of the latent classes with child BMI z-score and weight status were examined by a linear regression model and a logistic regression model respectively. Both models were adjusted for maternal educational level, maternal BMI, child gender, child ethnic background, child birth weight, child exact age, and study condition (the intervention or control conditions).

All the analyses were performed using SAS version 9.4. Latent class analysis was performed with the package 'PROC LCA' [31, 33].

Results

Table 2 presents the characteristics of our study population. Of the 2090 children included in the study, 51% were boys, 84% were of Dutch ethnic background. For the mothers, 33% were categorized as being overweight or obese, and 10% had a low educational level.

Table 2. Characteristics of the parents and children in our study population (n=2090).

Variables	N	Frequency (%)/ Mean (SD)
Maternal educational level	2070	
Low		208 (10.1)
Middle		732 (35.4)
High		1130 (54.6)
Maternal weight status	2061	
Normal		1377 (66.3)
Overweight		519 (25.0)
Obesity		181 (8.7)
Maternal age at child birth, years, mean (SD)	2061	31.12 (4.2)
Child ethnic background, Dutch	2090	1756 (84.1)
Child gender, male	2057	1059 (51.5)
Child age 36 months, mean (SD)	2090	36.72 (2.2)
Study condition	2090	
Control condition		730 (34.9)
'BBOFT+' Intervention		621 (29.7)
'E-health4Uth' Intervention		739 (35.4)
Parenting style	2055	
Authoritative		828 (40.3)
Permissive		301 (14.7)
Authoritarian		529 (25.8)
Neglectful		395 (19.2)

The final latent class model classified children into three subgroups based on their patterns of responses to multiple lifestyle behavior indicators. As shown in Table 3, the three latent classes included 36%, 48%, and 16% of the children respectively. Children allocated to the first latent class were characterized by high probabilities of having excessive sugar-containing drink and unhealthy snack consumption, low fruit and vegetable consumption, low physical activity level, and excessive screen time. The first latent class was therefore labeled as the 'unhealthy lifestyle' pattern. Children in latent class 2 were characterized by low probabilities of having excessive sugar-containing drink and unhealthy snack consumption, and excessive screen time. Latent class 2 was therefore labelled as the "low snacking and low screen time" pattern. Children in latent class 3 were characterized by high probabilities of having excessive sugar-containing drink and unhealthy snack consumption, excessive screen time, and low probabilities of having low fruit and vegetable consumption, and low physical activity level. Based on these characteristics, the third latent class was labeled as the "active, high fruit and vegetable, high snacking and high screen time" pattern.

Table 3. The probabilities of reporting each unfavorable lifestyle behaviors in the total sample and conditional on the latent classes.

Unfavorable lifestyle behaviors	Total sample (N=2090)	Class 1 "unhealthy lifestyle" (n=753, 36%)	Class 2 "low snacking and low screen time" (n=1003, 48%)	Class 3 "active, high fruit and vegetable, high snacking and high screen time" (n=334, 16%)	*p-values*[1]
Sugar-containing drink consumption> 2 cups per day	0.40	0.76	0.04	0.73	<0.001
Unhealthy snack consumption >1 serving per day	0.39	0.66	0.14	0.59	<0.001
Fruit consumption ≤1 serving per day	0.59	0.79	0.56	0.22	<0.001
Vegetable consumption ≤1 serving spoons per day	0.68	0.89	0.65	0.31	<0.001
Physical activity <1 hour per day	0.63	0.83	0.64	0.17	<0.001
Screen time >1 hour per day	0.43	0.59	0.24	0.63	<0.001

[1] The difference between groups were compared using Chi-square test.

Table 4 presents the results from multinomial logistic regression models for the association between the parental and child characteristics and the latent classes. The "low snacking and low screen time" pattern was treated as the reference group in the multinomial logistic regression models. In the univariate models, factors significantly ($P<0.05$) associated with both the "unhealthy lifestyle" pattern and the "active, high fruit and vegetable, high snacking and high screen time" pattern included lower maternal educational level, maternal obesity, permissive parenting style, and male gender of the child. In addition, an authoritarian parenting style was associated with lower probability of being allocated to the "active, high fruit and vegetable, high snacking and high screen time" pattern.

The result of the multivariate model reveals that factors independently associated with both the "unhealthy lifestyle" pattern and the "active, high fruit and vegetable, high snacking and high screen time" pattern included lower maternal educational level, permissive parenting style, and male gender of the child. In addition, an authoritarian parenting style was independently associated with lower probability of being allocated to the "active, high fruit and vegetable, high snacking and high screen time" pattern.

Table 4. The association between parental and child characteristics and the latent classes: results from multinomial logistic regression models (n=2090).

	Univariate Models[1]		Multivariate Model[2]	
	Class 1 "unhealthy lifestyles" OR(95%CI)	Class 3 "active, high fruit and vegetable, high snacking and high screen time" OR(95%CI)	Class 1 "unhealthy lifestyles" OR(95%CI)	Class 3 "active, high fruit and vegetable, high snacking and high screen time" OR(95%CI)
Maternal educational level				
Low	**2.05(1.45, 2.88)**	**3.23(2.17, 4.80)**	**2.05(1.44, 2.92)**	**2.95(1.94, 4.49)**
Middle	**1.55(1.26, 1.90)**	**1.59(1.21, 2.10)**	**1.53(1.24, 1.89)**	**1.56(1.17, 2.08)**
High	Ref	Ref	Ref	Ref
Maternal weight status				
Normal weight	Ref	Ref	Ref	Ref
Overweight	1.21(0.97, 1.51)	1.04(0.77, 1.40)	1.16(0.92, 1.46)	0.98(0.72, 1.34)
Obese	**1.55(1.10, 2 .19)**	**1.69(1.10, 2.59)**	1.43(0.99, 2.05)	1.52(0.97, 2.38)
Parenting style				
Authoritative	Ref	Ref	Ref	Ref
Permissive	**1.59(1.18, 2.14)**	**1.73(1.21, 2.47)**	**1.56(1.15, 2.12)**	**1.63(1.12, 2.36)**
Authoritarian	1.07(0.84, 1.35)	**0.67(0.48, 0.94)**	1.07(0.84, 1.37)	**0.66(0.47, 0.94)**
Neglectful	1.22(0.94, 1.59)	0.97(0.69, 1.38)	1.20(0.91, 1.57)	0.93(0.65, 1.34)
Child ethnic background				
Non-Dutch vs Dutch	0.78(0.60, 1.02)	0.93(0.66, 1.30)	0.79(0.60, 1.05)	0.86(0.60, 1.24)
Child gender				
Female vs male	**0.81(0.67, 0.98)**	**0.76(0.59, 0.98)**	**0.80(0.66, 0.98)**	**0.76(0.58, 0.98)**
Study conditions				
Control condition	Ref	Ref	Ref	Ref
The 'BBOFT+' intervention	1.01(0.80, 1.26)	0.87(0.65, 1.16)	1.05(0.83, 1.33)	0.92(0.68, 1.26)
The 'E-health4Uth' intervention	1.08(0.85, 1.36)	0.87(0.64, 1.18)	1.03(0.81, 1.32)	0.84(0.61, 1.17)

Note: For all the models, the "low snacking, low screen time" pattern (class 2) was taken as the reference group. All the models were adjusted for child exact age at the time of questionnaire measurement.

Numbers in bold are statistically significant at $p<0.05$.

[1] For the univariate models, each independent variable (the parental and child characteristics) were entered into the model separately to assess its association with the outcome variable (lifestyle behavior patterns).

[2] For the multivariate model, all the independent variables were entered into the model simultaneously to assess the independent association between each parental and child related factors and the lifestyle patterns.

As shown in Table 5, there was no significant association between the latent classes and child BMI and weight status (overweight vs normal weight) at age 36 months (all $p>0.1$).

Table 5. The association between the latent classes and child BMI z-score and weight status at child age 36 months (N=1310).

	Child BMI z-score		Child overweight	
	Mean(SD)	*β*(95%CI)[1]	N (%)	OR(95%CI)[2]
Class 1 "unhealthy lifestyle"	-0.45(0.97)	-0.08(-0.19, 0.03)	29(5.99)	0.82(0.50, 1.34)
Class 2 "low snacking and low screen time"	-0.34(1.05)	Ref	46(7.31)	Ref
Class 3 "active, high fruit and vegetable, high snacking, high screen time"	-0.36(1.02)	0.02(-0.14, 0.18)	13(6.57)	0.99(0.52, 1.91)

[1] Results from linear regression model. The model was adjusted for maternal educational level, maternal BMI, child ethnic background, child gender, child exact age at BMI measurement, child exact age at questionnaire measurement and intervention condition.
[2] Results from logistic regression model. The model was adjusted for maternal educational level, maternal BMI, child ethnic background, child gender, child exact age at BMI measurement, child exact age at questionnaire measurement and intervention condition.

Discussion

In this study, we examined the co-occurrence patterns of diet, physical activity, and sedentary behaviors among 3-year old children in a Dutch population-based sample. Latent class analysis identified three subgroups of children characterized by distinct patterns of diet, physical activity and sedentary behaviors: the "unhealthy lifestyle" pattern, the "low snacking and low screen time" pattern, and the "active, high fruit and vegetable, high snacking, high screen time" pattern. Low maternal educational level and a permissive parenting style were associated with both having an "unhealthy lifestyle" pattern, and an "active, high fruit and vegetable, high snacking, high screen time" pattern for the child. We found no differences in the distribution of BMI or the risk of overweight between the subgroups of children.

The first latent class represent a group of children characterized by high probabilities of reporting unhealthy behaviors on all the lifestyle behavior indicators, including excessive sugar-containing drink and unhealthy snack consumption, excessive screen time, low fruit and vegetable consumption, and low physical activity level. The co-occurrence of unhealthy dietary intake, high screen time, and low physical activity level has been observed by multiple previous studies among children of different age groups and from different regions [10, 12, 34]. For instance, Miguel-Berges et al (2017) observed an "unhealthy lifestyle" pattern among children aged 4-6 years from 6 European countries (n=5387) [10]; Seghers et al (2010) identified an "inactive media-oriented unhealthy eaters" cluster in a sample of 11-12 years old Flemish children (n=317) [34]; Huh et al (2010) identified a lifestyle pattern characterized by high snack consumption and high screen time combined with low fruit and vegetable consumption and low physical activity level among children aged 10 years from the US (n=997) [12]. Consistent with the previous research [10], we found that the "unhealthy lifestyle" pattern was more likely to be observed in children with lower educated mothers. In addition, our results suggested children with the "unhealthy lifestyle" were more likely to have parents with a permissive parenting style. The permissive parenting style has been suggested to be associated with individual unhealthy lifestyle behaviors [35-37]. Our study for the first time examined the association between parenting style and the co-occurring patterns of lifestyle behaviors among children.

About half of the children have a "low snacking and low screen time" pattern (latent class 2). Compared to the other subgroups, children with the "low snacking and low screen time" pattern was relatively healthy with regard to the consumption of sugar-containing drinks and unhealthy snacks, and screen time. The probabilities of having low fruit and vegetable consumptions and a low physical activity level in this subgroup of children were similar to the average level in the overall sample. A similar lifestyle pattern has been observed in a sample of 1773 children aged 3-6 years from 8 European countries (labeled as the "low beverage consumption and low sedentary" pattern) [38].

The "active, high fruit and vegetable, high snacking, high screen time" lifestyle pattern was characterized by high probabilities of both healthy (including high fruit and vegetable consumption and high physical activity level) and unhealthy lifestyle behaviors (including high sugar-containing drinks and unhealthy snack consumption and high screen time). A comparable lifestyle pattern has been reported in a study from Belgian and was labeled as the "sporty media-oriented mixed eaters" [34]. Similar to the "unhealthy lifestyle" pattern, the "active, high fruit and vegetable, high snacking, high screen time" pattern was more prevalent among children with lower educated mothers and children of parents with permissive parenting style.

Our findings revealed that high screen time tends to co-occur with high consumption of sugar-containing drinks and unhealthy snack foods (class 1 and class 3). Conversely, low screen time tends to co-occur with low consumption of sugar-containing drinks and unhealthy snacks (class 2). These co-occurrence patterns reveal the high correlations between sedentary behaviors (e.g. TV viewing and computer use) and the consumption of sugar-containing drinks and unhealthy snacks. The proposed mechanism for the correlations of sedentary behavior and the consumption of sugar-containing drinks and unhealthy snacks included the promoting effect of beverage and snack commercials on the consumption of these foods [39], and the provision of a context during sedentary activities that promotes passive snacking [40]. The clustering of unhealthy behaviors is also likely to be a result of parental influence. It is possible that this pattern exists in the parent [41], and is then transmitted to their children. Parents who allow their child to watch TV may also provide the child sugar-containing drinks and unhealthy snacks [42].

This study has identified a lifestyle pattern that was characterized by a high physical activity level (class 1) and low screen time, as well as a lifestyle pattern characterized by a high physical activity level and high screen time (class 3). Increasing time spent on sedentary behaviors such as TV watching or computer game playing has been often proposed to be one of the reasons for the lack of physical activity in children due to the displacement of time use [43, 44]. However, controversial findings exist with regard to the association between sedentary behaviors and physical activity [43, 45]. The existence of divergent co-occurrence pattern of screen time and physical activity level found in the present study might explain the inconsistent association between sedentary behaviors and physical activity in previous studies.

Our findings confirm that certain lifestyle behaviors may cluster or co-occur within subgroups of children, and that the co-occurrence of lifestyle behaviors can already be observed in children as young as 3 years. Public health practitioners should consider how the lifestyle behaviors co-occur and which background characteristics are associated with the co-occurring patterns of lifestyle behaviors in order to develop better targeted interventions to improve children's lifestyle tailored to different groups.

We found no association between the lifestyle patterns and children's BMI or weight status. Previous findings with regard to the association between lifestyle patterns and children's weight status are inconsistent [8, 9, 34, 38, 46]: while some studies have found evidence of possible synergistic effect of multiple unhealthy behaviors on childhood overweight [9], others found no association [34], or even reverse association [46]. A possible explanation for the lack of association between the lifestyle patterns and children's BMI or weight status may include the younger age of our study population. The adverse effect of multiple unhealthy lifestyle behaviors on child BMI or weight status may accumulate and manifest at later ages [47]. This might represent an opportunity for the primary prevention of overweight, as we would be able to prevent the accumulation of unhealthy lifestyle behaviors. In addition, parents may restrict the unhealthy behaviors such as sugar-containing drink consumption and unhealthy snack consumption of the overweight or obese children [46]. Further, it is a limitation of our study that only BMI was measured to represent the adiposity of children. Since BMI is an indicator for both fat mass and fat free mass, it could be that children in the unhealthy lifestyle group had lower muscle mass and higher fat mass compared to children with relatively healthier lifestyles [46].

Strengths and limitations

Firstly, by using a data driven method, we were able to provide insight into the determinants and outcomes of children's lifestyle behaviors in a multivariable and interactive perspective. Secondly, this study applied latent class analysis to assess the clustering patterns of lifestyle behaviors in the population. Compared to cluster analysis which was applied in most previous studies investigating the clustering patterns of lifestyle behaviors, latent class analysis uses statistical indexes to indicate the best model fit and therefore minimizes subjectivity when deciding the number of clusters [48]. Thirdly, we examined the lifestyle patterns among children as young as 3 years old.

However, the current study has some limitations. Firstly, information on children's lifestyle behavior variables were self-reported by parents through questionnaires. In addition, the questions concerning unhealthy snacks and fruit consumption did not measure serving size. Future studies with more accurate measurement of children's lifestyle behaviors are warranted to confirm our finding. Secondly, cluster patterns observed may only be specific to the culture and populations studied and caution is needed when generalizing results. Thirdly, variations in the variables included, and the way in which the lifestyle behaviors were dichotomized may hinder the comparison between studies. Fourthly, this study used data from an intervention trial. However, we found no association between the intervention groups and the lifestyle patterns (See Table 3). In addition, we have replicated the latent class analyses using data from the control group only, and comparable lifestyle patterns were generated (Table S3). Fifth, given the limitation of observational studies, we could not determine the causal relationships but only associations.

Conclusion

Our findings confirm that co-concurrence of lifestyle behaviors can be observed among children aged 3 years. Lower maternal educational level, and permissive parenting style and male gender of the child are associated with having an unhealthy lifestyle pattern for the child. We found no cross-sectional association between the lifestyle patterns and children's BMI or weight status. Our findings underline the importance of designing and implementing interventions that consider the diversity of lifestyle patterns and associated determinants.

References

1. Singh, A.S., et al., *Tracking of childhood overweight into adulthood: a systematic review of the literature.* Obesity reviews, 2008. **9**(5): p. 474-488.
2. Organization, W.H. *Report of the commision on ending childhood obesity*. 2016 [cited 2018; Available from: http://apps.who.int/iris/bitstream/handle/10665/204176/9789241510066_eng.pdf?sequence=1.
3. Valerio, G., et al., *[Health consequences of obesity in children and adolescents]*

Conseguenze dell'obesita sulla salute del bambino e dell' adolescente. Minerva Pediatr, 2014. **66**(5): p. 381-414.

4. Llewellyn, A., et al., *Childhood obesity as a predictor of morbidity in adulthood: a systematic review and meta‐analysis.* Obesity reviews, 2016. **17**(1): p. 56-67.
5. van Stralen, M.M., et al., *Weight status of European preschool children and associations with family demographics and energy balance-related behaviours: a pooled analysis of six European studies.* Obes Rev, 2012. **13 Suppl 1**: p. 29-41.
6. Pate, R.R., et al., *Factors associated with development of excessive fatness in children and adolescents: a review of prospective studies.* Obes Rev, 2013. **14**(8): p. 645-58.
7. te Velde, S.J., et al., *Energy balance-related behaviours associated with overweight and obesity in preschool children: a systematic review of prospective studies.* Obes Rev, 2012. **13 Suppl 1**: p. 56-74.
8. Leech, R.M., S.A. McNaughton, and A. Timperio, *The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review.* Int J Behav Nutr Phys Act, 2014. **11**: p. 4.
9. Leech, R.M., S.A. McNaughton, and A. Timperio, *Clustering of diet, physical activity and sedentary behaviour among Australian children: cross-sectional and longitudinal associations with overweight and obesity.* Int J Obes (Lond), 2015. **39**(7): p. 1079-85.
10. Miguel-Berges, M.L., et al., *Clustering of energy balance-related behaviours and parental education in European preschool children: the ToyBox study.* Br J Nutr, 2017. **118**(12): p. 1089-1096.
11. Santaliestra-Pasias, A.M., et al., *Clustering of lifestyle behaviours and relation to body composition in European children. The IDEFICS study.* Eur J Clin Nutr, 2015. **69**(7): p. 811-6.
12. Huh, J., et al., *Identifying patterns of eating and physical activity in children: a latent class analysis of obesity risk.* Obesity (Silver Spring), 2011. **19**(3): p. 652-8.
13. Kremers, S.P., *Theory and practice in the study of influences on energy balance-related behaviors.* Patient Educ Couns, 2010. **79**(3): p. 291-8.
14. Craigie, A.M., et al., *Tracking of obesity-related behaviours from childhood to adulthood: a systematic review.* Maturitas, 2011. **70**(3): p. 266-284.
15. Raat, H., et al., *Primary prevention of overweight in preschool children, the BeeBOFT study (breastfeeding, breakfast daily, outside playing, few sweet drinks, less TV viewing): design of a cluster randomized controlled trial.* BMC Public Health, 2013. **13**: p. 974.
16. van Grieken, A., et al., *Personalized Web-Based Advice in Combination With Well-Child Visits to Prevent Overweight in Young Children: Cluster Randomized Controlled Trial.* J Med Internet Res, 2017. **19**(7): p. e268.
17. A., B.-B. *Signaleringsprotocol overgewicht in de jeugdsgezondheidszorg Youth health care overweight-detection-protocol*. 2005; Available from: http://www.twenteinbalans.nl/images/stories/070917_sigaleringsprotocol_overgewicht_JGZ.pdf.

18. van Grieken, A., et al., *Population-based childhood overweight prevention: outcomes of the 'Be active, eat right'study.* PloS one, 2013. **8**(5): p. e65376.
19. Horst, K.v.d., et al., *The ENDORSE study: Research into environmental determinants of obesity related behaviors in Rotterdam schoolchildren.* BMC Public Health, 2008. **8**(1): p. 142.
20. Prevention, C.f.D.C.a. *How much physical activity do children need*. 2011 [cited 2018; Available from: https://www.cdc.gov/physicalactivity/basics/index.htm?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcancer%2Fdcpc%2Fprevention%2Fpolicies_practices%2Fphysical_activity%2Fguidelines.htm.
21. Media, C.O.C.a., *Media and Young Minds.* Pediatrics, 2016. **138**(5).
22. Tremblay, M.S., et al., *Canadian sedentary behaviour guidelines for the early years (aged 0–4 years).* Applied Physiology, Nutrition, and Metabolism, 2012. **37**(2): p. 370-380.
23. Davis, M.M., et al., *Recommendations for prevention of childhood obesity.* Pediatrics, 2007. **120**(Supplement 4): p. S229-S253.
24. Jeugdgezondheid, N.C. *Guideline: Nutrition and eating behavior (2013, adaptation 2017)*. 2017; Available from: https://www.ncj.nl/richtlijnen/alle-richtlijnen/richtlijn/?richtlijn=4&rlpag=527.
25. Bulk-Bunschoten AMW, R.C., Van Leerdam FJM, HiraSing RA *(Youth health care overweight prevention protocol) Overbruggingsplan voor kinderen met overgewicht*. 2005; Available from: https://www.nji.nl/nl/Databank/Databank-Effectieve-Jeugdinterventies/Overbruggingsplan-voor-kinderen-met-overgewicht.html.
26. Netherlands, S., *Dutch standard classification of education 2003.* Voorburg/Heerlen, Netherlands: Statistics Netherlands, 2004.
27. World Health, O., *WHO child growth standards: length/height for age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age, methods and development*. 2006: World Health Organization.
28. Cole, T.J., et al., *Establishing a standard definition for child overweight and obesity worldwide: international survey.* BMJ, 2000. **320**(7244): p. 1240.
29. Cole, T.J. and T. Lobstein, *Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity.* Pediatric Obesity, 2012. **7**(4): p. 284-294.
30. Wake, M., et al., *Preschooler obesity and parenting styles of mothers and fathers: Australian national population study.* Pediatrics, 2007. **120**(6): p. e1520-e1527.
31. Lanza, S.T., et al., *PROC LCA: A SAS procedure for latent class analysis.* Structural Equation Modeling, 2007. **14**(4): p. 671-694.
32. Goodman, L.A., *Exploratory latent structure analysis using both identifiable and unidentifiable models.* Biometrika, 1974. **61**(2): p. 215-231.
33. Lanza, S.T., Dziak, J. J., Huang, L., Wagner, A. T., & Collins, L. M. *Proc LCA & Proc LTA users' guide (Version 1.3.2).* 2015; Available from: https://methodology.psu.edu/sites/default/files/software/proclcalta/proc_lca_lta_1-3-2-1_users_guide.pdf.
34. Seghers, J. and C. Rutten, *Clustering of multiple lifestyle behaviours and its relationship with weight status and cardiorespiratory fitness in a sample of Flemish 11- to 12-year-olds.* Public Health Nutr, 2010. **13**(11): p. 1838-46.
35. Pearson, N., et al., *Parenting styles, family structure and adolescent dietary behaviour.* Public Health Nutr, 2010. **13**(8): p. 1245-53.
36. Vollmer, R.L. and A.R. Mobley, *Parenting styles, feeding styles, and their influence on child obesogenic behaviors and body weight. A review.* Appetite, 2013. **71**: p. 232-41.
37. Sleddens, E.F., et al., *General parenting, childhood overweight and obesity-inducing behaviors: a review.* Int J Pediatr Obes, 2011. **6**(2-2): p. e12-27.

38. Bel-Serrat, S., et al., *Clustering of multiple lifestyle behaviours and its association to cardiovascular risk factors in children: The IDEFICS study.* Eur J Clin Nutr, 2013. **67**(8): p. 848-854.
39. Halford, J.C.G., et al., *Beyond-brand effect of television (TV) food advertisements/commercials on caloric intake and food choice of 5–7-year-old children.* Appetite, 2007. **49**(1): p. 263-267.
40. Coon, K.A., et al., *Relationships Between Use of Television During Meals and Children9s Food Consumption Patterns.* Pediatrics, 2001. **107**(1): p. e7-e7.
41. Perez-Rodrigo, C., et al., *Lifestyle Patterns and Weight Status in Spanish Adults: The ANIBES Study.* Nutrients, 2017. **9**(6).
42. Rodenburg, G., et al., *Clustering of diet-and activity-related parenting practices: cross-sectional findings of the INPACT study.* International Journal of Behavioral Nutrition and Physical Activity, 2013. **10**(1): p. 36.
43. Marshall, S.J., et al., *Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis.* Int J Obes Relat Metab Disord, 2004. **28**(10): p. 1238-46.
44. Huhman, M., et al., *Effects of a mass media campaign to increase physical activity among children: year-1 results of the VERB campaign.* Pediatrics, 2005. **116**(2): p. e277-e284.
45. Biddle, S.J., et al., *Physical activity and sedentary behaviours in youth: issues and controversies.* J R Soc Promot Health, 2004. **124**(1): p. 29-33.
46. van der Sluis, M.E., et al., *Longitudinal associations of energy balance-related behaviours and cross-sectional associations of clusters and body mass index in Norwegian adolescents.* Public Health Nutr, 2010. **13**(10 A): p. 1716-1721.
47. Gubbels, J.S., et al., *Clustering of dietary intake and sedentary behavior in 2-year-old children.* J Pediatr, 2009. **155**(2): p. 194-8.
48. Muthén, B. and L.K. Muthén, *Integrating person ‐centered and variable ‐centered analyses: Growth mixture modeling with latent trajectory classes.* Alcoholism: Clinical and experimental research, 2000. **24**(6): p. 882-891.

Table S1. Non-response analyses.

Variables	Population for analyses (n=2090) %/ mean(SD)	Population Excluded (n=913) %/ mean(SD)	*p-value*
Maternal educational level			<0.001
Low	10.14	22.27	
Middle	35.29	37.91	
High	54.57	39.82	
Maternal weight status baseline			0.15
Normal	12.11	14.78	
Overweight	31.94	30.51	
Obesity	55.95	54.71	
Maternal age at child birth, years, mean (SD)	31.12(4.16)	30.26(0.15)	<0.001
Child ethnic background, Dutch	84.11	80.37	0.01
Child gender, male	51.48	49.49	0.32
Intervention group			0.003
Control group	34.89	39.96	
'BBOFT+'	29.68	30.74	
'E-health4Uth'	35.42	29.31	
Parenting style			
Authoritative	40.34	31.43	0.10
Permissive	14.7	15.24	
Authoritarian	25.74	24.76	
Permissive	19.22	28.57	

Table S2. The questionnaire for child lifestyle behaviors at child age 36 months.

	Answering categories and value assignment
Sugar-containing drinks consumption	
A1. How many cups or packages do your child drink on average on a weekday of the sugar-sweetened drinks (drinks with additional sugar: soft drinks such as cola, 7-ups … Ice-tea, fruit cordials or syrup; fruit juice with added sugars; sport and energy drinks with sugar; sweetened dairy drinks; tea or water with sugar)	No or lower than 1=0, 1, 2, …, 9 or more=9;
A2. How many cups or packages do your child drink on average on a weekend day of the sugar-sweetened drinks?	No or lower than 1=0, 1, 2, …, 9 or more=9;
Child sugar-containing drinks consumption per day=(A1*5+A2*2)/7	
Unhealthy snacks consumption	
B1 How many servings of the following snacks will your child eat on average one day? Candy (cake, ice cream, chocolate, candies, mars)	0 or less than 1=0, 1, 2, …, 9 or more=9;
B2 How many servings of the following snacks will your child eat on average one day? Snacks (chips, nuts, fries, pizza, hamburger)	0 or less than 1=0,1, 2, …, 9 or more=9;
Child unhealthy snack consumption per day=B1+B2	
Fruit consumption	
How many servings of fruit does your child eat on average per day? (e.g. apple, orange, pear, kiwi, banana, mandarin, strawberry)	No intake, less than ½ serving, ½ serving, 1 serving, 2 serving, 3 serving, 4 serving, 5 serving or more;
Vegetable consumption	
How many serving spoons of vegetable does your child eat on average per day? (examples of vegetables: Green beans, Carrots, Cauliflower, Sweet pepper, Broccoli, Red cabbage, Sprouts, Tomato, Lettuce, Kale, Spinach, Leek, Cucumber)	No intake, less than ½ serving, ½ serving, 1 serving, 2 serving, 3 serving, 4 serving, 5 serving or more;
Screen time (questions asked about the conditions in last four weeks)	
C1. Does your child watch TV/video/DVD?	NO=0, Yes=1;
C2. On how many days does your child watch TV/video/DVD during the weekdays (number of days)?	Not applicable=0, less than one day=0.5, 1 day=1, 2 days=2, 3 days=3, 4 days=4, 5 days=5;

C3. How long per day does your child watch TV/video/DVD on average during the weekdays (hours)?	Not applicable=0, less than 30 minutes per day =0.25, 30 minutes to 1 hour per day=0.75, 1 to 2 hours per day =1.5, 2 to 3 hours per day =2.5, 3 to 4 hours per day =3.5, 4 to 5 hours per day =4.5, 5 to 6 hours per day =5.5, more than 6 hours=6.5;
C4. On how many days does your child watch TV/video/DVD during the weekends (number of days)?	Not applicable=0, less than one day =0.5, 1 day=1, 2 days=2;
C5. How long per day does your child watch TV /video/DVD on average on weekends (hours)?	Not applicable=0, less than 30 minutes per day =0.25, 30 minutes to 1 hour per day=0.75, 1 to 2 hours per day =1.5, 2 to 3 hours per day =2.5, 3 to 4 hours per day =3.5, 4 to 5 hours per day =4.5, 5 to 6 hours per day =5.5, more than 6 hours=6.5;
C6. Does your child play computer games?	NO=0, Yes=1;
C7. On how many days does your child spend time on playing computer games during the weekdays (number of days)??	Not applicable=0, less than one day=0.5, 1 day=1, 2 days=2, 3 days=3, 4 days=4, 5 days=5;
C8. How long per day does your child spend on playing computer games on average during the weekday (hours)?	Not applicable=0, less than 30 minutes per day =0.25, 30 minutes to 1 hour per day=0.75, 1 to 2 hours per day =1.5, 2 to 3 hours per day =2.5, 3 to 4 hours per day =3.5, 4 to 5 hours per day =4.5, 5 to 6 hours per day =5.5, more than 6 hours=6.5;
C9. On how many days does your child spend time on playing computer games during the weekends (number of days)?	Not applicable=0, less than one day =0.5, 1 day=1, 2 days=2;
C10. How long per day does your child play computer games on average during the weekends (hours)?	Not applicable=0, less than 30 minutes per day =0.25, 30 minutes to 1 hour per day=0.75, 1 to 2 hours per day =1.5, 2 to 3 hours per day =2.5, 3 to 4 hours per day =3.5,

	4 to 5 hours per day =4.5, 5 to 6 hours per day =5.5, more than 6 hours=6.5 ;
Child average screen time per day =(C2*C3+ C4*C5)/7+ (C7*C8+C9*C10)/7	
Physical activity	
How many days a week does your child engage in activities that he/she can move actively? (Eg. Swimming, toddler gym, movement to music, walking to the store) Ordinary playing at home we do not count here.	Less than one day, 1 day, 2 days, 3 days, …, 6 days, everyday
How many hours per day on average does your child engage in activities that he/she can move actively?	Not applicable less than 30 minutes per day 30 minutes to 1 hour per day 1 to 2 hours per day 2 to 3 hours per day More than 3 hours per day

Table S3. The probabilities of reporting each unfavorable lifestyle behaviors in the total sample and conditional on the latent classes: results from the control group only.

Unfavorable lifestyle behaviors	Overall Sample (N=730)	Class 1 "unhealthy lifestyle" (27%)	Class 2 "low snacking and low sedentary" (48%)	Class 3 "active, high vegetable, high snacking and high screen time" (24%)	*p-value*[1]
Sugar-containing drinks> 2 cups per day	0.41	0.63	0.10	0.78	<0.001
Unhealthy snacks >1 serving per day	0.41	0.60	0.15	0.72	<0.001
Fruit intake ≤1 servings per day	0.57	0.76	0.46	0.58	<0.001
Vegetable intake ≤1 serving spoons per day	0.66	1.00	0.62	0.37	<0.001
Screen time >1 hours per day	0.47	0.71	0.18	0.80	<0.001
Physical activity <1 hour per day	0.63	1.00	0.62	0.26	<0.001

[1] The difference between groups were compared using Chi-square test.

PART III

Factors associated with children’s health behaviors

CHAPTER 5

Factors associated with early introduction of complementary feeding and consumption of non-recommended foods among Dutch infants: the BeeBOFT study

BMC Public Health 2019; 19:388

Lu Wang, Amy van Grieken, Laura A. van der Velde, Eline Vlasblom, Maaike Beltman, Monique P L'Hoir, Magda M Boere-Boonekamp, Hein Raat

Abstract

Background

Timing and types of complementary feeding in infancy affect nutritional status and health later in life. The present study aimed to investigate the factors associated with early introduction of complementary feeding (i.e., before age 4 months), and factors associated with infants consumption of non-recommended foods, including sweet beverages and snack foods.

Methods

This study used cross-sectional data from the BeeBOFT study (n=2157). Data on complementary feeding practices and potential determinants were obtained by questionnaire at infant's age of 6 months. Logistic regression models were used to investigate factors associated with early introduction of complementary feeding and infants' consumption of non-recommended foods.

Results

21.4% of infants had received complementary feeding before 4 months of age. At the age of 6 months, 20.2% of all infants were consuming sweet beverages daily and 16.5% were consuming snack foods daily. Younger maternal age, lower maternal educational level, absence or shorter duration of breastfeeding, parental conviction that "my child always wants to eat when he/she sees someone eating" and not attending day-care were independently associated with both early introduction of complementary feeding and the consumption of non-recommended foods. Higher maternal pre-pregnancy BMI and infant postnatal weight gain were associated only with early introduction of complementary feeding.

Conclusion

We identified several demographical, biological, behavioral, psychosocial, and social factors associated with inappropriate complementary feeding practices. These findings are relevant for designing intervention programs aimed at educating parents.

Background

Complementary feeding for infants is defined as feeding solid foods and liquids other than breast milk or infant formula [1, 2]. Since 2001, the WHO has recommended that complementary feeding be introduced after the age of 6 months [2]. The European Society for Pediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) recommends introducing complementary feeding not before 17 weeks and no later than 26 weeks [1, 3]. In the Netherlands, *Jeugdgezondheidszorg* (preventive Youth Health Care) is a government-funded program for monitoring children's health and development, and providing health promotion and disease prevention at set ages; the care is offered for free [4]. Approximately 95% of children in the Netherlands participate in this preventive Youth Health Care (henceforth YHC) program [4]. In line with ESPGHAN guidelines, the YHC guideline suggests introducing complementary feeding after the age of 4 months [5].

Despite the inconsistencies in the current guidelines regarding when to introduce complementary feeding, all guidelines agree that complementary feeding should not be introduced before the age of 4 months [1, 3, 5]. Although introducing complementary feeding earlier may contribute to more rapid weight gain during infancy [6-8] and increased risk of childhood obesity in affluent populations [9-12], the introduction of complementary feeding before 4 months is common in many countries. For instance, the percentage of infants introduced to complementary feeding before the age of 4 months was 37% in a birth cohort born in 2007 and 2008 in Northwest Italy [13], 30% across the UK in 2010 [14], and 40% among infants born between 2005 and 2007 participating in a national study in the US [15]. To the best of our knowledge, no study has reported the prevalence of introducing complementary feeding before 4 months in the Netherlands.

It is not only the timing of the introduction of complementary feeding that is important but also the type of food introduced. Current guidelines recommend avoiding foods high in fat, salt or sugar and low in nutritional value in the first year of life [3, 5, 16]. A high intake of foods such as sweet desserts [17] and sweet beverages [18] during infancy is associated with a high intake of these food types in later life, and with childhood overweight and obesity [17]. Furthermore, excessive intake of sugar-containing drinks during infancy may result in diarrhea [19], failure to thrive [20], tooth decay [21], and decline in the consumption of other nutritious foods. It has been shown that a substantial proportion of infants consume sweet beverages and snack foods such as chocolate, cookies, and chips [22-25].

To develop targeted interventions to discourage the early introduction of complementary feeding and the consumption of non-recommended food types among infants, it is important to identify the determinants of both practices. Previous studies have identified a range of maternal and infant related factors associated with early introduction of complementary feeding, such as maternal age, maternal educational level, and maternal Body Mass Index (BMI), infant size or postnatal weight gain, and the initiation and duration of breastfeeding [26-33]. Psychosocial factors have so far received scant research attention: one study has suggested that mothers may introduce complementary feeding earlier in response to the infant's fussy temperament [34], another has shown the influence of certain parental beliefs about infant feeding and infant weight status [35]. Factors associated with infants' consumption of non-recommended foods (i.e., energy-dense, nutrient-poor foods and sweet beverages) have also received little attention [24, 25]. Furthermore, the single study we found performed in the Netherlands on factors associated with the timing of complementary feeding introduction [29] did not assess factors associated with the introduction of complementary feeding before child age 4 months [29].

As complementary feeding practices have been found to differ between countries [36], in order to develop population-specific strategies it is important to explore factors associated with complementary feeding practices in different settings. Our study therefore aimed to investigate factors associated with inappropriate complementary feeding practices, including the early introduction of complementary feeding, and the consumption of non-recommended foods, including sweet beverages and snack foods, in a population-based sample of parents and children in the Netherlands. We considered a range of demographic, biological, behavioral, psychosocial, and social factors, and explored their associations with inappropriate complementary feeding practices.

Methods

Study design and study population

We performed secondary data analysis using data from the BeeBOFT study, which is a population-based cluster randomized controlled trial for the primary prevention of overweight among young children (0–3 years) in the Netherlands [37]. In total, 51 YHC teams covering urban and rural areas in the Netherlands participated. Each YHC organization serves a region of the Netherlands, and each YHC team within an organization serves one or more municipalities of the region [4]. A team comprises a physician, nurse, and assistant [4]. The 51 YHC teams were randomly allocated to three study arms, the “BBOFT+” intervention (17 teams), the “E-health4Uth” intervention (17 teams), or the control group (17 teams). At each routine YHC visit (scheduled at child ages of 0.5, 1, 2, 3, 4, 6, 9, 11, 14, 18, and 36 months), parents allocated to the “BBOFT+” group received an intervention on child-rearing skills concerning healthy behavioral lifestyle habits of the child from birth onward. Parents allocated to the “E-health4Uth” group received intervention twice: at child ages of circa 18 and 24 months. Parents in the control group received usual care. After reviewing the research proposal of the BeeBOFT study, the Erasmus University Medical Center Medical Ethics Committee concluded that the Dutch Medical Research Involving Human Subjects Act did not apply to it. The Medical Ethics Committee therefore had no objection to the execution of the BeeBOFT study (proposal number MEC-2008-250).

From January 2009 through September 2010, parents were invited to participate in the BeeBOFT study when one of the 51 participating YHC teams visited them at home 2–4 weeks after the birth of the child. In total, 3003 parents provided written informed consent and filled in the baseline questionnaire. At child age 6 months, all the parents were invited to complete a questionnaire regarding their child’s health-related behaviors, including timing of introduction of complementary feeding, the frequency of consumption of complementary feeding, and the determinants of these behaviors. A total of 2331 parents returned the questionnaire at child age 6 months (age range 6–8 months). The questionnaire asked about the timing of the introduction of 22 types of food. Children for whom values were missing for more than five food types were excluded (n=48). We also excluded preterm babies (gestational age <37 weeks, n=126). Finally, 2157 parent-child dyads were included in the present study.

Compared with the 672 infants excluded due to non-response for the questionnaire, the infants whose parents have responded the questionnaire (n=2331) at child age 6 months had higher educated (20.0 % low educated VS 11.4 % low educated, p<0.01).

Measurements

Infant complementary feeding

Timing of complementary feeding

At child age 6 months, parents were asked to report in the questionnaire at which age the child had received the following products (Table S1): fruit juice; fruit juice concentrate; soft drinks (e.g., cola, iced tea); light soft drinks; fruit cordials or syrup; sweetened dairy drinks; milk or buttermilk; yogurt; porridge; bread; baby cookies; chocolate or candy; crackers or breadsticks; fruit from a jar; fresh fruit; vegetables from a jar; vegetables with fish or meat from a jar; pasta/rice/potato; fresh vegetable; fish/meat/meat substitutes. The response categories included: “<1 month”, “between 1–2 months”, “between 2–3 months”, “between 3–4 months”, “between 4–5 months”, “older than 5 months”, and “never given”. Parents could choose “never given” if at the time they filled in the questionnaire they had not introduced that food item. For descriptive analysis, the response categories “<1 month”, “between 1–2 months”, “between 2–3 months”, and “between 3–4 months” were combined into “before 4 months”. The average age of the infants when parents filled in the questionnaire was 6.3 months, SD=0.6. The drinks fruit juice, fruit juice concentrate, soft drinks, fruit cordial or syrup, and sweetened dairy drinks were combined into one category called sweet beverages. The foods baby cookies and chocolate or candy were combined into one category called snack foods. The timing of introduction of complementary feeding was defined as the earliest time point that any of the abovementioned drinks and foods were first given to the child. Early introduction of complementary feeding was defined as introduction of complementary feeding (i.e., drinks and foods) before 4 months.

Frequent consumption of non-recommended foods

The questionnaire also assessed how frequently on average the child was given the abovementioned food products when parents filled in the questionnaire at 6 months. The response categories included: “never given”, “<once per week”, “1–3 times per week”, “4–6 times per week”, “1–2 times per day”, “3–4 times per day”, and “>5 times per day”. The non-recommended foods included sweet beverages and snack foods as defined above. Frequent consumption of non-recommended foods was defined as the consumption of sweet beverages and/or snack foods ≥1 time per day.

Independent variables

Based on previous research [26-32, 38], the following variables were selected as potential determinants for the early introduction of complementary feeding and consumption of non-recommended foods.

Demographic characteristics

The demographic characteristics obtained by the baseline questionnaire were maternal age (years), maternal educational level, maternal ethnic background (native/non-native), maternal employment status (employed/unemployed), family structure (single parent/two parents), child gender (girl/boy), parity (primipara/multipara), and gestational age (weeks). Maternal educational level was categorized as high (higher vocational training, university degree), middle (>4 years general secondary school or intermediate vocational training), and low (no education, primary school, or 4 years or less general secondary school) [39]. The mother's ethnic background was classified as non-native if one of her parents had been born outside the Netherlands [40].

Biological factors

Maternal pre-pregnancy weight and height were self-reported in the baseline questionnaire. Maternal pre-pregnancy BMI was calculated by weight (kg)/height^2 (meters). Data on child weight at birth and at age 3 months were acquired from the YHC registration files. Child weight and height were measured by YHC professionals in accordance with standardized protocols at each routine visit (set at ages 0, 1, 2, 3, 4, 6 months) [41]. Child weight for age Z-score 7was calculated using the Dutch 1997 age- and gender- specific reference values [42]. Infant postnatal weight gain between age 0–3 months was calculated by subtracting the weight for age Z-score at birth from the weight for age Z-score at 3 months.

Behavioral factors

At child age 6 months, parents were asked to report whether they had started breastfeeding (yes, no), and, if so, how old the child was when the mother stopped breastfeeding (response categories included within 2 weeks, between 2 and 4 weeks, between 1 and 2 months, between 2 and 3 months, between 3 and 4 months, between 4 and 5 months, older than 5 months, and still breastfeeding) (Table S1). The responses to these two questions led us to create a new variable indicating the duration of any breastfeeding: "no breastfeeding", "breastfeeding for 0.5–4 months", or "breastfeeding for 4 months or longer".

Psychosocial factors

The psychosocial factors maternal depressive symptoms, parental beliefs, and infant temperament were assessed by parental questionnaire at child age 6 months. Maternal depressive symptoms were assessed using the 10-question Edinburgh Postnatal Depression Scale [43]. Mothers scoring 10 or higher were classified as having depressive symptoms. This variable was defined as missing if the questionnaire had been filled in by the father or another care giver (n=107).

Parental beliefs/perceptions about infant characteristics, feeding, and infant weight were assessed. The items are based on a previous study investigating parental views on child overweight-related behaviors [44]. Example items included the following statements "My child always wants to eat when he/she sees someone eating", "Fruit and vegetables can be given to the baby freely earlier than 4 months" and "I don't like my child to be fat". Parents could respond on a 5-point scale ranging from "strongly agree" to "strongly disagree". The responses were dichotomized into "1" indicating agree/strongly agree, and "0" indicating neutral, disagree, or strongly disagree.

Infant temperament, e.g., soothability, distress to limitations, and distress to novel food, was measured using subscales from the Infant Behavior Questionnaire [45]. The subscales were chosen based on previous research on infant temperament and infant feeding [34]. An example item used to measure soothability was "When part of the child's body was patted or stroked, how often did she/he calm down immediately?", for distress to limitations, "When having to wait for food or liquids during the last week, how often did the child cry loudly", and for distress to novel food, "When given a new food or liquid, how often did the child accept it immediately?". Parents rated these specific child behaviors on a 7-point scale ranging from 1 ("Never") to 7 ("always").

Social factors

Day-care attendance of the infants was reported by parents in the questionnaire at child age 6 months. In addition, we included a variable entitled "intervention group" for the current study. Parents allocated to the "BBOFT+" study arm were defined as the "BBOFT+ intervention" group, while parents allocated to the control group or the "E-health" intervention group were combined to form a "no intervention" group.

Statistical analysis

All statistical analyses were performed using SAS version 9.4. Descriptive statistics for the study population were presented in relation to the timing of the introduction of complementary feeding (<4 months vs ≥4 months). Differences between the two groups were compared by independent sample *t* test for continuous variables, and by the test for categorical variables.

Intra-class coefficients (ICC) for our outcome variables (early introduction of complementary feeding and consumption of non-recommended foods) were calculated to decide whether the outcome variables differed for the participating YHC teams. The ICCs for both outcome variables were 0.02, suggesting a very low intra-class correlation and therefore multilevel modeling was not used. In addition, we found no significant influence of the intervention group on both outcome variables (both $p>0.25$). We therefore applied normal logistic regression analyses to the data on all available participants to assess the factors associated with the early introduction of complementary feeding and with the frequent consumption of non-recommended foods. First, univariate logistic regression models were fitted for each of the independent variables with the outcome variables. Second, independent variables that were significantly ($p<0.05$) associated with the outcome variables in the univariate models were included in the multivariate model, to assess the independent association between the factors and outcome variables. The univariate and multivariate models were both adjusted for the exact age of the child.

Results

Sample characteristics

Table 1, which presents the characteristics of the mothers and infants in relation to the timing of the introduction of complementary feeding, shows that 11.3% of mothers were low educated, 36.0% were middle educated, and 52.7% high educated, and that 24.6% had not breastfed, whereas 40.6% of the mothers had breastfed but stopped doing so before the child was 4 months.

Complementary feeding practices

Table 2 presents the timing of the introduction of different types of complementary food. Overall, the percentage of infants who had been given any type of complementary food at the age of 3, 4, and 5 months was 4.5% (data not shown in table), 21.4%, and 38.1% respectively. At the moment parents filled in the questionnaire (mean age=6.4 months, SD=0.7), 98.7% of the infants had been given some type of complementary food. The food products most frequently introduced before 4 months were porridge (11.8%), fruit (11.0%), vegetables (6.4%), and sweet beverages (6.1%).

Table 2. The timing of introduction of different types of complementary food (N=2157)

Type of complementary food	Before 4 months	Between 4–5 months	After age 5 months[1]	Never given[2]
	N (%)	N (%)	N (%)	N (%)
Sweet beverages [3]	132(6.1)	251(11.6)	740(34.3)	1036(48.0)
Milk or buttermilk	18(0.8)	8(0.4)	57(2.7)	2067(96.1)
Yogurt	32(1.5)	99(4.6)	611(28.4)	1413(65.6)
Porridge	255(11.8)	605(28.0)	719(33.3)	580(26.9)
Bread	10(0.5)	81(3.8)	1019(47.2)	1047(48.5)
Snack foods [4]	16(0.7)	124(5.7)	713(33.0)	1306(60.5)
Crackers or breadsticks	4(0.2)	55(2.6)	484(22.5)	1610(74.8)
Fruit	236(11.0)	791(36.7)	1067(49.5)	62(2.9)
Vegetables	137(6.4)	638(29.6)	1240(57.4)	144(6.7)
Pasta/potato/rice	16(0.7)	112(5.2)	1072(49.8)	952(44.2)
Fish/meat/meat substitutes	34(1.6)	163(7.6)	1120(51.9)	841(39.0)
Any complementary food	462(21.4)	875(40.5)	794(36.8)	28(1.3)

[1]: After the child reached the age of 5 months, and before the time parent completed the questionnaire on infant feeding. The mean age of the infants at questionnaire completion was 6.3 months (SD=0.6).
[2]: Complementary feeding had not yet been introduced to the infant when parents filled in the questionnaire.
[3]: Including fruit juice, fruit juice concentrate, soft drinks (e.g. cola, iced tea), fruit cordials or syrup, and sweetened dairy products.
[4]: Including baby cookies, and chocolate or candy

Figure 1 presents the frequency of consumption of sweet beverages and snack foods by the infants. At the age of 6 months, 41% of the infants were consuming sweet beverages at least once a week and 20.2% of the infants were consuming sweet beverages daily. In addition, 35% of the infants were consuming snack food at least once weekly, and 16.5 % of the infants were consuming snack food daily. In total, 27.0% of the infants were consuming non-recommended foods (i.e., sweet beverages and/or snack food) at least once daily.

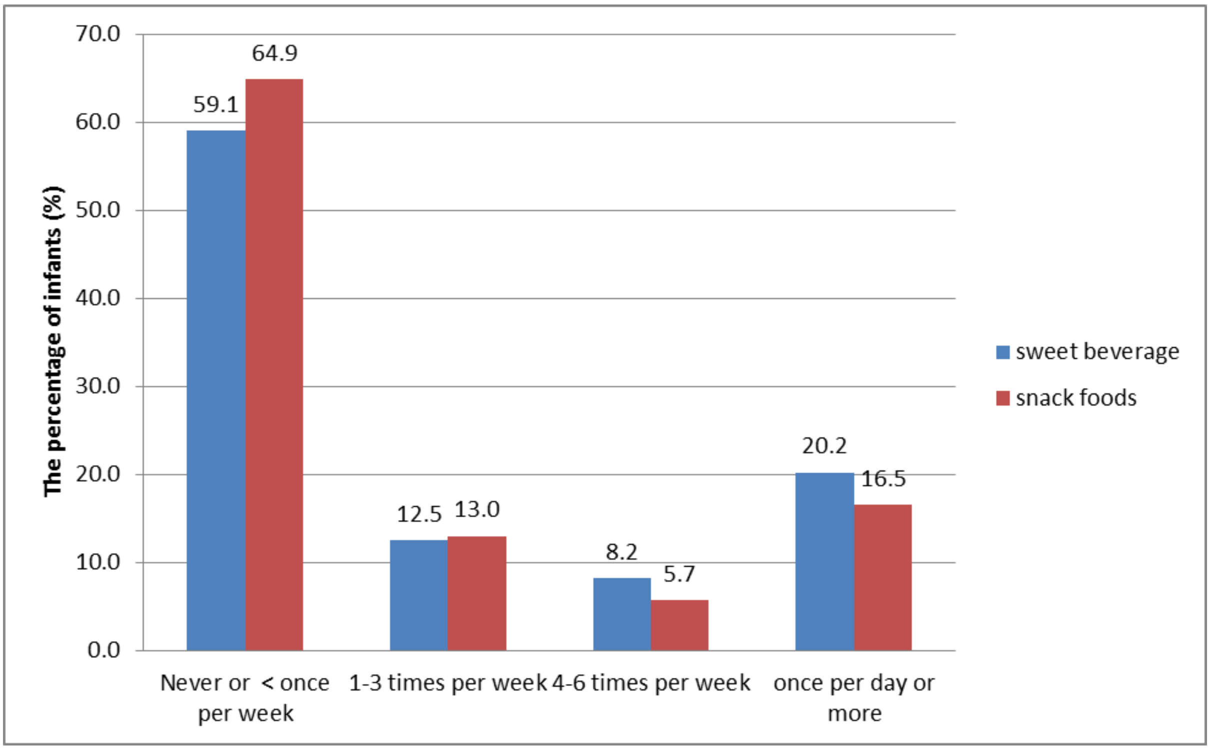

Figure 1. The frequency of consumption of non-recommended foods by the infant at the age of 6 months (n=2157)

Factors associated with early introduction of complementary feeding

Table 3 shows the results of univariate and multivariate logistic regression models for factors associated with early introduction of complementary feeding (i.e., introduction of complementary feeding before child age 4 months). The demographic characteristics independently associated with early introduction of complementary feeding were younger maternal age and lower maternal educational level. For biological factors: increased maternal pre-pregnancy BMI and increased infant postnatal weight gain were independently associated with higher odds of early introduction of complementary feeding. For behavioral factors: compared to any breastfeeding for 4 months or longer, no breastfeeding or breastfeeding for less than 4 months was independently associated with early introduction of complementary feeding. For psychosocial factors: the beliefs "fruit and vegetables can be given to the baby freely earlier than 4 months", and "my child always wants to eat when he/she sees someone eating" were independently associated with higher odds of early introduction of complementary feeding. For social factors, day-care attendance was independently associated with lower odds of early introduction of complementary feeding.

Factors associated with frequent consumption of non-recommended foods

The results of the multivariate logistic regression model (Table 4) suggest that younger maternal age, lower maternal educational level, and no breastfeeding or breastfeeding for less than 4 months were associated with frequent consumption of non-recommended foods (once or more per day) of the infants at the age of 6 months. Of the psychosocial factors, the beliefs “fruit and vegetables can be given to the child freely earlier than 4 months” and “my child always wants to eat when he/she sees someone eating” were associated with frequent consumption of non-recommended foods. Infant temperament “soothability” was positively associated with frequent consumption of non-recommended foods, while “distress to novel food” was negatively associated with frequent consumption of non-recommended foods. Of the social factors, day-care attendance was associated with lower consumption of non-recommended foods.

Discussion

In our population-based sample of parent–child dyads from the Netherlands, 21% of the infants were introduced to complementary feeding before the age of 4 months, and 38% of the infants were introduced to complementary feeding after 5 months. Less than 2% of the infants had not received any complementary feeding at the moment of questionnaire completion (mean age of the infants then was 6.3 months). In addition, we observed that a significant proportion of the infants were consuming sweet beverages or snack food at age 6 months, pointing to a need to put greater emphasis on discouraging giving sweet beverages and snack foods to infants.

In line with previous research [25, 26, 33, 46], we found that mothers who were younger, less educated, and who did not initiate breastfeeding or breastfed for shorter duration were more likely to introduce complementary feeding early. In addition, our results suggest that these factors are also associated with frequent consumption of non-recommended foods among the infants. Our findings underline the need to develop effective interventions targeting these groups of mothers (i.e., younger, lower educated, and not breastfeeding) to improve their feeding practices, including the timing and types of complementary feeding.

Our results suggest that mothers with higher pre-pregnancy BMI were more likely to introduce complementary feeding early. Previous studies have suggested that maternal pre-pregnancy overweight/obesity is linked to impaired lactogenesis [47-49]. Overweight or obese mothers may have difficulty initiating or sustaining breastfeeding, and therefore may introduce complementary feeding earlier to compensate for the insufficiencies in breastmilk. In line with this hypothesis, we found that the association between maternal pre-pregnancy BMI and early introduction of complementary feeding was reduced to borderline significance after adjusting for breastfeeding duration (data not shown).

Our results reveal that infants with more rapid postnatal weight gain were more likely to receive complementary feeding early. This finding is consistent with previous evidence [6, 50, 51]. Our study further confirmed that rapid postnatal weight gain was associated with early introduction of complementary feeding independent of factors such as breastfeeding duration. A possible explanation for this association is that infants who grow faster in the first few months may show more hunger cues, or signs of readiness for complementary feeding. Rapid weight gain in the first few months is associated with increased risk of overweight [52-54], and cardiovascular risk factors in later life [55-57]. Early introduction of complementary feeding may further increase infants' energy intake and growth velocity [6-8]. Future research investigating the influence of complementary feeding practices on infant weight gain should be aware of the reverse causality: that rapid postnatal weight gain may induce early introduction of complementary feeding.

Our study further revealed that psychosocial factors play an important role in parents' adoption of complementary feeding practices. We identified several parental perceptions/beliefs concerning infant characteristics and infant weight that may contribute to inappropriate complementary feeding practices. For instance, parents who perceived that "my child always wants to eat when he/she sees someone eating" and parents who agree with the idea that "fruit and vegetables can be given to the child freely earlier than 4 months" were more likely to introduce complementary feeding early, and to give their infants non-recommended foods more frequently. We are aware of only one study that has included the parental perceptions or beliefs as determinants of infant complementary feeding [58], and comparison with that study is difficult because the outcome variables was defined differently. As psychosocial factors tend to be more modifiable than demographical and biological factors, in future intervention programs it would be beneficial to target these psychosocial contributors for inappropriate complementary feeding. In view of the cross-sectional nature of our data, no causal relationship can be inferred from the present study. We recommend further longitudinal studies or controlled trials to confirm our findings. In addition, we recommend conducting further qualitative or quantitative to obtain more thorough understanding of the psychosocial factors contributing to inappropriate complementary feeding.

With regard to social factors, we found that infants who attended day-care were less likely to receive complementary feeding early and were less likely to consume non-recommended foods frequently. Previous studies conducted in other countries have found no association between day-care attendance and early introduction of complementary feeding [33]. However, differences in the overall child-care systems in different countries (for example, different policies, social norms), might have influenced the findings. Consistent with our study, a previous study in the Netherlands suggested that day-care attendance is associated with less unhealthy lifestyles of young children [44]. It has also been reported that day-care attendance in the first year of life was associated with better general health and lower risk of overweight and obesity of the children across the age span of 1 to 8 years in a birth cohort from the Netherlands [59]. The association of day-care use and more favorable infant feeding practices in the present study and more favorable lifestyles and general health of children found in previous studies might reflect other characteristics of families using day-care facilities. In our study, the mothers of children who attended day-care at age 6 months were more often higher educated, employed, and less often overweight. We recommend further studies to investigate the reasons for the role of day-care attendance on children's healthy lifestyles and health outcomes.

A limitation of the present study is that the timing of introduction of complementary feeding was self-reported by parents retrospectively. However, the data were collected when infants were 6 months, which was close to the time of introduction of complementary feeding. This may have reduced the recall bias on timing of introduction of complementary feeding. Secondly, it should be noted that the participants who responded to the questionnaire had a higher educational level and higher rate of breastfeeding than those who did not. Our study may therefore have underestimated the proportion of infants in the population who had received complementary feeding before 4 months. Thirdly, it is a limitation of the present study that we were unable to precisely estimate the percentage of infants who were introduced to complementary feeding after the age of 6 months. However, this study followed the ESPHAGAN recommendation adopted by many countries in Europe, which defines early introduction of complementary feeding as the introduction of complementary feeding before 4 months [3, 5, 36]. Finally, our study used data from a cluster randomized controlled trial for prevention of childhood overweight [37]. Parents allocated to the BBOFT+ group received intervention on child-rearing practices from birth onwards. The intervention did not include specific information on timing of the introduction of complementary feeding. The intervention is unlikely to have influenced our results, as the ICC was low and a sensitivity analysis using a sample from the control group generated comparable results.

Conclusions

In conclusion, the present study addresses the need to improve the compliance with complementary feeding guidelines among parents in the Netherlands, more specifically the introduction of complementary feeding after age 4 months, and the avoidance of giving infants sweet beverages and snack foods. Factors associated with inappropriate complementary feeding practices include younger maternal age, lower maternal educational level, absence or shorter duration of breastfeeding, increased maternal pre-pregnancy BMI and infant postnatal weight gain, and not attending day-care. We also identified several psychosocial factors associated with inappropriate complementary feeding practices. These findings are relevant for designing targeted interventions aimed at educating parents to improve their complementary feeding practices.

References

1. Agostoni, C., et al., *Complementary feeding: a commentary by the ESPGHAN Committee on Nutrition.* Journal of pediatric gastroenterology and nutrition, 2008. **46**(1): p. 99-110.
2. *Global strategy for infant and young child feeding*. 2003: Geneva: World Health Organization.
3. Fewtrell, M., et al., *Complementary feeding: A position paper by the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) committee on nutrition.* Journal of pediatric gastroenterology and nutrition, 2017. **64**(1): p. 119-132.
4. Verbrugge, H.P., *Youth health care in The Netherlands: a bird's eye view.* Pediatrics, 1990. **86**(6 Pt 2): p. 1044-7.
5. Lanting CI, H.-O.H., Schuit-van Raamsdonk. *Richtlijn: Voeding en eetgedrag (2013, aanpassing 2017). Guideline: Nutrition and eating behavior (2013, adaptation 2017)*. 2017; Available from: https://www.ncj.nl/richtlijnen/alle-richtlijnen/richtlijn/voeding-en-eetgedrag.
6. van Rossem, L., et al., *Weight change before and after the introduction of solids: results from a longitudinal birth cohort.* Br J Nutr, 2013. **109**(2): p. 370-5.
7. Vail, B., et al., *Age at Weaning and Infant Growth: Primary Analysis and Systematic Review.* J Pediatr, 2015. **167**(2): p. 317-24 e1.
8. Baker, J.L., et al., *Maternal prepregnant body mass index, duration of breastfeeding, and timing of complementary food introduction are associated with infant weight gain.* Am J Clin Nutr, 2004. **80**(6): p. 1579-88.
9. Huh, S.Y., et al., *Timing of solid food introduction and risk of obesity in preschool-aged children.* Pediatrics, 2011. **127**(3): p. e544-51.
10. Pearce, J., M.A. Taylor, and S.C. Langley-Evans, *Timing of the introduction of complementary feeding and risk of childhood obesity: a systematic review.* Int J Obes (Lond), 2013. **37**(10): p. 1295-306.
11. Moss, B.G. and W.H. Yeaton, *Early childhood healthy and obese weight status: potentially protective benefits of breastfeeding and delaying solid foods.* Matern Child Health J, 2014. **18**(5): p. 1224-32.
12. Daniels, L., et al., *The timing of solid introduction in an 'obesogenic' environment: a narrative review of the evidence and methodological issues.* Aust N Z J Public Health, 2015. **39**(4): p. 366-73.
13. Carletti, C., et al., *Introduction of Complementary Foods in a Cohort of Infants in Northeast Italy: Do Parents Comply with WHO Recommendations?* Nutrients, 2017. **9**(1).
14. McAndrew, F., et al., *Infant feeding survey 2010.* Leeds: Health and Social Care Information Centre, 2012.
15. Clayton, H.B., et al., *Prevalence and reasons for introducing infants early to solid foods: variations by milk feeding type.* Pediatrics, 2013: p. peds. 2012-2265.
16. (USDA), U.S.D.o.A., *Infant Nutrition and Feeding: A Guide for Use in the WIC and CSF Programs.* USDA; Washington, DC, 2008.
17. Rose, C.M., L.L. Birch, and J.S. Savage, *Dietary patterns in infancy are associated with child diet and weight outcomes at 6 years.* International Journal of Obesity, 2017. **1**: p. 6.
18. Park, S., et al., *The association of sugar-sweetened beverage intake during infancy with sugar-sweetened beverage intake at 6 years of age.* Pediatrics, 2014. **134**(Supplement 1): p. S56-S62.
19. Hoekstra, J.H., *Toddler diarrhoea: more a nutritional disorder than a disease.* Archives of disease in childhood, 1998. **79**(1): p. 2-5.
20. Smith, M.M. and F. Lifshitz, *Excess fruit juice consumption as a contributing factor in nonorganic failure to thrive.* Pediatrics, 1994. **93**(3): p. 438-443.

21. Holt, R.D. and P.J. Moynihan, *The weaning diet and dental health.* British dental journal, 1996. **181**(7): p. 254-259.
22. Fox, M.K., et al., *Feeding infants and toddlers study: What foods are infants and toddlers eating?* J Am Diet Assoc, 2004. **104**(1 Suppl 1): p. s22-30.
23. Tarrant, R.C., et al., *Factors associated with weaning practices in term infants: a prospective observational study in Ireland.* Br J Nutr, 2010. **104**(10): p. 1544-54.
24. Hendricks, K., et al., *Maternal and child characteristics associated with infant and toddler feeding practices.* J Am Diet Assoc, 2006. **106**(1 Suppl 1): p. S135-48.
25. Schrempft, S., et al., *Family and infant characteristics associated with timing of core and non-core food introduction in early childhood.* Eur J Clin Nutr, 2013. **67**(6): p. 652-7.
26. Kronborg, H., E. Foverskov, and M. Vaeth, *Predictors for early introduction of solid food among Danish mothers and infants: an observational study.* BMC Pediatr, 2014. **14**: p. 243.
27. Scott, J.A., et al., *Predictors of the early introduction of solid foods in infants: results of a cohort study.* BMC Pediatr, 2009. **9**: p. 60.
28. Klingberg, S., J. Ludvigsson, and H.K. Brekke, *Introduction of complementary foods in Sweden and impact of maternal education on feeding practices.* Public Health Nutr, 2016: p. 1-9.
29. Tromp, II, et al., *Factors associated with the timing of introduction of complementary feeding: the Generation R Study.* Eur J Clin Nutr, 2013. **67**(6): p. 625-30.
30. Tatone-Tokuda, F., L. Dubois, and M. Girard, *Psychosocial determinants of the early introduction of complementary foods.* Health Educ Behav, 2009. **36**(2): p. 302-20.
31. Castro, P.D., J. Kearney, and R. Layte, *A study of early complementary feeding determinants in the Republic of Ireland based on a cross-sectional analysis of the Growing Up in Ireland infant cohort.* Public Health Nutr, 2015. **18**(2): p. 292-302.
32. Doub, A.E., K.J. Moding, and C.A. Stifter, *Infant and maternal predictors of early life feeding decisions. The timing of solid food introduction.* Appetite, 2015. **92**: p. 261-8.
33. Wijndaele, K., et al., *Determinants of early weaning and use of unmodified cow's milk in infants: a systematic review.* J Am Diet Assoc, 2009. **109**(12): p. 2017-28.
34. Wasser, H., et al., *Infants perceived as "fussy" are more likely to receive complementary foods before 4 months.* Pediatrics, 2011. **127**(2): p. 229-37.
35. Brown, A. and H. Rowan, *Maternal and infant factors associated with reasons for introducing solid foods.* Matern Child Nutr, 2016. **12**(3): p. 500-15.
36. Schiess, S., et al., *Introduction of complementary feeding in 5 European countries.* J Pediatr Gastroenterol Nutr, 2010. **50**(1): p. 92-8.
37. Raat, H., et al., *Primary prevention of overweight in preschool children, the BeeBOFT study (breastfeeding, breakfast daily, outside playing, few sweet drinks, less TV viewing): design of a cluster randomized controlled trial.* BMC Public Health, 2013. **13**: p. 974.
38. Alzaheb, R.A., *Factors Associated with the Early Introduction of Complementary Feeding in Saudi Arabia.* Int J Environ Res Public Health, 2016. **13**(7).
39. Netherlands, S., *Dutch standard classification of education 2003.* Voorburg/Heerlen, Netherlands: Statistics Netherlands, 2004.
40. Netherlands, S. *How does Statistics Netherlands define an immigrant*. 2016; Available from: https://www.cbs.nl/nl-nl/faq/specifiek/wat-verstaat-het-cbs-onder-een-allochtoon-.
41. Bulk-Bunschoten, A.M.W., et al. *Signaleringsprotocol overgewicht in de jeugdsgezondheidszorg Youth health care overweight-detection-protocol*. 2004; Available from: https://www.ggdghorkennisnet.nl/?file=748&m=1310480599&action=file.download.
42. Fredriks, A.M., et al., *Continuing positive secular growth change in The Netherlands 1955–1997.* Pediatric research, 2000. **47**(3): p. 316-323.
43. Cox, J.L., J.M. Holden, and R. Sagovsky, *Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale.* The British journal of psychiatry, 1987. **150**(6): p. 782-786.

44. Boere-Boonekamp, M.M., et al., *Overweight and obesity in preschool children (0-4 years): behaviour and views of parents.* Nederlands tijdschrift voor geneeskunde, 2008. **152**(6): p. 324-330.
45. Rothbart, M.K., *Measurement of temperament in infancy.* Child development, 1981: p. 569-578.
46. Boudet-Berquier, J., et al., *Introduction of complementary foods with respect to French guidelines: description and associated socio-economic factors in a nationwide birth cohort (Epifane survey).* Matern Child Nutr, 2016.
47. Rasmussen, K.M. and C.L. Kjolhede, *Prepregnant overweight and obesity diminish the prolactin response to suckling in the first week postpartum.* Pediatrics, 2004. **113**(5): p. e465-71.
48. Buonfiglio, D.C., et al., *Obesity impairs lactation performance in mice by inducing prolactin resistance.* Sci Rep, 2016. **6**: p. 22421.
49. Garcia, A.H., et al., *Maternal weight status, diet, and supplement use as determinants of breastfeeding and complementary feeding: a systematic review and meta-analysis.* Nutr Rev, 2016. **74**(8): p. 490-516.
50. Jobe, A.H., *Age of weaning and infant growth.* The Journal of pediatrics, 2015. **167**(2): p. 219-221.
51. Wright, C.M., K.N. Parkinson, and R.F. Drewett, *Why are babies weaned early? Data from a prospective population based cohort study.* Arch Dis Child, 2004. **89**(9): p. 813-6.
52. Baird, J., et al., *Being big or growing fast: systematic review of size and growth in infancy and later obesity.* Bmj, 2005. **331**(7522): p. 929.
53. Monteiro, P.O. and C.G. Victora, *Rapid growth in infancy and childhood and obesity in later life--a systematic review.* Obes Rev, 2005. **6**(2): p. 143-54.
54. Salgin, B., et al., *Even transient rapid infancy weight gain is associated with higher BMI in young adults and earlier menarche.* Int J Obes (Lond), 2015. **39**(6): p. 939-44.
55. Singhal, A., et al., *Is slower early growth beneficial for long-term cardiovascular health?* Circulation, 2004. **109**(9): p. 1108-13.
56. Leunissen, R.W., et al., *Timing and tempo of first-year rapid growth in relation to cardiovascular and metabolic risk profile in early adulthood.* Jama, 2009. **301**(21): p. 2234-42.
57. Marinkovic, T., et al., *Early Infant Growth Velocity Patterns and Cardiovascular and Metabolic Outcomes in Childhood.* J Pediatr, 2017. **186**: p. 57-63 e4.
58. Thompson, A.L. and M.E. Bentley, *The critical period of infant feeding for the development of early disparities in obesity.* Soc Sci Med, 2013. **97**: p. 288-96.
59. Ruijsbroek, A., et al., *The development of socio-economic health differences in childhood: results of the Dutch longitudinal PIAMA birth cohort.* BMC Public Health, 2011. **11**(1): p. 225.

Table 1. Characteristics of the total study population (n=2157).

Variable	Missing	Age at introduction of complementary feeding		*p* value
		>4 months N (%)	<4 months N (%)	
Total		1695(78.6)	462 (21.4)	
Demographic characteristics				
Maternal age at child birth, years, mean (SD)	31	31.36(4.1)	29.7(4.3)	<0.001
Maternal educational level	13			<0.001
Low		147(8.7)	96(21.1)	
Middle		576(34.1)	195(42.8)	
High		967(57.2)	165(36.2)	
Maternal ethnic background, native	4	1533(90.3)	407(88.1)	0.15
Maternal employment status, employed	4	1449(85.6)	377(81.6)	0.04
Family structure, single parent	23	1659(98.7)	440(96.7)	<0.01
Infant gender, boy	1	843(49.7)	263(57.1)	<0.01
Parity, primipara	0	747(44.0)	251(54.3)	<0.001
Biological factors				
Maternal pre-pregnancy BMI	5	24.0(4.3)	25.0(4.9)	0.02
Infant gestational age at birth, weeks, mean (SD)	0	39.8(1.0)	39.7(1.0)	0.10
Infant weight at birth, Z-score, mean (SD)	10	0.4(1.0)	0.3(1.0)	0.03
Infant postnatal weight gain, Z-score, mean (SD)	677	-0.7(0.8)	-0.5(0.9)	<0.001
Behavioral factors				
Duration of any breastfeeding	6			<0.001
No breastfeeding		360(21.3)	169(36.8)	
Breastfeeding for 0.5–4 months		547(19.4)	207(26.8)	
Breastfeeding for 4 months or longer		789(46.6)	83(18.1)	
Psychosocial factors				
Maternal depressive symptom, yes [1]	119	1445(89.7)	371(86.5)	0.054
Parental perceptions on infant characteristics, (agree/strongly agree)				
"My baby drinks greedily"	23	477(28.4)	135(29.6)	0.07
"My child always wants to eat when he/she sees someone eating"	23	559(33.3)	212(46.6)	<0.001
"My child does not like plain water"	45	293(17.6)	114(25.2)	<0.001
"My child cried a lot in the first 3 months"	16	300(17.8)	99(21.6)	0.06
Parental beliefs about feeding, (agree/strongly agree)				
"Fruit and vegetables can be given to the baby freely earlier than 4 months"	20	39(2.3)	70(15.4)	<0.001
Parental beliefs about infant weight, (agree/strongly agree)				
"I don't like my child to be fat"	20	1206(71.7)	296(64.9)	<0.01
"I don't like my child to be thin"	15	924(54.8)	234(51.1)	0.18

Infant temperament				
Soothability, mean (SD)	31	4.8(1.2)	4.7(1.3)	0.06
Distress to limitation, mean (SD)	33	2.8(0.9)	2.7(0.9)	0.27
Distress to novel food, mean (SD)	36	2.3(1.4)	2.2(1.3)	0.02
Social care factors				
Day-care attendance, yes	25	1250(74.4)	297(65.4)	<0.001
"BBOFT+" intervention [2]	0	509(30.0)	127(27.5)	0.27

[1]: Maternal depressive symptom was defined as a score of 10 or greater on the Edinburgh Postnatal Depression Scale. This variable was defined as missing if the questionnaire had been filled in by the father or other care givers (n=107).

[2]: The "BBOFT+ Intervention" group comprised the group of parents allocated to the BBOFT+ study arm; "no intervention" comprised the groups of parents allocated to the control group or to the "E-health" intervention group.

Table 3. Factors associated with early introduction of complementary feeding.

	Early introduction of complementary feeding < 4 months vs > 4 months	
	Univariate models OR (95%CI)	Multivariate model OR (95%CI)
Demographic characteristics		
Maternal age at child birth (years)	0.91(0.88,0.93)***	0.94(0.91,0.98)**
Maternal educational level		
Low	3.82(2.82,5.19)***	2.48(1.57,3.92)***
Middle	1.98(1.57,2.50)	1.26(0.91,1.75)
High	Ref	Ref
Maternal ethnic background, non-native vs native	1.23(0.88,1.71)	
Maternal employment status, unemployed vs employed	1.33(1.02,1.75)*	0.90(0.57,1.39)
Family structure, single parent vs two parents	2.56(1.32,4.97)**	1.88(0.69,5.13)
Infant gender, girl vs boy	0.74(0.60,0.92)**	0.90(0.67,1.20)
Parity, multipara vs primipara	0.66(0.54,0.81)***	0.79(0.58,1.08)
Biological factors		
Maternal pre-pregnancy BMI	1.05(1.02,1.07)***	1.02(1.00,1.06)
Infant gestational age (weeks)	0.92(0.83,1.02)	
Infant weight at birth, Z-score	0.82(0.66,1.01)	
Infant postnatal weight gain, Z-score [1]	1.33(1.15,1.55)***	1.24(1.05,1.50)*
Behavioral factor		
Duration of any breastfeeding		
No breastfeeding	4.47(3.34,5.97)***	2.84(1.90,4.30)*
Breastfeeding for 0.5–4 months	3.62(2.75,4.78)**	2.63(1.82,3.80)*
Breastfeeding for 4 months or longer	Ref	Ref
Psychosocial factors		
Maternal depressive symptom, yes vs no [2]	1.35(0.98,1.86)	
Parental perceptions on infant characteristics [3]		
"My child drinks greedily"	1.06(0.85,1.34)	
"My child always wants to eat when he/she sees someone eating"	1.75(1.42,2.16)***	1.50(1.11,2.01)**
"My child does not like plain water"	1.58(1.23,2.02)***	1.08(0.76,1.54)
"My child cried a lot in the first 3 months"	1.28(0.99,1.65)	
Parental belief about feeding [3]		
"Fruit and vegetables can be given to the baby freely earlier than 4 months"	7.61(5.07,11.44)***	5.60(3.18,9.85)***
Parental beliefs about infant weight [3]		
"I don't like my child to be fat"	0.73(0.59,0.91)**	0.82(0.59,1.11)
"I don't like my child to be thin"	0.86(0.70,1.06)	
Infant temperament		
Soothability	0.93(0.86,1.01)	
Distress to limitations	0.94(0.83,1.05)	
Distress to novel food	0.91(0.84,0.98)	0.90(0.80,1.01)
Social care factors		

Day-care attendance, yes vs no	0.65(0.52,0.81)**	0.66(0.47,0.93)*
"BBOFT+" intervention vs no intervention	0.89(0.70,1.11)	

Note: The multivariate model included the factors significantly ($p<0.05$) associated with the outcome variable in the univariate models.

1:Calculated by changes in weight for age Z-scores in the first 3 months

2:Maternal depressive symptom was defined as scored 10 or greater on the Edinburgh Postnatal Depression Scale. This variable was defined as missing if the questionnaire had been filled in by the father or other care givers (n=107).

3: Agree/strongly agree vs neutral, disagree, or strongly disagree.

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 4. Factors associated with the consumption of non-recommended foods.

	Frequent consumption of non-recommended foods (≥ once per day vs < once per day)	
	Univariate models OR (95%CI)	Multivariate model OR (95%CI)
Demographic characteristics		
Maternal age at child birth (years)	0.93(0.91,0.96)***	0.96(0.94,0.99)*
Maternal educational level		
Low	2.90(2.15,3.92)***	2.02(1.42,2.86)***
Middle	1.73(1.40,2.15)*	1.36(1.07,1.73)*
High	Ref	Ref
Maternal ethnic background, non-native vs native	1.28(0.94,1.75)	
Maternal employment status, unemployed vs employed	1.23(0.95,1.60)	
Family structure, single parent vs two parents	1.36(0.67,2.76)	
Infant gender, girl vs boy	0.79(0.65,0.97)*	0.86(0.70,1.06)
Parity, multipara vs primipara	0.77(0.63,0.93)**	0.85(0.68,1.08)
Biological factors		
Maternal pre-pregnancy BMI	1.01(0.99,1.03)	
Infant gestational age (weeks)	0.90(0.82,1.00)*	0.94(0.84,1.04)
Infant weight at birth, Z-score	0.94(0.84,1.04)	
Infant postnatal weight gain, Z-score [1]	0.92(0.80,1.06)	
Behavioral factor		
Duration of any breastfeeding		
No breastfeeding	2.37(1.85,3.03)***	1.91(1.44,2.52)***
Breastfeeding for 0.5–4 months	1.51(1.19,1.91)*	1.35(1.04,1.74)*
Breastfeeding for 4 months or longer	Ref	Ref
Psychosocial factors		
Maternal depressive symptom, yes vs no [2]	1.14(0.83,1.55)	
Parental perceptions on characteristics [3]		
"My child drinks greedily"	0.81(0.65,1.01)	
"My child always wants to eat when he/she sees someone eating"	1.59(1.30,1.94)***	1.44(1.16,1.79)***
"My child does not like plain water"	1.31(1.03,1.67)*	1.08(0.83,1.41)
"My child cried a lot in the first 3 months"	0.93(0.72,1.20)	
Parental belief about feeding [3]		
"Fruit and vegetables can be given to the baby freely earlier than 4 months"	2.36(1.58,3.52)*	1.66(1.07,2.56)*
Parental beliefs about infant weight [3]		
"I don't like my child to be fat"	0.78(0.63,0.96)*	0.80(0.64,1.01)
"I don't like my child to be thin"	0.96(0.79,1.17)	
Infant temperament		
Soothability	1.12(1.04,1.22)***	1.15(1.06,1.26)**
Distress to limitations	1.00(0.90,1.12)	
Distress to novel food	0.91(0.85,0.98)*	0.92(0.85,0.99)*
Social care factors		

Day-care attendance, yes vs no	0.63(0.51,0.78)***	0.76(0.60,0.96)*
"BBOFT+" intervention vs no intervention	0.91(0.73,1.13)	

Note: Both the univariate models and the multivariate model adjusted for age at questionnaire measurement. The multivariate model included the factors significantly (p<0.05) associated with the outcome variable in the univariate models.

[1]: Calculated by changes in weight for age Z-scores in the first 3 months.

[2]: Maternal depression symptom was defined as scored 10 or greater on the Edinburgh Postnatal Depression Scale. This variable was defined as missing if the questionnaire had been filled in by the father or other care givers (n=107).

[3]: Agree/strongly agree vs neutral, disagree, or strongly disagree.

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table S1. Factors associated with early introduction of complementary feeding: results in the non-intervention condition.

	Early introduction of complementary feeding (< 4 months vs > 4 month)	
	Univariate models OR (95%CI)	Multivariate model OR (95%CI)
Demographic characteristics		
Maternal age at child birth (years)	0.91(0.88,0.94) ***	0.93(0.89,0.98) **
Maternal educational level		
Low	3.33(2.30,4.83) ***	1.99(1.12,3.54) ***
Middle	1.92(1.46,2.52)	0.98(0.65,1.49)
High	Ref	Ref
Maternal ethnic background, non-native vs native	1.15(0.79,1.67)	
Maternal employment status, unemployed vs employed	1.23(0.89,1.70)	
Family structure, single parent vs two parents	3.38(1.57,7.27) **	2.13(0.71,6.38)
Infant gender, girl vs boy	0.78(0.61,0.99) *	0.86(0.60,1.23)
Parity, multipara vs primipara	0.69(0.54,0.88) ***	0.81(0.55,1.19)
Biological factors		
Maternal pre-pregnancy BMI	1.07(1.04,1.10) ***	1.06(1.02,1.10)
Infant gestational age (weeks)	0.95(0.83,1.07)	
Infant weight at birth, Z-score	0.92(0.80,1.05)	
Infant postnatal weight gain, Z-score [1]	1.35(1.13,1.63) ***	1.19(0.96,1.48)
Behavioral factor		
Duration of any breastfeeding		
No breastfeeding	5.11(3.60,7.26) ***	3.64(2.16,6.13) ***
Breastfeeding for 0.5–4 months	4.00(2.87,5.57) ***	3.06(1.91,4.90) *
Breastfeeding for 4 months or longer	Ref	Ref
Psychosocial factors		
Maternal depressive symptoms, yes vs no [2]	1.28(0.87,1.87)	
Parental perceptions on infant characteristics [3]		
"My child drinks greedily"	0.99(0.76,1.29)	
"My child always wants to eat when he/she sees someone eating"	1.82(1.42,2.34) ***	1.56(1.08,2.25) *
"My child does not like plain water"	1.38(1.03,1.85) *	0.79(0.50,1.23)
"My child cried a lot in the first 3 months"	1.21(0.89,1.64)	
Parental belief about feeding [3]		
"Fruit and vegetables can be given to the baby freely earlier than 4 months"	7.38(4.60,11.85) ***	7.05(3.52,14.10) ***
Parental beliefs about infant weight [3]		
"I don't like my child to be fat"	0.76(0.58,0.98) *	0.58(0.37,0.89) *
"I don't like my child to be thin"	0.74(0.58,0.94) *	0.54(0.36,0.81) *
Infant temperament		
Soothability	0.93(0.84,1.03)	
Distress to limitations	0.95(0.83,1.09)	

Distress to novel food	0.97(0.88,1.06)	
Social care factors		
Day-care attendance, yes vs no	0.72(0.55,0.94) *	0.72(0.48,1.08)

Note: The multivariate model included the factors significantly (p<0.05) associated with the outcome variable in the univariate models.

[1]: Calculated by changes in weight for age Z-scores in the first 3 months

[2]: Maternal depressive symptom was defined as scored 10 or greater on the Edinburgh Postnatal Depression Scale. This variable was defined as missing if the questionnaire had been filled in by the father or other care givers (n=107).

[3]: Agree/strongly agree vs neutral, disagree, or strongly disagree.

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table S2. Factors associated with the consumption of non-recommended foods: results in the non-intervention condition.

	Frequent consumption of non-recommended foods (≥ once per day vs < once per day)	
	Univariate models OR (95%CI)	Multivariate model OR (95%CI)
Demographic characteristics		
Maternal age at child birth (years)	0.93(0.90,0.96) ***	0.95(0.92,0.98) ***
Maternal educational level		
Low	2.95(2.04,4.26) ***	2.01(1.33,3.05) ***
Middle	2.00(1.55,2.58)	1.52(1.15,2.02) ***
High	Ref	Ref
Maternal ethnic background, non-native vs native	1.21(0.92,1.60)	
Maternal employment status, unemployed vs employed	1.25(0.91,1.70)	
Family structure, single parent vs two parents	1.33(0.58,3.04)	
Infant gender, boy vs girl	0.78(0.62,0.99) *	0.78(0.61,1.01)
Parity, primipara vs multipara	0.84(0.66,1.06)	
Biological factors		
Maternal pre-pregnancy BMI	1.01(0.98,1.04)	
Infant gestational age (weeks)	0.93(0.83,1.05)	
Infant weight at birth, Z-score	0.95(0.84,1.09)	
Infant postnatal weight gain, Z-score [1]	0.89(0.75,1.06)	
Behavioral factor		
Duration of any breastfeeding		
No breastfeeding	2.29(1.70,3.08) ***	1.68(1.21,2.33) ***
Breastfeeding for 0.5–4 months	1.43(1.08,1.88)	1.27(0.95,1.71)
Breastfeeding for 4 months or longer	Ref	Ref
Psychosocial factors		
Maternal depressive symptoms, yes vs no [2]	1.12(0.78,1.63)	
Parental perceptions on characteristics [3]		
"My child drinks greedily"	0.76(0.58,0.99) *	0.77(0.58,1.02)
"My child always wants to eat when he/she sees someone eating"	1.40(1.11,1.78) **	1.31(1.01,1.70) *
"My child does not like plain water"	1.28(0.96,1.70)	
"My child cried a lot in the first 3 months"	0.90(0.67,1.22)	
Parental belief about feeding [3]		
"Fruit and vegetables can be given to the baby freely earlier than 4 months"	2.27(1.42,3.62) ***	1.59(0.96,2.62)
Parental beliefs about infant weight [3]		
"I don't like my child to be fat"	0.85(0.66,1.10)	
"I don't like my child to be thin"	0.95(0.75,1.20)	
Infant temperament		
Soothability	1.22(1.11,1.35) ***	1.23(1.11,1.37) ***
Distress to limitations	1.01(0.88,1.14)	
Distress to novel food	0.94(0.86,1.02)	

Social care factors		
Day-care attendance, yes vs no	0.68(0.53,0.87) **	0.88(0.68,1.14)

Note: Both the univariate models and the multivariate model adjusted for age at questionnaire measurement. The multivariate model included the factors significantly ($p<0.05$) associated with the outcome variable in the univariate models.

[1]: Calculated by changes in weight for age Z-scores in the first 3 months.

[2]: Maternal depression symptom was defined as scored 10 or greater on the Edinburgh Postnatal Depression Scale. This variable was defined as missing if the questionnaire had been filled in by the father or other care givers (n=107).

[3]: Agree/strongly agree vs neutral, disagree, or strongly disagree.

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

CHAPTER 6

Parental bedtime practices during infancy and child sleep outcomes in infancy and early childhood

Manuscript submitted

Lu Wang, Amy van Grieken, Wilma Jansen, Eline Vlasblom, Magda M Boere-Boonekamp, Monique P L'Hoir, Hein Raat

Abstract

Objective

This aim of the present study was to determine whether parental bedtime practices during infancy are associated with child sleep outcomes cross-sectionally and longitudinally.

Methods

The population-based sample included 2287 parent-child dyads from the Netherlands. Parental bedtime practices including room-sharing, parental presence at child sleep onset, putting the child to bed awake, and bedtime routine were measured at child age 6 months. The primary outcomes were total and night sleep duration, number of night awakenings, and sleep onset latency of the child reported by parents at child age 6, 14 and 36 months.

Results

Room-sharing at child age 6 months was independently associated with shorter night sleep duration, and more night awakenings of the child; parental presence at child sleep onset at 6 months was independently associated with shorter total and night sleep duration, more night awakenings, and longer sleep onset latency of the child both cross-sectionally and longitudinally at 36 months; putting the child to bed awake at 6 months was independently associated with longer total sleep duration of the child cross-sectionally; bedtime routine at 6 months was independently associated with shorter sleep onset latency of the child cross-sectionally.

Conclusion

Our study confirms the cross-sectional associations between parental bedtime practices and child sleep outcomes. In addition, our results suggest that parental presence at child sleep onset at 6 months was associated with less favorable sleep outcomes of the child at age 36 months, including shorter sleep duration, more night awakenings and more sleep onset problems.

Introduction

Sleep problems in infancy and early childhood, such as inadequate sleep duration, excessive night awakenings, and sleep onset problems, are associated with various adverse outcomes for child health including poorer cognitive development [1-3], emotional and behavioral problems [4-6], and impaired growth [7]. In addition, inadequate sleep duration has been increasingly recognized as a risk factor for childhood obesity [8-10], and is related to cardiovascular risk factors in children [11]. It has been estimated that 20% to 30% of children experience sleep problems during the first 3 years of life [12-14].

As there is continuity for sleep problems from early childhood to school age [15], it is important to identify the early predictors of children's sleep problems, especially the modifiable predictors. Parent-child room-sharing is one of the most frequently studied modifiable predictors for child sleep problems [16-22]. In addition to room-sharing, other parental bedtime practices, such as parental presence at child sleep onset, putting the child to bed awake, and bedtime routine may influence child sleep outcomes [23-29]. It has been indicated that room-sharing during infancy may negatively influence the sleep quality of both parents and infants [16-21]. However, inconsistent findings exists [29]. It has been argued that the reported associations between room-sharing and child sleep problems could be due to other parental bedtime practices [29, 30]. For example, Paul et al (2017) [21] and Mindell et al (2017) [20] suggested that parents who apply room-sharing for their child use less regular bedtime routine [20, 21], are less likely to put the child to bed awake [21], and are more likely to be present when the child falls asleep [20]. None of the previous studies investigating the association between room-sharing and child sleep outcomes have controlled for other parental bedtime practices [16-21, 25, 26]. Furthermore, whether room-sharing and other parental bedtime practices during infancy are associated with child sleep outcomes in early childhood is unclear [21, 22, 31].

Our study therefore aimed to examine the association of parental bedtime practices during infancy (at age 6 months) with child sleep outcomes during infancy and early childhood (at age 6, 14 and 36 months) in a population based sample of parents and children in the Netherlands. Based on the limited previous evidence, it is expected that room-sharing, parental presence at child sleep onset, and putting the child to bed asleep are associated with less favorable sleep outcomes of the child including shorter sleep duration, more night awakenings, and more sleep onset problems perceived by parents, and regular bedtime routine is associated with better sleep outcomes including longer sleep duration, less night awakenings, and less sleep onset problems perceived by parents.

Methods

Study design and study population

We used data from the BeeBOFT Study, a population-based cluster randomized controlled trial for the primary prevention of overweight among infants and toddlers conducted in the Netherlands [32, 33]. From January 2009 through September 2010, parent-child dyads were invited to participate in the BeeBOFT study by the Youth Health Care professionals during their first routine visit, scheduled at child age approximately 0.5 months. In total, 3003 parent-child dyads agreed to participate, and provided written informed consent and returned the baseline questionnaire (participation rate =37.61%). The 3003 participants were randomly allocated to 3 study arms, including 2 intervention conditions, i.e. the 'BBOFT+' intervention and the 'E-health4Uth' intervention, and one control condition. Both interventions were targeted to parents and aimed at promoting healthy nutrition and activity behaviors of children (i.e. breast feeding, daily exercise/outdoor playing, breakfast daily, fewer sweet drinks and less TV viewing). The 'BBOFT+' intervention also aimed at promoting children's sleep behaviors.

Parents allocated to the 'BBOFT+' intervention group received interventions at each Youth Health Care routine visit scheduled at child age 0.5, 1, 2, 3, 4, 6, 9, 11, 14, 18, 24 and 36 months. Parents in the 'E-health4Uth' intervention group received an online personalized advice intervention at child age 18 and 24 months, respectively. In the control condition, children received usual care. The Medical Ethics Committee of the Erasmus Medical Centre reviewed the study protocol for the BeeBOFT study and declared that the Dutch Medical Research Involving Human Subjects Act did not apply to this research proposal. The Medical Ethics Committee therefore had no objection to the execution of the BeeBOFT study (proposal number MEC-2008-250).

At child age 6, 14 and 36 months respectively, all parents participating in the BeeBOFT study were invited to complete a questionnaire. In total, parents of 2331 children returned the questionnaire at child age 6 months. Children were included in the present study if they had information on at least one of the parental bedtime practices, and at least one of the child sleep outcomes at child age 6 months. Finally, 2287 children were included in the present study (the flow chart for the study population is shown in Figure 1). Non-response analyses suggested that the parent-child dyads included for the present study have higher maternal educational level than those excluded ($p<0.001$, see Table S1).

Measurement

Parental bedtime practices

Parental bedtime practices including room-sharing, parental presence at child sleep onset, putting the child to bed awake, and bedtime routine were assessed by questionnaire at child age 6 months. The questions on parental bedtime practices were adapted from the sleep behavior questionnaire developed by Simonds & Parraga [34] (Table S2). When answering the questions, parents were asked to keep in mind the average condition in the past four weeks. For room-sharing, parents were asked to report whether the child slept with parents in the same bedroom, or slept solitarily in a separate bedroom (including on their own and with siblings). Parents also reported how often a parent was present in the room when the child fell asleep (response categories included every evening, almost every evening, several nights per week, about once per week, almost never, and never); how often the child was put to bed while awake (response categories included always awake, almost always awake, sometimes awake and sometimes asleep, almost always asleep, and always asleep); and how often the child was put to bed with bedtime rituals, e.g. first put in a sleeping bag, sing a song, a hug, then go to bed (response categories included always, almost always, sometimes, almost never and never). The original response categories for each practice were collapsed into two categories (Yes vs No), of which "Yes" represent the parents perform that practice for almost every day/almost always (Table S2).

Child sleep outcomes

Child sleep outcomes were assessed by questionnaires at child age 6, 14, and 36 months (Table S2) [34]. When answering the questions, parents were asked to keep in mind the sleep of their child in the past four weeks. Parents were asked to report the average number of hours their child slept at night, i.e. between 6:00 pm and 8:00 am, and during the day time, i.e. between 8:00 am and 6:00 pm. Total daily sleep duration was calculated by adding up the night time and day time average sleep duration. Parents were also asked to report the number of night awakenings per night the child had, sleep onset latency, and bedtime difficulties. In addition, at child age 6 months only, parents rated their child's sleep quality on a scale of 1-10, with a higher score indicating a better sleep quality.

Potential confounding factors

Potential confounding factors were chosen by biological plausibility and data availability. Demographic characteristics including child's gender, ethnic background (Dutch/non-Dutch), parity, maternal age, maternal educational level, and family structure (one parent/two parents) were assessed in the baseline questionnaire when the child was 0.5 months old. Child gestational age in weeks was calculated according to the reported due date and actual birth date of the child. At child age 6 months, parents reported the type of feeding their child receives at that moment, including 'exclusive breastfeeding', 'exclusive formula feeding', and 'mixed breast- and formula feeding' [35, 36] by questionnaire. Child temperament was measured using subscales (i.e. 'soothability', and 'distress to limitations') from the Infant Behavior Questionnaire [37] at child age 6 months.

Statistical analysis

Differences in child sleep outcomes at age 6, 14 and 36 months by parental bedtime practices at 6 months were tested by Student's t-tests for continuous sleep outcome variables (including total sleep duration, night sleep duration and number of night awakenings) and by Chi-square tests for categorical sleep outcome variable (sleep onset latency).

To examine the independent associations of parental bedtime practices at child age 6 months with child sleep outcomes at 6, 14 and 36 months, general linear regression models for continuous sleep outcome variables and logistic regression models for categorical sleep outcome variables were used. Separate models were built for each pair of parental bedtime practice and child sleep outcome variable. All the models were adjusted for potential confounding factors including the child's exact age, gender, ethnic background, parity, gestational age, and temperament, maternal age and education, breastfeeding status at 6 months, family structure, and intervention groups (model 1). For the longitudinal associations of parental bedtime practice at 6 months with each child sleep outcome at 14 or 36 months, we further adjusted for baseline child sleep outcome (model 2). Models were further adjusted for the other parental bedtime practices to examine the association of each practice with child sleep outcomes independent of the other parental bedtime practices (model 2 for the cross-sectional models and model 3 for the longitudinal models).

Complete case analyses were applied for the regression models. The number of cases that were excluded due to missing values was less than 10% of the total study population. Results were considered as significant when $p<0.05$ for a two-tailed test. Data were analyzed using SAS version 9.4 (SAS institute, Cary, NC).

Results

Table 1 presents the characteristics of the study sample. At age 6 months, 6.6% of the children slept in the same bedroom with parents, 16.5% of the children fell asleep with the presence of a parent in the room, 14.7% of the children were often put to bed asleep, and 90.1% of the children had regular bedtime routines.

Table 2 shows the descriptive statistics for child sleep outcomes at age 6, 14 and 36 months respectively by parental bedtime practices at child age 6 months. Compared to solitary sleeping children, children who shared bedroom with parents at 6 months had longer night sleep duration at all three ages (all $p<0.05$), longer total sleep duration and more night awakenings at both 6 months and 14 months (all $p<0.01$), higher probability of sleep onset latency >30 min ($p<0.001$) and more frequent bedtime difficulties ($p<0.05$) at 36 months. Children with a parent present when falling asleep at 6 months had shorter total and night sleep duration, more night awakenings, higher probability of sleep onset latency > 30 min, and more frequent bedtime difficulties over the three ages (all $p<0.05$). Children who were put to bed awake at age 6 months had longer total and night sleep duration, and less night awakenings over the three ages ($p<0.05$). Compared to children without a regular bedtime routine, children with a regular bedtime routine at age 6 months had longer total and night sleep duration, lower probability of sleep onset latency >30 min, and less frequent bedtime difficulties at 6 months (all $p<0.05$), more night awakenings at 14 months ($p<0.05$), and lower probability of sleep onset latency > 30 min at 36 months ($p<0.05$).

At child age 6 months (Table 3), after adjusting for potential confounding factors and other bedtime practices, room-sharing was associated with shorter night sleep duration (β=-0.28, $p<0.01$, hours), and more night awakenings (β=0.27, $p<0.01$, times); parental presence at child sleep onset was independently associated with shorter total (β=-0.53, $p<0.001$) and night sleep duration (β=-0.27, $p<0.001$), more night awakenings (β=0.43, $p<0.001$), lower parental rating of child sleep quality (β=-0.60, $P<0.001$, scores on 1-10 scale), higher odds of having longer sleep onset latency (OR=1.43, $p<0.05$), and higher odds of having more frequent bedtime difficulties (OR=1.81, $p<0.001$); putting the child to bed awake was independently associated with longer total sleep duration (β=0.45, $p<0.001$); bedtime routine was independently associated with higher parental rating of child sleep quality (β=0.33, $p<0.01$), lower odds of having longer sleep onset latency (OR=0.60, $p<0.01$) and lower odds of having more frequent bedtime difficulties (OR=0.57, $p<0.001$).

Longitudinally (Table 4), room-sharing at child age 6 months was independently associated with higher odds of having longer sleep onset latency of the child at 14 months (OR=2.05, $p<0.001$). Parental presence at child sleep onset at 6 months was independently associated with less frequent bedtime difficulties of the child at 14 months (OR=1.40, $p<0.05$), and shorter total (β=-0.24, $p<0.01$) and night sleep duration (β=-0.21, $p<0.01$), more night awakenings (β=0.21, $p<0.01$), longer sleep onset latency (OR=1.33, $p<0.05$), and more frequent bedtime difficulties (OR=1.55, $p<0.01$) of the child at 36 months. Putting the child to bed awake at 6 months was independently associated with longer total (β=0.22, $p<0.05$) and night sleep duration (β=0.15, $p<0.05$) of the child at 14 months.

Discussion

This study investigated the cross-sectional as well as the longitudinal association between parental bedtime practices at child age 6 months and child sleep outcomes. Our results suggest that room-sharing at child age 6 months was independently associated with shorter night sleep duration and more night awakening of the child cross-sectionally. Parental presence in the room when the child is falling asleep at child age 6 months was independently associated with shorter sleep duration, more night awakenings, and more sleep onset problems of the child both cross-sectionally and longitudinally at child age 36 months. Bedtime routine was associated with less sleep onset problems of the child cross-sectionally. Our study is one of the first to investigate the longitudinal association of parental bedtime practices during infancy with sleep outcomes in early childhood.

Our finding that room-sharing children have shorter total and night sleep duration and more frequent night awakenings reported by parents at age 6 months is in line with previous research conducted in predominantly western populations [20, 21, 26]. It has been hypothesized that the associations between room-sharing and child sleep outcomes are mediated by parental bedtime practices such as parental involvement in child sleep initiation and bedtime routine [27, 29]. However, in the present study, the above associations remained significant after adjusting for other parental bedtime practices including parental presence in the room when the child is falling asleep, putting the child to bed awake, and bedtime routine. Notably, we found no significant association between room-sharing and parental rating of child sleep quality. This result is similar to two previous studies which reported no relationship between sleep location and parent-perceived child sleep problems [20, 37]. It is possible that the decreased sleep duration and increased night awakenings perceived by room-sharing parents are not necessarily considered as problematic by parents. Using actigraph data, the study of Teti et al (2016) [18] and Volkovich et al (2015) [17] found no association between room-sharing and child sleep disruption. The observed association of room-sharing with shorter night sleep duration and increased night awakenings reported by parents could be a result of higher parental awareness of the child's sleep among room-sharing parents [16].

We observed an association between room-sharing at 6 months and longer sleep onset latency of the child at 14 months. However, there was no association between room-sharing at 6 months and the frequency of bedtime difficulties of the child at 14 months. The observed association between room-sharing at 6 months and sleep onset latency at 14 months could be due to higher parental awareness of children's sleep onset latency. Beijers et al (2018) also found no association between room-sharing during the first months of life and child sleep problems at age 6 years [22].

Parental presence in the room when the child is falling asleep at child age 6 months was associated with shorter total and night sleep duration, more night awakenings, and shorter sleep onset latency, both cross-sectionally and longitudinally at child age 36 months. Previous research has consistently showed that parental presence or parental involvement in child sleep initiation was associated with less consolidated sleep pattern of the child [23, 25, 27, 29, 31, 38-40]. Possible explanation for the observed associations is that parents who are present when the child is falling asleep are more likely to provide active physical comforting to the child, which may impede the development of children's self-soothing abilities [41, 42], and therefore contribute to the development of sleep problems [40, 41]. Reversely, children with existing sleep problems may elicit parents to be present to help them falling asleep [42]. A non-causal explanation is also possible: parents are more aware of children's true sleep duration, night awakenings, and sleep onset latency when they are present than not present in the room while the child is falling asleep. Our findings extend previous study by showing that parental presence at child sleep onset at age 6 months was associated with less favorable sleep outcomes of the child at age 36 months, independent of the baseline child sleep outcomes, suggesting that parental presence at child sleep onset during infancy could contribute to the development of child sleep problems at later ages.

Our results showed that children who were put to bed awake had longer sleep duration and less night awakenings. This finding supports the currently sleep guideline [43] which suggests the parents to put the child to bed awake for the prevention of child sleep problems, and is in line with previous intervention trails [38]. However, most of the associations between putting the child to bed awake and child sleep outcomes became non-significant after adjusting for the other parental bedtime practices (comparing results of Model 1 versus Model 2 shown in Table 3). This might be due to the high correlation between putting the child to bed asleep and parental presence in the room when the child is falling asleep, as children who are put to bed asleep must have a parent present in the room while falling asleep.

We found that regular bedtime routine at child age 6 months was independently and cross-sectionally associated with shorter sleep onset latency, less frequent bedtime difficulties, and higher parental rating of child sleep quality, suggesting that regular bedtime routine might be important for preventing child sleep onset problems. Previous cross-sectional studies performed in children aged 0-5 years have reported that having a bedtime routine was associated with shorter sleep onset latency [28], longer total/night sleep duration [26, 28], and decreased night awakenings [26-28]. It is possible that the associations between bedtime routine and shorter sleep duration, and more night awakenings observed in the previous studies [26-28] were confounded by other parental bedtime practices, as none of these studies have adjusted for the other parental bedtime practices. Our longitudinal analyses suggest that these beneficial effect of bedtime routine during infancy might not persist to later ages of the child.

Strengths and limitations

The strengths of the present study include the relatively large sample size, and the longitudinal design with follow-up until the age of 3 years. In addition, we were able to adjust for potential confounding factors, including social-demographical characteristics, breastfeeding status, and child temperament. Furthermore, we were able to assess the independent contribution of each parental bedtime practices on child sleep outcomes.

This study is subject to a few limitations. Firstly, child sleep outcomes were parent-reported by questionnaire. The observed association of room-sharing and parental bedtime presence with child sleep outcomes could be affected by the differences in parental awareness of child sleep among parents being present versus parents not present in the room with the child. However, parental perception of child sleep problems is mainly determined by parental perceived insufficient sleep duration, excessive night awakenings, and sleep onset difficulties. Therefore, the results of the present study may still be useful for the development of guidelines aiming at preventing sleep problems among infants and toddlers. Secondly, we used data from a 3-armed cluster randomized controlled trial. Parents allocated to one of the study arm, the 'BBOFT+' group, received information on optimal sleep duration, putting the child to bed awake, and bedtime rituals at set ages of the child [36]. However, all the models were adjusted for intervention condition. Further, sensitivity analysis using data from the control group showed similar results with our main analyses (details can be found in Table S3). Thirdly, our study was performed in a population with a predominantly Dutch ethnic background and relatively high educational level. Generalization to other populations should be done with caution. Finally, due to the limitation of observational studies, causal inferences should be considered carefully and requires further research.

Conclusion

Our results confirm the cross-sectional associations between parental bedtime practices and child sleep outcomes during infancy. More specifically, room-sharing was independently associated with shorter night sleep duration and more night awakenings of the child reported by parents cross-sectionally. Bedtime routine was mainly associated with less sleep onset problems of the child cross-sectionally. Parental presence at child sleep onset was the factor most strongly associated with child sleep outcomes, and was associated with shorter sleep duration, more night awakenings and more sleep onset problems of the child. Further, parental presence at child sleep onset 6 months was independently associated with less favorable sleep outcomes of the child at 36 months. Our findings support the recommendations to encourage independent sleep initiation of the child in the middle of infancy

References

1. Kocevska, D., et al., *Early Childhood Sleep Patterns and Cognitive Development at Age 6 Years: The Generation R Study.* J Pediatr Psychol, 2017. **42**(3): p. 260-268.
2. Tham, E.K., N. Schneider, and B.F. Broekman, *Infant sleep and its relation with cognition and growth: a narrative review.* Nat Sci Sleep, 2017. **9**: p. 135-149.
3. Walsh, J.J., et al., *Associations between 24 hour movement behaviours and global cognition in US children: a cross-sectional observational study.* The Lancet Child & Adolescent Health, 2018.
4. Sivertsen, B., et al., *Later emotional and behavioral problems associated with sleep problems in toddlers: a longitudinal study.* JAMA pediatrics, 2015. **169**(6): p. 575-582.
5. Jansen, P.W., et al., *Does disturbed sleeping precede symptoms of anxiety or depression in toddlers? The generation R study.* Psychosom Med, 2011. **73**(3): p. 242-9.
6. Quach, J.L., et al., *Bidirectional Associations Between Child Sleep Problems and Internalizing and Externalizing Difficulties From Preschool to Early Adolescence.* JAMA Pediatr, 2018. **172**(2): p. e174363.
7. Chaput, J.P., et al., *Systematic review of the relationships between sleep duration and health indicators in the early years (0-4 years).* BMC Public Health, 2017. **17**(Suppl 5): p. 855.
8. Felső, R., et al., *Relationship between sleep duration and childhood obesity: Systematic review including the potential underlying mechanisms.* Nutrition, Metabolism and Cardiovascular Diseases, 2017. **27**(9): p. 751-761.
9. Ash, T. and E.M. Taveras, *Associations of short sleep duration with childhood obesity and weight gain: summary of a presentation to the National Academy of Science's Roundtable on Obesity Solutions.* Sleep Health, 2017. **3**(5): p. 389-392.
10. Taylor, R.W., et al., *Sleep, nutrition, and physical activity interventions to prevent obesity in infancy: follow-up of the Prevention of Overweight in Infancy (POI) randomized controlled trial at ages 3.5 and 5 y.* The American journal of clinical nutrition, 2018. **108**(2): p. 228-236.
11. Matthews, K.A. and E.J. Pantesco, *Sleep characteristics and cardiovascular risk in children and adolescents: an enumerative review.* Sleep Med, 2016. **18**: p. 36-49.
12. Wake, M., et al., *Prevalence, stability, and outcomes of cry-fuss and sleep problems in the first 2 years of life: prospective community-based study.* Pediatrics, 2006. **117**(3): p. 836-842.
13. Hanafin, S., *Sleep patterns and problems in infants and young children in Ireland.* Child Care Health Dev, 2017.
14. Thunström, M., *Severe sleep problems among infants in a normal population in Sweden: prevalence, severity and correlates.* Acta paediatrica, 1999. **88**(12): p. 1356-1363.
15. Jenni, O.G., et al., *A longitudinal study of bed sharing and sleep problems among Swiss children in the first 10 years of life.* Pediatrics, 2005. **115**(1 Suppl): p. 233-40.
16. Ramos, K.D., D. Youngclarke, and J.E. Anderson, *Parental perceptions of sleep problems among co‐sleeping and solitary sleeping children.* Infant and Child Development: An International Journal of Research and Practice, 2007. **16**(4): p. 417-431.
17. Volkovich, E., et al., *Sleep patterns of co-sleeping and solitary sleeping infants and mothers: a longitudinal study.* Sleep medicine, 2015. **16**(11): p. 1305-1312.
18. Teti, D.M., et al., *Sleep arrangements, parent-infant sleep during the first year, and family functioning.* Dev Psychol, 2016. **52**(8): p. 1169-81.
19. Huang, X.N., et al., *Feeding methods, sleep arrangement, and infant sleep patterns: a Chinese population-based study.* World J Pediatr, 2016. **12**(1): p. 66-75.
20. Mindell, J.A., E.S. Leichman, and R.M. Walters, *Sleep location and parent-perceived sleep outcomes in older infants.* Sleep Med, 2017. **39**: p. 1-7.
21. Paul, I.M., et al., *Mother-Infant Room-Sharing and Sleep Outcomes in the INSIGHT Study.* Pediatrics, 2017. **140**(1).

22. Beijers, R., et al., *Parent–Infant Room Sharing During the First Months of Life: Longitudinal Links With Behavior During Middle Childhood.* Child development, 2018.
23. Adair, R., et al., *Night waking during infancy: role of parental presence at bedtime.* Pediatrics, 1991. **87**(4): p. 500-4.
24. Anders, T.F., L.F. Halpern, and J. Hua, *Sleeping through the night: a developmental perspective.* Pediatrics, 1992. **90**(4): p. 554-560.
25. Touchette, É., et al., *Factors associated with fragmented sleep at night across early childhood.* Archives of pediatrics & adolescent medicine, 2005. **159**(3): p. 242-249.
26. Sadeh, A., et al., *Sleep and sleep ecology in the first 3 years: a web-based study.* J Sleep Res, 2009. **18**(1): p. 60-73.
27. Mindell, J.A., et al., *Parental behaviors and sleep outcomes in infants and toddlers: a cross-cultural comparison.* Sleep Med, 2010. **11**(4): p. 393-9.
28. Mindell, J.A., et al., *Bedtime Routines for Young Children: A Dose-Dependent Association with Sleep Outcomes.* Sleep, 2015. **38**(5): p. 717-722.
29. Yu, X.T., et al., *Parental behaviors and sleep/wake patterns of infants and toddlers in Hong Kong, China.* World J Pediatr, 2017. **13**(5): p. 496-502.
30. Moon, R.Y. and F.R. Hauck, *Are There Long-term Consequences of Room-Sharing During Infancy?* Pediatrics, 2017: p. e20171323.
31. Morrell, J. and H. Steele, *The role of attachment security, temperament, maternal perception, and care ‐ giving behavior in persistent infant sleeping problems.* Infant Mental Health Journal: Official Publication of The World Association for Infant Mental Health, 2003. **24**(5): p. 447-468 %@ 0163-9641.
32. Raat, H., et al., *Primary prevention of overweight in preschool children, the BeeBOFT study (breastfeeding, breakfast daily, outside playing, few sweet drinks, less TV viewing): design of a cluster randomized controlled trial.* BMC Public Health, 2013. **13**: p. 974.
33. van Grieken, A., et al., *Personalized Web-Based Advice in Combination With Well-Child Visits to Prevent Overweight in Young Children: Cluster Randomized Controlled Trial.* J Med Internet Res, 2017. **19**(7): p. e268.
34. Simonds, J.F. and H. Parraga, *Prevalence of sleep disorders and sleep behaviors in children and adolescents.* J Am Acad Child Psychiatry, 1982. **21**(4): p. 383-8.
35. Figueiredo, B., et al., *Exclusive breastfeeding at three months and infant sleep-wake behaviors at two weeks, three and six months.* Infant Behav Dev, 2017. **49**: p. 62-69.
36. Smith, L.A., et al., *Infant Sleep Location and Breastfeeding Practices in the United States, 2011-2014.* Acad Pediatr, 2016. **16**(6): p. 540-9.
37. Rothbart, M.K., *Measurement of temperament in infancy.* Child development, 1981: p. 569-578.
38. Byars, K.C., et al., *Prevalence, patterns, and persistence of sleep problems in the first 3 years of life.* Pediatrics, 2012. **129**(2): p. e276-e284.
39. Crichton, G.E. and B. Symon, *Behavioral Management of Sleep Problems in Infants Under 6 Months--What Works?* J Dev Behav Pediatr, 2016. **37**(2): p. 164-71.
40. Tikotzky, L. and A. Sadeh, *Maternal sleep ‐ related cognitions and infant sleep: A longitudinal study from pregnancy through the 1st Year.* Child development, 2009. **80**(3): p. 860-874 %@ 0009-3920.
41. Morrell, J. and M. Cortina ‐ Borja, *The developmental change in strategies parents employ to settle young children to sleep, and their relationship to infant sleeping problems, as assessed by a new questionnaire: the parental interactive bedtime behaviour scale.* Infant and Child Development: An International Journal of Research and Practice, 2002. **11**(1): p. 17-41.
42. Sadeh, A., L. Tikotzky, and A. Scher, *Parenting and infant sleep.* Sleep Med Rev, 2010. **14**(2): p. 89-96.

43. Burnham, M.M., et al., *Nighttime sleep-wake patterns and self-soothing from birth to one year of age: a longitudinal intervention study.* J Child Psychol Psychiatry, 2002. **43**(6): p. 713-25.
44. Raat, H., et al., *Primary prevention of overweight in preschool children, the BeeBOFT study (breastfeeding, breakfast daily, outside playing, few sweet drinks, less TV viewing): design of a cluster randomized controlled trial.* BMC Public Health, 2013. **13**(1): p. 974.

Table 1. Characteristics of the study sample, parental bedtime practices at child age 6 months, and child sleep outcomes at age 6, 14 and 36 months (n=2287).

	N	No. (%) or Mean (SD)
Child gender, boys, No. (%)	2252	1161 (51.6)
Child ethnic background [1], Dutch, No. (%)	2287	1890 (82.6)
Child gestational age, weeks, mean (SD)	2230	39.7 (1.4)
Maternal age, years, mean (SD)	2251	31.0 (4.2)
Maternal education level, No. (%)	2270	
≤4 years secondary school		260 (11.5)
>4 years secondary school or middle level vocational training		815 (35.9)
Universities or above		1101 (52.6)
Family structure, two parents, No. (%)	2258	2220 (98.2)
Parity, primipara, No. (%)	2287	1071 (46.8)
Intervention condition, No. (%)	2287	
Control		769(33.6)
"BBOFT+" intervention		687(30.0)
"E-Health4Uth" intervention		831(36.3)
Breastfeeding status at child age 6 months, No. (%)	2278	
Exclusive breastfeeding		270 (11.9)
Mixed feeding		252 (11.1)
Exclusive formula		1756 (77.1)
Child temperament, scores, mean (SD)		
Soothability	2283	4.8 (1.2)
Distress to limitation	2283	2.8 (0.9)
Parental bedtime practices at child age 6 months		
Bedroom sharing, yes, No. (%)	2285	151 (6.6)
Parental presence at child sleep onset, yes, No. (%)	2284	377 (16.5)
Putting on bed awake, yes, No. (%)	2285	1949 (85.3)
Bedtime routine, yes, No. (%)	2273	2049 (90.2)
Child sleep outcomes		
Total sleep duration, h/day, mean (SD)		
At age 6 months	2235	14.9 (1.6)
At age 14 months	1938	14.2 (1.3)
At age 36 months	1777	12.1 (1.2)
No. of night awakenings, mean (SD)		
At age 6 months	2267	1.1 (1.2)
At age 14 months	1977	0.9 (1.0)
At age 36 months	1803	0.7 (0.9)
Sleep latency, > 30 min, No. (%)		
At age 6 months	2259	58 (2.6)
At age 14 months	1983	74 (3.7)
At age 36 months	1808	176 (9.7)
Bedtime difficulties, ≥3 nights per week, No. (%)		
At age 6 months	2276	203 (8.9)
At age 14 months	1988	155 (7.8)
At age 36 months	1816	222 (12.2)

[1]A child's ethnic background was defined according to the ethnic backgrounds of his/her parents. A parent was classified as non-Dutch if one of his/her own parents was born outside the Netherlands. If one or both of the child's parents were classified as non-Dutch, that child's ethnic background was non-Dutch

Table 2. Child sleep outcomes at age 6, 14 and 36 months according to parental bedtime practices at child age 6 months.

	Parental bedtime practices at child age 6 months							
	Room-sharing		Parental presence at child sleep onset		Putting to bed awake		Bedtime routine	
	Yes Mean (SD)/No. (%)	No Mean (SD)/No. (%)	Yes Mean (SD)/No. (%)	No Mean (SD)/No. (%)	Yes Mean (SD)/No. (%)	No Mean (SD)/No. (%)	Yes Mean (SD)/No. (%)	No Mean (SD)/No. (%)
Child sleep outcome at 6 months								
Total sleep duration, hours	**14.5(1.6)**	**14.9(1.6)** **	**14.1(1.7)**	**15.0(1.5)** ***	**15.0(1.5)**	**14.2(1.8)** ***	**14.9(1.5)**	**14.6(1.8)** **
Night sleep duration, hours	**10.9(1.3)**	**11.2(1.1)** ***	**10.8(1.3)**	**11.3(1.1)** ***	**11.2(1.1)**	**11.0(1.3)** ***	**11.2(1.1)**	**11.0(1.2)** ***
No. of night awakenings, times	**1.5(1.3)**	**1.1(1.1)** ***	**1.6(1.3)**	**1.0(1.1)** ***	**1.1(1.1)**	**1.4(1.3)** ***	1.1(1.2)	1.2(1.2)
Sleep quality[1]	**7.8(1.7)**	**8.0(1.5)** *	**7.5(1.7)**	**8.1(1.4)** ***	**8.1(1.5)**	**7.7(1.6)** ***	**8.1(1.5)**	**7.6(1.6)** ***
Sleep onset latency, >30 min, No. (%)	4(2.7)	54(2.6)	**28(7.5)**	**30(1.6)** ***	**44(2.3)**	**14(4.2)** *	**44(2.2)**	**12(5.4)** **
Bedtime difficulties, >3 times per week, No. (%)	18(12.0)	184(8.7)	**60(16.1)**	**143(7.5)** ***	**160(8.3)**	**43(12.9)** **	**161(7.9)**	**40(17.9)** ***
Child sleep outcome at 14 months								
Total sleep duration, hours	**13.8(1.5)**	**14.2(1.3)** **	**13.8(1.4)**	**14.3(1.3)** ***	**14.2(1.3)**	**13.8(1.5)** ***	14.2(1.3)	14.1(1.5)
Night sleep duration, hours	**11.2(1.2)**	**11.5(1.0)** **	**11.3(1.2)**	**11.5(1.0)** ***	**11.5(1.0)**	**11.3(1.2)** ***	11.5(1.0)	11.4(1.1)
No. of night awakenings, times	**1.1(1.1)**	**0.9(1.0)** **	**1.1(1.2)**	**0.8(1.0)** ***	**0.9(1.0)**	**1.03(1.1)** *	**0.9(1.0)**	**1.1(1.1)** **
Sleep onset latency, >30 min, No. (%)	8(7.0)	66(3.5)	**20(6.4)**	**54(3.2)** **	60(3.5)	14(5.2)	64(3.6)	10(5.4)
Bedtime difficulties, > 3 times per week, No. (%)	12(10.4)	143(7.6)	**38(12.2)**	**117(7.0)** **	**122(7.1)**	**33(12.2)** **	134(7.5)	21(11.1)
Child sleep outcome at 36 months								
Total sleep duration, hours	11.9(1.4)	12.1(1.2)	**11.75(1.3)**	**12.1(1.2)** ***	**12.1(1.2)**	**11.93(1.4)** *	12.1(1.2)	12.1(1.2)
Night sleep duration, hours	**11.0(1.0)**	**11.3(1.0)** *	**10.94(1.1)**	**11.3(0.9)** ***	**11.3(0.9)**	**11.1(1.1)** *	11.2(1.0)	11.1(0.9)
No. of night awakenings, times	0.9(1.0)	0.7(0.9)	**0.98(1.1)**	**0.7(0.9)** ***	**0.7(0.9)**	**0.9(1.0)** **	0.7(0.9)	0.7(0.9)
Sleep onset latency, >30 min, No. (%)	**12(10.4)**	**143(7.6)** ***	**51(17.7)**	**125(8.2)** ***	**140(9.0)**	**36(14.4)** **	**150(9.2)**	**25(14.9)** *
Bedtime difficulties, > 3 times per week, No. (%)	**23(22.1)**	**153(9.0)** *	**53(18.3)**	**168(11.0)** ***	183(11.7)	39(15.5)	198(12.1)	23(13.7)

Note: Numbers present **bold** represent the difference in child sleep outcomes according to parental bedtime practices were significant at $p<0.05$.
***: $p<0.001$; **: $p<0.01$; *: $p<0.05$.
[1] Scores rated by parents at child's age of 6 months on a scale of 1-10.

Table 3. The cross-sectional associations between parental bedtime practices and child sleep outcomes at age 6 months (n=2287).

Child sleep outcomes at age 6 months	**Parental bedtime practices at child age 6 months**			
	Room-sharing	Parental presence at child sleep onset	Putting to bed awake	Bedtime routine
	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)
Total sleep duration (hours)				
Model 1	**-0.38(-0.66, -0.11)** **	**-0.71(-0.89, -0.53)** ***	**0.67(0.48, 0.86)** ***	0.21(-0.02, 0.43)
Model 2	-0.26(-0.53, 0.01)	**-0.53(-0.72, -0.34)** ***	**0.45(0.25, 0.65)** ***	0.04(-0.18, 0.27)
Night sleep duration (hours)				
Model 1	**-0.30(-0.50, -0.10)** **	**-0.31(-0.44, -0.18)** ***	**0.15(0.00, 0.29)** *	**0.20(0.04, 0.36)** *
Model 2	**-0.28(-0.48, -0.08)** **	**-0.27(-0.41, -0.13)** ***	0.00(-0.15, 0.15)	0.16(-0.01, 0.32)
No. of night awakenings (times)				
Model 1	**0.35(0.15, 0.55)** ***	**0.48(0.35, 0.61)** ***	**-0.28(-0.43, -0.14)** ***	-0.04(-0.21, 0.12)
Model 2	**0.27(0.07, 0.47)** **	**0.43(0.29, 0.57)** ***	-0.11(-0.26, 0.05)	0.03(-0.13, 0.20)
Sleep quality (score)[1]				
Model 1	-0.22(-0.48, 0.04)	**-0.64(-0.81, -0.47)** ***	**0.29(0.11, 0.47)** **	**0.42(0.21, 0.63)** ***
Model 2	-0.11(-0.36, 0.15)	**-0.60(-0.78, -0.42)** ***	0.03(-0.16, 0.22)	**0.33(0.12, 0.54)** **
	OR(95%CI)	OR(95%CI)	OR(95%CI)	OR(95%CI)
Sleep onset latency				
Model 1	1.03(0.72, 1.48)	**1.53(1.21, 1.94)** ***	1.23(0.95, 1.58)	**0.50(0.37, 0.67)** ***
Model 2	0.81(0.51, 1.30)	**1.43(1.05, 1.93)** *	1.36(0.98, 1.89)	**0.60(0.42, 0.85)** **
Bedtime difficulties				
Model 1	0.95(0.67, 1.35)	**1.87(1.50, 2.33)** ***	0.82(0.64, 1.04)	**0.53(0.41, 0.70)** ***
Model 2	0.85(0.59, 1.22)	**1.81(1.42, 2.30)** ***	1.05(0.81, 1.36)	**0.57(0.43, 0.75)** ***

Note: Model 1 adjusted for potential confounding factors including child's exact age, gender, ethnic background, parity, gestational age, screen time, and temperament, and maternal age, education, and depressive symptoms, breastfeeding status at child age 6 months, family structure, and intervention groups; Model 2 further adjusted for the effect of the other parental bedtime practices.

Numbers present in **bold** represent the association were significant at $p<0.05$: * $p<0.05$, ** $p<0.01$, *** $p< 0.001$.

[1] Scores rated by parents at child's age of 6 months on a scale of 1-10.

Table 4. The longitudinal associations between parental bedtime practices at child age 6 months and child sleep outcomes at age 14 and 36 months.

Child sleep outcomes	**Parental bedtime practices at child age 6 months**			
	Room sharing	Parental presence at child sleep onset	Putting to bed awake	Bedtime routine
	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)
Sleep outcomes at 14 months				
Total sleep duration (hours)				
Model 1	**-0.35(-0.62, -0.08)** *	**-0.38(-0.55, -0.21)** ***	**0.47(0.29, 0.65)** ***	0.13(-0.08, 0.34)
Model 2	**-0.27(-0.52, -0.02)** *	-0.16(-0.32, 0.01)	**0.27(0.10, 0.44)** **	0.07(-0.13, 0.27)
Model 3	-0.24(-0.49, 0.01)	-0.08(-0.25, 0.09)	**0.22(0.03, 0.40)** *	0.06(-0.14, 0.26)
Night sleep duration (hours)				
Model 1	-0.19(-0.39, 0.02)	**-0.20(-0.33, -0.08)** **	**0.21(0.08, 0.35)** **	0.07(-0.09, 0.23)
Model 2	-0.11(-0.31, 0.08)	-0.12(-0.24, 0.01)	**0.18(0.05, 0.31)** **	0.01(-0.14, 0.16)
Model 3	-0.08(-0.28, 0.11)	-0.08(-0.21, 0.06)	**0.15(0.01, 0.29)** *	0.00(-0.16, 0.15)
No. of night awakenings (times)				
Model 1	0.20(-0.01, 0.41)	**0.26(0.12, 0.39)** ***	-0.10(-0.25, 0.04)	**-0.18(-0.35, -0.02)** *
Model 2	0.07(-0.13, 0.27)	0.13(0.00, 0.26)	-0.03(-0.17, 0.10)	-0.16(-0.31, 0.00)
Model 3	0.06(-0.14, 0.26)	0.12(-0.01, 0.26)	0.03(-0.12, 0.17)	-0.14(-0.30, 0.01)
	OR(95%CI)	OR(95%CI)	OR(95%CI)	OR(95%CI)
Sleep onset latency				
Model 1	**1.91(1.29, 2.85)** ***	**1.31(1.02, 1.70)** *	0.85(0.64,1.12)	**0.66(0.48, 0.90)** *
Model 2	**2.05(1.36, 3.08)** ***	1.18(0.90, 1.54)	0.80(0.60,1.06)	0.79(0.57, 1.09)
Model 3	**2.05(1.33, 3.02)** ***	1.07(0.80, 1.42)	0.86(0.63, 1.17)	0.81(0.58, 1.12)
Bedtime difficulties				
Model 1	1.42(0.90, 2.25)	**1.87(1.41, 2.49)** ***	**0.60(0.44, 0.82)** **	**0.59(0.41, 0.84)** **
Model 2	1.39(0.87, 2.23)	**1.62(1.21, 2.17)** **	**0.61(0.44, 0.83)** **	**0.68(0.47, 0.97)** *
Model 3	1.29(0.80, 2.09)	**1.40(1.02, 1.92)** *	0.72(0.51, 1.01)	0.73(0.50, 1.05)
Sleep outcomes at 36 months				
Total sleep duration (hours)				
Model 1	-0.21(-0.47, 0.05)	**-0.34(-0.50, -0.17)** ***	0.16(-0.01, 0.34)	-0.08(-0.28, 0.12)
Model 2	-0.12(-0.38, 0.13)	**-0.21(-0.38, -0.05)** *	0.07(-0.10, 0.24)	-0.14(-0.33, 0.06)
Model 3	-0.10(-0.35, 0.16)	**-0.24(-0.42, -0.07)** **	-0.01(-0.20, 0.18)	-0.19(-0.39, 0.02)
Night sleep duration (hours)				
Model 1	-0.20(-0.40, 0.00)	**-0.27(-0.39, -0.14)** ***	0.07(-0.06, 0.21)	0.08(-0.07, 0.24)
Model 2	-0.13(-0.32, 0.07)	**-0.21(-0.33, -0.08)** **	0.05(-0.08, 0.19)	0.04(-0.11, 0.19)
Model 3	-0.10(-0.30, 0.09)	**-0.21(-0.34, -0.08)** **	-0.03(-0.17, 0.11)	0.01(-0.15, 0.16)
No. of night awakenings (times)				
Model 1	0.12(-0.08, 0.32)	**0.29(0.17, 0.42)** ***	**-0.20(-0.34,-0.07)** **	-0.04(-0.19, 0.11)
Model 2	0.07(-0.13, 0.27)	**0.24(0.12, 0.37)** ***	**-0.18(-0.31, -0.04)** *	-0.04(-0.19, 0.11)
Model 3	0.03(-0.16, 0.23)	**0.21(0.08, 0.34)** **	-0.09(-0.23, 0.05)	0.00(-0.15, 0.16)
	OR(95%CI)	OR(95%CI)	OR(95%CI)	OR(95%CI)
Sleep onset latency				
Model 1	1.33(0.89, 2.00)	**1.43(1.10, 1.84)** **	0.87(0.66, 1.14)	0.75(0.55, 1.03)
Model 2	1.39(0.92, 2.09)	**1.39(1.07, 1.81)** *	0.82(0.62, 1.09)	0.81(0.59, 1.11)
Model 3	1.34(0.89, 2.01)	**1.33(1.00, 1.76)** *	0.95(0.70, 1.28)	0.87(0.63, 1.20)
Bedtime difficulties				
Model 1	1.28(0.83, 1.98)	**1.80(1.38, 2.34)** ***	**0.71(0.53, 0.96)** *	**0.66(0.48, 0.93)** *
Model 2	1.30(0.84, 2.02)	**1.66(1.26, 2.18)** ***	**0.73(0.54, 0.98)** *	0.73(0.52, 1.02)
Model 3	1.21(0.77, 1.89)	**1.55(1.16, 2.08)** **	0.89(0.65, 1.22)	0.80(0.56, 1.13)

Note: Model 1 adjusted for potential confounding factors including child's exact age, gender, ethnic background, parity, gestational age, screen time, and temperament, and maternal age, education, and depressive symptoms, breastfeeding status at child age 6 months, family structure, and intervention groups; Model 2 further adjusted for the baseline sleep outcome variable in addition to model 1; Model 3 further adjusted for the other parental bedtime practices in addition to model 2.
Numbers present in **bold** represent the association were significant at $p<0.05$: * $p<0.05$, ** $p<0.01$, *** $p< 0.001$.

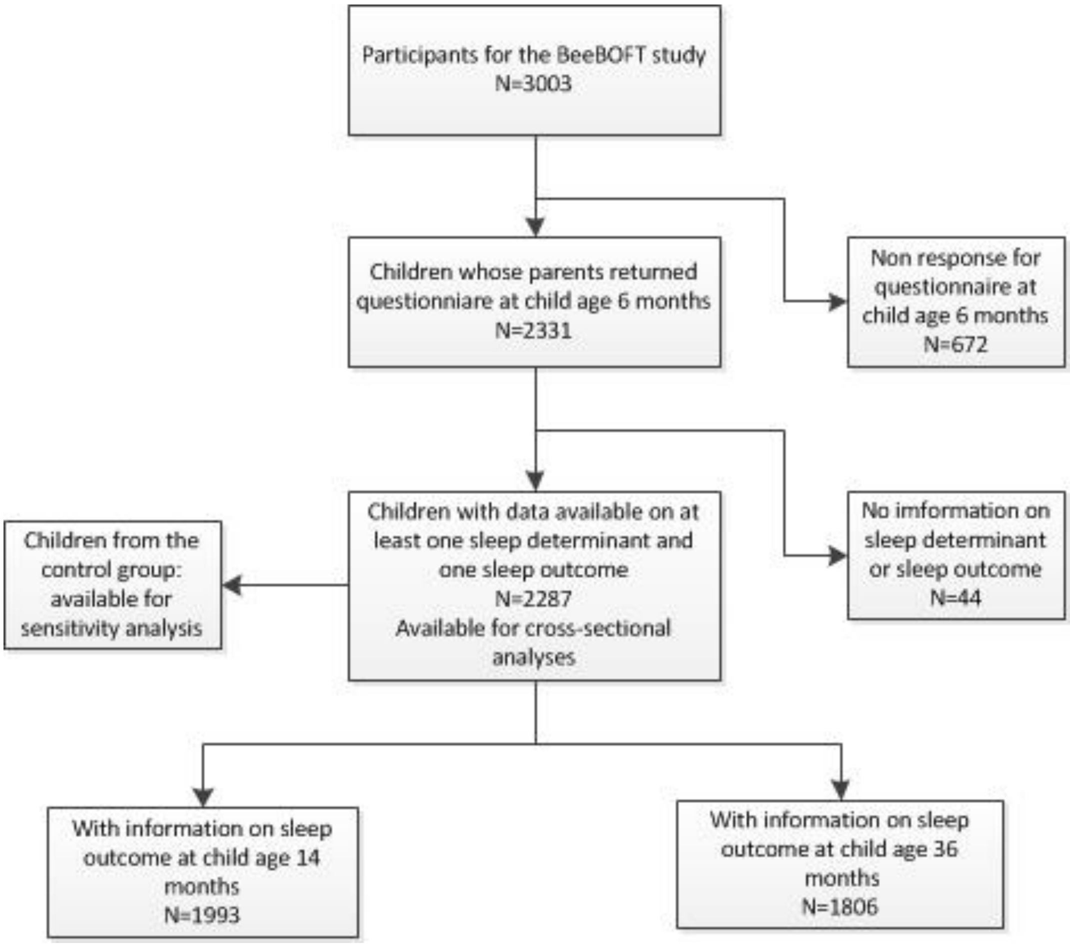

Figure 1. Flow chart for the inclusion and exclusion of the study population

Additional Files

Table S1. Non-response analyses.

	Population for analyses	**Population excluded**	
	N (%) or Mean (SD)	N (%) or Mean (SD)	*p-value*
Child gender, boys, n (%)	1161(51.55)	340(48.71)	0.19
Child ethnic background [1], Dutch, n (%)	1890(82.64)	597(84.08)	0.37
Child gestational age	39.65(1.35)	39.63(1.44)	0.77
Maternal age, years, mean (SD)	30.99(4.18)	30.46(4.69)	0.004
Maternal education level, n (%)			
≤4 years secondary school	260(11.45)	149(21.32)	<0.001
>4 years secondary school or middle level vocational training	815(35.90)	256(36.62)	
Universities or above	1195(52.64)	294(42.06)	
Family structure, two parents	2220(98.32)	683(96.88)	0.02
Parity, primipara, n (%)	1071(46.83)	307(42.88)	0.06
Intervention groups			0.98
Control group	769(33.62)	239(33.38)	
BBOFT+ group	687(30.04)	214(29.89)	
E-Health4Uth group	831(36.34)	263(36.73)	

[1]A child's ethnic background was defined according to the ethnic backgrounds of his/her parents. A parent was classified as non-Dutch if one of his/her own parents was born outside the Netherlands. If one or both of the child's parents were classified as non-Dutch, that child's ethnic background was non-Dutch

Table S2. The questions measuring parental bedtime practices and child sleep outcomes.

Variable	**Questions**	**Response categories**	**Recoding of the response categories**
Parental bedtime practices (measured at child age 6 months)			
Room-sharing	1.Does your child sleep in his/her own bedroom? 2.If not, who else dose the child sleep with?	Yes, no Mother, father, siblings, parents	Yes ("Yes" for question 1 and "siblings" for question 2) and no (no for question 1 and not selecting siblings for question 2)
Parental presence at child sleep onset	How often are you or the other parent present in the room when your child falls asleep?	Every evening, almost every evening, several nights per week, about once per week, almost never, and never	yes (every evening, almost every evening) and no (a few nights per week, about once per week, almost never, and never)
Put to bed awake	When you put your child in bed at night, it is awake or asleep	Always awake, almost always awake, sometimes awake and sometimes asleep, almost always asleep, always asleep	yes (always and almost always) and no (sometimes, almost never and never)
Bedtime routine	Do you put your child to bed in the evening according to a fixed pattern or ritual? (for example, first put in a sleeping bag, sing a song, then a hug and then in bed)	Always, almost always, sometimes, almost never, never	yes (always and almost always) and no (sometimes, almost never and never)
Childs sleep outcomes (measured at child age 6, 14 and 36 months)			
Night sleep duration	How many hours did your child sleep on average during the night time (between 18:00 pm and 8:00 am)	7 hours or less, 8, 9, 10, 11, 12, 13, 14	7 hours or less=7
Day sleep duration	How many hours did your child sleep on average during the day time (between 8:00 am and 18:00 pm)	0 hour, 1, 2, 3, 4, 5, 6 or more	6 hours or more=6
Night awakenings	How often did your child wake up on average per night?	0, 1, 2, 3, 4, 5, 6 times or more times per night	6 times or more times per night=6
Sleep onset latency	How long did it take on average for your child to fall asleep?	<10 min, 10-30 min, 30min-1 hour,	≤30 min, > 30 min

		1-2 hours, more than 2 hours	
Bedtime difficulties	How often did you experience problems when bringing your child to sleep at night (e.g. crying, whining, screaming)	Never, 1-2 days per week, 3-4 days per week, 5-6 days per week, and 7 days per week	< 3 time per week, ≥3 times per week

Note: when answering the above questions, parents were reminded in the questionnaire to report the average condition in the past 4 months

Table S3. The cross-sectional and longitudinal associations between parental bedtime practices and child sleep outcomes: results from the control group only (n=831).

	Parental bedtime practices at child age 6 months			
	Room-sharing	Parental presence at child sleep onset	Putting to bed awake	Bedtime routine
Child sleep outcomes	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)
At 6 months (n=831)				
Total sleep duration (hours)	-0.43(-0.89, 0.02)	**-0.48(-0.81, -0.16)**	**0.49(0.15, 0.83)**	-0.11(-0.49, 0.27)
Night sleep duration (hours)	**-0.35(-0.69, -0.02)**	**-0.26(-0.50, -0.02)**	-0.01(-0.25, 0.24)	0.12(-0.15, 0.40)
No. of night awakenings (times)	0.15(-0.20, 0.50)	**0.41(0.17, 0.66)**	-0.02(-0.27, 0.24)	0.12(-0.16, 0.41)
Sleep quality (score)[1]	-0.10(-0.55, 0.34)	**-0.65(-0.97, -0.34)**	-0.13(-0.46, 0.19)	0.28(-0.08, 0.64)
	OR(95%CI)	OR(95%CI)	OR(95%CI)	OR(95%CI)
Sleep onset latency[2]	1.36(0.75, 2.45)	**1.07(0.70, 1.63)** [2]	1.32(0.85, 2.05)	**0.41(0.25, 0.66)**
Bedtime difficulties[3]	0.95(0.54, 1.69)	1.47(0.99, 2.18)	1.16(0.76, 1.77)	**0.43(0.28, 0.67)**
At 14 months (n=702)				
Total sleep duration (hours)	**-0.64(-1.07, -0.20)** [2]	0.04(-0.25, 0.34)	0.29(-0.01, 0.60)	0.04(-0.31, 0.39)
Night sleep duration (hours)	-0.19(-0.52, 0.15)	-0.06(-0.29, 0.16)	**0.30(0.06, 0.53)**	-0.14(-0.40, 0.13)
No. of night awakenings (times)	-0.11(-0.46, 0.24)	0.11(-0.13, 0.34)	0.03(-0.21, 0.27)	0.08(-0.19, 0.35)
	OR(95%CI)	OR(95%CI)	OR(95%CI)	OR(95%CI)
Sleep onset latency[1]	1.66(0.83, 3.31)	1.03(0.64, 1.66)	0.72(0.44, 1.17)	0.93(0.53, 1.63)
Bedtime difficulties[2]	1.14(0.51, 2.53)	1.02(0.60, 1.75)	**0.48(0.29, 0.81)** [2]	0.63(0.36, 1.13)
At 36 months (n=627)				
Total sleep duration (hours)	-0.13(-0.59, 0.33)	**-0.32(-0.62, -0.02)**	0.01(-0.30, 0.32)	-0.42(-0.78, -0.06)
Night sleep duration (hours)	-0.09(-0.44, 0.27)	**-0.23(-0.46, -0.01)**	0.01(-0.22, 0.24)	-0.15(-0.42, 0.11)
No. of night awakenings (times)	0.02(-0.32, 0.36)	0.21(-0.01, 0.43)	0.00(-0.22, 0.23)	-0.05(-0.31, 0.21)
	OR(95%CI)	OR(95%CI)	OR(95%CI)	OR(95%CI)
Sleep onset latency[1]	0.78(0.38, 1.60)	**1.62(1.03, 2.56)**	0.87(0.54, 1.40)	1.32(0.76, 2.30)
Bedtime difficulties[2]	1.66(0.78, 3.54)	**1.67(1.04, 2.68)**	0.71(0.43, 1.18)	1.18(0.63, 2.18)

Note: Models adjusted for baseline child sleep outcomes, other parental bedtime practices, and potential confounding factors including child exact age at questionnaire measurement, child gender, child ethnic background, parity, gestational age, and child temperament, maternal age, maternal education, breastfeeding status at child age 6 months, family structure, and intervention groups.

Numbers present **bold** represent the association were significant at p<0.05.

[1] Scores rated by parents at child's age of 6 months on a scale of 1-10.

[2] The magnitude of the association differed in the control group compared to the intervention group (p<0.05). We compared the associations in the control group vs the intervention group by examining the interaction terms of intervention condition and the parental bedtime practices in the models

.

CHAPTER 7

Feeding styles, parenting styles and snacking behavior in children attending primary schools in multi-ethnic neighborhoods: a cross-sectional study

BMJ Open 2017;7:e015495.

Lu Wang, Amy van Grieken, Wilma Jansen, Eline Vlasblom, Magda M Boere-Boonekamp, Monique P L'Hoir, Hein Raat

Abstract

Objective

The aim of the present study was to investigate whether feeding styles and parenting styles are associated with children's unhealthy snacking behavior and whether the associations differ according to children's ethnic background.

Methods

Cross-sectional data from the population-based 'Water Campaign' study were used. Parents (n=644) of primary school children (6 to 13 years) completed a questionnaire covering socio-demographic characteristics, feeding style dimensions ('control over eating', 'emotional feeding', 'encouragement to eat' and 'instrumental feeding'), parenting style dimensions ('involvement' and 'strictness'), and children's unhealthy snacking behavior. Logistic regression analyses were performed to determine whether feeding styles and parenting styles were associated with children's unhealthy snacking behavior.

Results

Over all, children whose parents had a higher extent of 'control over eating' had a lower odds of eating unhealthy snacks more than once per day (odds ratio [OR], 0.57; 95% CI: 0.42 to 0.76). Further stratified analysis showed that 'control over eating' was associated with less unhealthy snacking behavior only in children with a Dutch (OR, 0.37; 95% CI: 0.20 to 0.68), or a Moroccan/Turkish (OR, 0.44; 95% CI: 0.25 to 0.77) ethnic background. 'Encouragement to eat' was associated with a lower odds of eating unhealthy snacks every day in children with a Dutch ethnic background only (OR, 0.48; 95% CI: 0.25 to 0.90). 'Instrumental feeding' was associated with a higher odds of eating unhealthy snacks more than once a day in children with a Moroccan/Turkish ethnic background only (OR, 1.43; 95% CI: 1.01 to 2.04).

Conclusion

Our results suggest that 'control over eating' may be associated with less unhealthy snack consumption in children. The associations of feeding styles and parenting styles with children's unhealthy snacking behavior differed between children with different ethnic backgrounds.

Introduction

A high intake of unhealthy snack foods – i.e. snack foods high in fat, sugar and salt but low in micronutrients – is known to have adverse health outcomes (e.g. obesity, metabolic syndrome and dental caries) [1-4]. Studies performed among children living in both developed and developing countries showed that the consumption of unhealthy snack foods among children has largely increased during the past few decades [5-10]. According to the 2007-2010 Netherlands' national food consumption survey, children aged 7 to 12 years had an average of 3.3 events during the day eating energy-dense snack foods, with 90% of children consuming more energy from unhealthy snack foods than is recommended (837 to 1255 kJ per day) [11]. Given that snacking habits are established during childhood and often persist into adulthood [12], unhealthy snacking behavior should be discouraged at an early age.

Parents play an important role in shaping children's eating behaviors, through feeding styles and parenting styles [13-19]. Parental feeding styles can be measured using the Parental Feeding Style Questionnaire [20]. This measure assesses four commonly used aspects of parental feeding, including 'control over eating' (controlling the child's food intake) [13, 15], 'encouragement to eat' (encouraging the child to eat a variety of foods) [14, 15], 'instrumental feeding' (using food as a reward) and 'emotional feeding' (offering food to soothe the child's negative emotions).[20] Previous studies have indicated that 'control over eating'[13, 15] and 'encouragement to eat'[14] are associated with lower child unhealthy snack intake. While 'instrumental feeding' and 'emotional feeding' have been associated with a higher unhealthy snack intake among children [13-15].

Parenting style can be defined as a constellation of attitudes and beliefs towards the child that create an emotional climate in which parents' behaviors are expressed [21]. Based on variations in two parenting dimensions – 'involvement' (also called responsiveness), and 'strictness' (also called demandingness) – four parenting styles can be defined: authoritative, authoritarian, indulgent and neglectful [21, 22]. In general, an authoritative parenting style is characterized by high involvement and high strictness and is associated with healthier dietary behaviors of the child [17, 18, 23, 24], including lower unhealthy snack intake [16].

To date, only limited studies have investigated the associations of feeding styles and parenting styles with children's unhealthy snacking behavior. The majority of these studies have focused on native European populations [14-16]. The impact of parental feeding styles and parenting styles may differ by ethnic subgroups [25-31]. For instance, a study in the US indicated that among children with Hispanic background, parental 'emotional feeding' and 'instrumental feeding' predicted increased child sweet beverage consumption [32]. However, among children with an Afro-American background, this study observed no association between parental feeding styles and child sweet beverage consumption [32]. In the Netherlands, to the best of our knowledge, thus far no study has been published evaluating differences in feeding styles or parenting styles among groups with differential ethnic background. With regard to the development of interventions in ethnically diverse populations, it is important to study the differential influence of feeding styles and parenting styles on children's unhealthy snack consumption in each ethnic subgroup separately.

Therefore, the aim of the present study was to determine whether feeding styles and parenting styles are associated with children's unhealthy snacking behavior, and to explore whether the associations differ according to the children's ethnic background. We hypothesized that 1) 'control over eating' and 'encouragement to eat' were associated with less unhealthy snacking behavior among children, 2) 'instrumental feeding' and 'emotional feeding' were associated with more unhealthy snacking behavior among children, 3) an authoritative parenting style was associated with less unhealthy snacking behavior among children. In addition, we hypothesized that the associations of feeding styles and parenting styles with child unhealthy snacking behavior differed between distinct ethnic subgroups.

Materials and Methods

Study population

Our cross-sectional study used baseline data from the population-based 'Water campaign' study [33]. This controlled trial assessed the effects of a combined school- and community-based intervention on children's sugar- sweetened beverages consumption. Four primary schools located in disadvantaged multi-ethnic neighborhoods in Rotterdam, the Netherlands, were included in the study. The 'Water Campaign' study is an extension of the municipal overweight intervention program 'Enjoy being Fit' [34].

At the participating schools, all children in grades 2 to 8 (1288 children, aged 6 to 13 years) were invited to participate. Passive parental consent was obtained; parents (and children) were informed about the intervention and the study and were free to refuse participation without giving any explanation (reference number MEC-2011-183).

Measurements were performed at baseline and after one year, using questionnaires (child and parental) and observations at school. The questionnaires were shown to be feasible during pre-testing in a comparable population before the start of the study. Parents of all children in grades 2 to 8 (aged 6 to 13 years) at participating schools received the baseline questionnaires on paper from the teachers. The parental questionnaire could be completed at home by the main caregiver of the child, within a period of maximum 4 weeks [33]. For the present study, data from the baseline parental questionnaire (administered March/April 2011) was used. A study population of 644 parent-child dyads was available for analyses.

Measures

Socio-demographic characteristics

The socio-demographic characteristics of the child were assessed using the parental questionnaire: age (years), gender (boy/girl), ethnic background. The child's ethnic background was based on the country of birth of the parents, according to definitions given by Statistics Netherlands [35]. The child's ethnic background was Dutch only if both parents had been born in the Netherlands; if one of the parents had been born in another country, then the ethnic background of the child was defined according to that country. If both of the parents had been born in other countries, the ethnic background of the child was defined according to the mother's country of birth [35]. The ethnic background of the child was categorized as Dutch, Surinamese/Antillean, Moroccan/Turkish, or other [33]. Children categorized to the 'other' subgroup were of mixed ethnic background, such as German, or Cape-Verdean. Respondents were either the father or the mother of the child, and parental gender was based on this item (male/female). Parental age (years) and educational level were also reported. According to the standard Dutch cut-off points, the educational level of the responding parent was categorized as 'low' (no education; primary school; ≤ 3 years of general secondary school); 'mid-low' (>3 years of general secondary school); 'mid-high' (higher vocational training; undergraduate programs); or 'high' (higher academic education) [36]. Respondents reported whether the child lived with both parents vs single parent, and how many siblings the child had.

Weight status of the child

The child's height and weight were measured in light clothing without shoes by trained personnel, according to the Youth Health Care protocol [37]. The child's body mass index (BMI) was calculated as weight/(height).[2] The child's weight status was categorized as being 'non-overweight', 'overweight or obese' based on the age and gender specific BMI cut-off points published by the International Obesity Task Force [38].

Feeding style

The validated Dutch version of the Parental Feeding Style Questionnaire (PFSQ) [20] was used to assess the four feeding style dimensions: 'control over eating' (10 items), 'emotional feeding' (4 items), 'instrumental feeding' (5 items) and 'encouragement to eat' (8 items). Parents were asked to respond on a five-point Likert scale ranging from 'never' (1 point) to 'always' (5 points). Average scores on each scale were calculated for each parent, and the score was considered as missing if 50% or more of the items of the scale were missing. The percentage of parents with any missing item ranged from 4.6% to 10.1% for the four scales (Table S1). There was no difference in the percentage of parents with any missing item or with 50% or more missing items between ethnic subgroups ($p>0.05$). In addition we did a sensitivity analyses using complete-cases only, results were comparable (data not shown). A higher score indicated a greater tendency for parents to apply a specific feeding style. In the present study, the Cronbach's α was 0.78 for the 'control over eating' scale, 0.87 for the 'emotional feeding' scale, 0.79 for the 'instrumental feeding' scale and 0.77 for the 'encouragement to eat' scale.

Parenting style

The validated Dutch version of the Steinberg parenting style instrument [39-41] was used to measure the two parenting style dimensions: 'involvement' and 'strictness'. The 'involvement' scale contains nine items that assess indicators of parental loving, responsiveness, and involvement (e.g. 'My child can count on me when he or she has some kind of problem'). The 'strictness' scale contains six items that assess parental monitoring and supervision of the child (e.g. 'I know what my child does in his or her free time'). Parents were asked to respond on a five-point Likert scale ranging from 'strongly disagree' (1 point) to 'strongly agree' (5 points). Average scores on each scale were calculated for each parent, and the score was considered as missing if 50% or more of the items of the scale were missing. The percentage of parents with any missing item was 7.1% and 10.1% for the involvement and strictness scale respectively (Table S1). There was no difference in the percentage of parents with 50% or more missing items between ethnic subgroups ($p>0.05$). In addition we did a sensitivity analyses using complete-cases only, results were comparable (data not shown). Based on the median split of both scales [40], the dimensions of parenting style were further defined into the following categories: authoritative (high involvement and high strictness), authoritarian (low involvement and high strictness), indulgent (high involvement and low strictness), and neglectful (low involvement and low strictness).

Unhealthy snacking behavior of the child

Two items in the parental questionnaire were used to assess children's unhealthy snacking behavior. The questionnaire items were based on previously used questionnaires, mainly used in earlier Dutch studies [42, 43]. In the present study, unhealthy snacks were defined as energy-dense nutrient-poor foods eaten between the three main meals. Parents were provided with the following examples of unhealthy snacks: crisps, nuts, chocolate, mars bars, pastry, iced cake, ice cream, pizza, meatballs, and burgers. Parents reported how many days in a normal week the child ate unhealthy snacks (response categories: 'every day' and 'not every day') and the frequency of eating unhealthy snacks on such a day (response categories ranged from 'none', '1 per day' to '5 or more per day'). The frequency of eating unhealthy snacks per day was dichotomized into '≤1 snack per day' and '>1 snack per day'.

Statistical analysis

Descriptive statistics were used to present the demographic characteristics of the children and the responding parents. Differences in demographic characteristics between subgroups according to the child's ethnic background were compared using a ANOVA or Kruskal-Wallis test for continuous variables and a Chi-square test for categorical variables.

Logistic regression analyses were used to investigate whether feeding styles and parenting styles were associated with the children's unhealthy snacking behavior. Unhealthy snacking behavior of the child was assessed using two variables: unhealthy snacks every day (yes/no), and unhealthy snack frequency per day (≤1 or >1 per day). Descriptive results of the dimensions of feeding style, dimensions of parenting style, the parenting style categories according to child snacking behavior are presented in supplemental material (Table S2). Separate logistic regression models were built for each dimension of feeding style, dimension of parenting style and parenting style categories, adjusted for potential confounders. In order to select potential confounders, we used logistic and general linear regression to examine the associations between potential confounders and children's unhealthy snacking behavior, and dimensions of feeding style, and dimensions of parenting style and parenting style categories. Factors were considered as potential confounders if they were associated with both the children's unhealthy snacking behavior and any of the dimensions of feeding style, dimensions of parenting style and parenting style categories. The following factors were evaluated as potential confounders: responding parents' age, gender, education level, weight status, single parent vs both parents, and child age, gender, weight status, and number of siblings.

To examine whether the associations between dimensions of feeding style, dimensions of parenting style, parenting style categories and the children's unhealthy snacking behavior differed according to the children's ethnic background, an interaction term of the independent variable with child ethnic background was added to the model. The interaction term was considered significant at a level of $p<0.10$ [44]. The logistic regression models were repeated for subgroups of children with a Dutch, Surinamese/Antillean, Moroccan/Turkish, and other ethnic background respectively. Assuming a random missing pattern of data, complete–subject analyses were chosen to handle the missing values [45]. All analyses were conducted using the statistical software SAS (version 9.3, SAS Institute Inc., Cary, NC, 2010).

Results

Characteristics of the study population

The characteristics of the children and parents are shown in Table 1, which presents data from the overall sample as well as for each subgroup based on the children's ethnic background. The mean age of the children in our study was 9.4 (SD 1.8) years; 45.9% of them were boys and 30.3% had a Dutch ethnic background. Based on the parents' report, 14.6% of the children ate unhealthy snacks on a daily basis, and 29.7% ate unhealthy snacks more than once a day. The mean age of the responding parents was 37.9 (SD 7.4), 87.4% of them were mothers, and 18.5% indicated having completed a high level of education.

Over all, the scores for all the dimensions of feeding styles , parenting style and parenting style categories were different between the ethnic subgroups ($p<0.05$) (Table 2). In addition, post hoc analysis showed that parents of children with a Dutch ethnic background reported using the highest levels of 'control over eating', and 'encouragement to eat', but the lowest levels of 'instrumental feeding' and 'emotional feeding'($p<0.05$). Parents of children with a Surinamese/Antillean ethnic background had similar levels of 'encouragement to eat', 'instrumental feeding', and 'emotional feeding' compared to parents of children with a Dutch ethnic background, but a lower level of 'control over eating' ($p<0.05$). Parents of children with a Moroccan/Turkish ethnic background reported using the highest levels of 'instrumental feeding' and 'emotional feeding' ($p<0.05$). With regard to the dimensions of parenting style, the levels of parental 'involvement' and 'strictness' were similar between parents of children with a Dutch, Surinamese/Antillean, and Moroccan/Turkish ethnic background ($p>0.05$). Parents of children with Surinamese/Antillean ethnic background used 'authoritarian' parenting style less often than as Dutch parents did ($p<0.05$).

Associations between dimensions of feeding style, parenting style, parenting style categories and children's unhealthy snacking behavior

Table 3 presents the associations between dimensions of feeding style, dimensions of parenting style and parenting style categories and children's unhealthy snacking behavior. With regard to the dimensions of feeding style, children whose parents had a higher score on 'control over eating' had a lower odds of eating unhealthy snacks every day (OR 0.63; 95% CI :0.44 to 0.91), and of eating unhealthy snacks more than once per day (OR 0.57; 95% CI :0.42 to 0.76). With regard to the dimensions of parenting style, no significant association was observed for neither the 'involvement' nor the 'strictness' dimension with children's unhealthy snacking behavior. Children of parents having an 'indulgent' parenting style were less likely to eat unhealthy snacks every day (OR 0.25; 95% CI :0.09 to 0.73), compared to children of parents using an 'authoritative' parenting style.

Analyses according to the children's ethnic background

Table 4 shows the associations of dimensions of feeding style, dimensions of parenting style, and parenting style categories with children's unhealthy snacking behavior according to the children's ethnic background. With regard to feeding style dimensions, a higher score on the 'control over eating' was associated with a lower possibility of eating unhealthy snacks every day for children with a Dutch ethnic background (OR=0.41; 95% CI: 0.21 to 0.79), and for children with a Moroccan/Turkish ethnic background (OR=0.40; 95% CI: 0.19 to 0.88). A higher score on the 'encouragement to eat' was associated with lower possibility of eating unhealthy snacks every day for children with Dutch ethnic background only (OR=0.48; 95% CI: 0.25 to 0.90). In addition, a higher score on the 'control over eating' was associated with a lower possibility of eating unhealthy snacks more than once per day for children with a Dutch ethnic background (OR=0.37; 95% CI: 0.20 to 0.68), and for children with a Moroccan/Turkish ethnic background (OR=0.44; 95% CI: 0.25 to 0.77). Finally, 'instrumental feeding' was associated with a higher possibility of eating unhealthy snacks more than once per day for children with a Moroccan/Turkish ethnic background only (OR=1.43; 95% CI: 1.01 to 2.04).

With regard to parenting style dimensions, a higher score on parental 'involvement' was associated with a lower possibility of eating unhealthy snacks every day in children with an 'other' ethnic background (OR=0.21; 95% CI: 0.08 to 0.59). Children with an 'other' ethnic background whose parents had a 'neglectful' parenting style were more likely to eat unhealthy snacks more than once a day (OR=2.78; 95% CI: 1.05 to 7.33) compared to children from parents that had an 'authoritative' parenting style.

Discussion

In this study, we investigated the associations of dimensions of feeding style, dimensions of parenting style and parenting style categories with unhealthy snack consumption in school-aged children from a multi-ethnic population. In line with our hypothesis, 'control over eating' was associated with lower unhealthy snacking behavior of the child. We did not observe significant associations between 'encouragement to eat', 'instrumental feeding' and 'emotional feeding' and child unhealthy snacking behavior. Also, no association between an 'authoritative' parenting style and child unhealthy snacking behavior was observed. Our hypothesis with regard to different associations of dimensions of feeding style, dimensions of parenting style and parenting style categories with children's unhealthy snack consumption according to the ethnic background of the child, was confirmed for some of the ethnic subgroups.

In line with previous studies, the present study found that children whose parents had a higher level of 'control over eating' had a lower unhealthy snack consumption [13-15]. Further stratified analysis showed that 'control over eating' was associated with lower unhealthy snack consumption in most of the ethnic subgroups, except for the subgroup of children with a Surinamese/Antillean ethnic background. An explanation for the lack of finding among the Surinamese/Antillean ethnic subgroup may be their compliance to their traditional dietary pattern [46]. This traditional dietary pattern contains more vegetables and fruits and less unhealthy snack food [46]. Therefore, parents may facilitate child's healthy snacking behavior, without having to use control over eating.

In the present study, 'encouragement to eat' was associated with a lower unhealthy snack consumption only in the subgroup of children with a Dutch ethnic background. It is possible that the association between 'encouragement to eat' and lower unhealthy snack consumption only exists when parents provide the child with more healthy alternative foods instead of unhealthy snack foods. Further studies examining the association between parental encouragement and children's unhealthy snack consumption should consider the potential influence of food provision.

Previous research suggested that 'emotional feeding' and 'instrumental feeding' were positively associated with children's unhealthy snack intake [13-15]. While in our study, the associations of 'instrumental feeding' and 'emotional feeding' with children's unhealthy snack intake only existed among children with a Moroccan/Turkish ethnic background and in children with an 'other' ethnic background. In addition, our study results showed that parents of children with a Moroccan/Turkish ethnic background were also more likely to apply, i.e. scored higher on these dimensions, 'instrumental feeding' and 'emotional feeding' compared to the Dutch, Surinamese/Antillean and other ethnic background subgroups. These findings combined are comparable to previous findings indicating that parents mainly offer unhealthy snack food in the context of 'emotional' and 'instrumental' feeding styles [47]. As a consequence hereof, using snacks as a reward may increase children's preference for the rewarding snack [48]. Consequently, higher exposure together with increased preference for the unhealthy snack food may contribute to an increased risk of high unhealthy snack intake among children. Therefore, further interventions should discourage the use of 'instrumental feeding' and 'emotional feeding' in parents of children with a Moroccan/Turkish ethnic background.

Although previous studies suggested that having an 'authoritative' parenting style was associated with lower unhealthy snack consumption of children, we found no association between this parenting style category and children's unhealthy snack consumption. The lack of association might be due to the low variability on the scores of both the 'involvement' and 'strictness' dimensions among parents. Only in the subgroup of children with an 'other' ethnic background, a 'neglectful' parenting style, which is characterized by low 'involvement' and low 'strictness', was associated with a higher unhealthy snack consumption. This observation, of an association between having a neglectful parenting style and more unhealthy snacking behavior is in line with previous research [16, 17]. However, the contribution of ethnic background in this association is difficult to explain due to the diverse population (i.e. children with mixed ethnic background) within this subgroup.

Our study suggests that the associations of feeding style dimensions, parenting style dimensions and parenting style categories with child unhealthy snack consumption differed according to the ethnic background of the child. Moreover, the findings suggest differences between subgroups in the appliance of the different feeding styles and parenting styles. Differences in parental beliefs, parental practices (e.g.: modeling, food provision) and children's food preferences between ethnic subgroups [25, 27] may contribute to these differential applications and associations. We recommend conducting further qualitative and quantitative research to gain more insight in these ethnic-group differences in associations between feeding styles and children's snacking behavior. Increased understanding may be helpful in developing tailored interventions for reducing unhealthy snack consumption in different ethnic subgroups.

The main strengths of our study include the ethnically diverse study population, which enabled us to analyze the associations of feeding styles and parenting styles with children's unhealthy snacking behaviors in different ethnic subgroups, and the use of validated questionnaires, which allowed comparisons with other studies. Several limitations of this study should be noted. Firstly, as we relied on parents' self-reports for the child's snack consumption, social desirability and recall bias could have been possible. Parental reports have shown to be an accurate method to estimate dietary intake in school aged children [49]. However, further studies may include a combination of parental report, child report and observational measures to estimate the child's snacking behavior. In addition, the questionnaires were provided in Dutch only, which could have been a barrier for some parents given the diverse ethnicity of our study population. We did not collect data related to language spoken, however parents in all ethic subgroups were living in the Netherlands for, on average, over 20 years, indicating a familiarity with the Dutch language and culture (data not shown). Secondly, performing stratified analysis, reduced our sample size and therewith power to detect differences. Finally, given the observational nature of cross-sectional design, this study does not allow firm conclusions with regard to causality.

Conclusion

Our results suggest that 'control over eating' may be associated with less unhealthy snack consumption in children. The associations of feeding styles and parenting styles with children's unhealthy snacking behavior differ between children with different ethnic background. However, due to the limitations of cross-sectional design, future longitudinal studies with larger sample sizes are recommended. In the meantime, to improve the effectiveness of interventions focusing on parenting behaviors to reduce unhealthy snacking of children, developers should take into account the potential role of children's ethnic background.

References

1. Bellisle, F., *Meals and snacking, diet quality and energy balance.* Physiol Behav, 2014. **134**: p. 38-43.
2. Mirmiran, P., et al., *Effects of energy-dense nutrient-poor snacks on the incidence of metabolic syndrome: a prospective approach in Tehran Lipid and Glucose Study.* Nutrition, 2014. **30**(5): p. 538-43.
3. Who, J. and F.A.O.E. Consultation, *Diet, nutrition and the prevention of chronic diseases.* World Health Organ Tech Rep Ser, 2003. **916**(i-viii).
4. Chapelot, D., *The role of snacking in energy balance: a biobehavioral approach.* J Nutr, 2011. **141**(1): p. 158-62.
5. Larson, N. and M. Story, *A review of snacking patterns among children and adolescents: what are the implications of snacking for weight status?* Child Obes, 2013. **9**(2): p. 104-15.
6. Ford, C.N., M.M. Slining, and B.M. Popkin, *Trends in dietary intake among US 2- to 6-year-old children, 1989-2008.* J Acad Nutr Diet, 2013. **113**(1): p. 35-42.
7. Juul, F. and E. Hemmingsson, *Trends in consumption of ultra-processed foods and obesity in Sweden between 1960 and 2010.* Public Health Nutr, 2015. **18**(17): p. 3096-107.
8. Wang, Z., et al., *Trends in Chinese snacking behaviors and patterns and the social-demographic role between 1991 and 2009.* Asia Pac J Clin Nutr, 2012. **21**(2): p. 253-62.
9. Duffey, K.J., R.A. Pereira, and B.M. Popkin, *Prevalence and energy intake from snacking in Brazil: analysis of the first nationwide individual survey.* Eur J Clin Nutr, 2013. **67**(8): p. 868-74.
10. Macdiarmid, J., et al., *Meal and snacking patterns of school-aged children in Scotland.* European journal of clinical nutrition, 2009. **63**(11): p. 1297-1304.
11. Gevers, D.W., et al., *Intake of energy-dense snack foods and drinks among Dutch children aged 7-12 years: how many, how much, when, where and which?* Public Health Nutr, 2015: p. 1-10.
12. Craigie, A.M., et al., *Tracking of obesity-related behaviours from childhood to adulthood: A systematic review.* Maturitas, 2011. **70**(3): p. 266-84.
13. Lo, K., et al., *Associations between Parental Feeding Styles and Childhood Eating Habits: A Survey of Hong Kong Pre-School Children.* PLoS One, 2015. **10**(4): p. e0124753.
14. Sleddens, E.F., et al., *Relationship between parental feeding styles and eating behaviours of Dutch children aged 6-7.* Appetite, 2010. **54**(1): p. 30-6.
15. Rodenburg, G., et al., *Associations of parental feeding styles with child snacking behaviour and weight in the context of general parenting.* Public Health Nutr, 2014. **17**(5): p. 960-9.
16. Boots, S.B., et al., *Managing young children's snack food intake. The role of parenting style and feeding strategies.* Appetite, 2015. **92**: p. 94-101.
17. Pearson, N., et al., *Parenting styles, family structure and adolescent dietary behaviour.* Public Health Nutr, 2010. **13**(8): p. 1245-53.
18. Vollmer, R.L. and A.R. Mobley, *Parenting styles, feeding styles, and their influence on child obesogenic behaviors and body weight. A review.* Appetite, 2013. **71**: p. 232-241.
19. Hughes, S.O., et al., *Food parenting measurement issues: working group consensus report.* Child Obes, 2013. **9 Suppl**: p. S95-102.
20. Wardle, J., et al., *Parental feeding style and the inter-generational transmission of obesity risk.* Obes Res, 2002. **10**(6): p. 453-62.
21. Darling, N. and L. Steinberg, *Parenting style as context: An integrative model.* Psychological bulletin, 1993. **113**(3): p. 487.
22. Steinberg, L., J.D. Elmen, and N.S. Mounts, *Authoritative parenting, psychosocial maturity, and academic success among adolescents.* Child development, 1989: p. 1424-1436.

23. Sleddens, E.F., et al., *General parenting, childhood overweight and obesity-inducing behaviors: a review.* Int J Pediatr Obes, 2011. **6**(2-2): p. e12-27.
24. Blissett, J., *Relationships between parenting style, feeding style and feeding practices and fruit and vegetable consumption in early childhood.* Appetite, 2011. **57**(3): p. 826-31.
25. Sherry, B., et al., *Attitudes, practices, and concerns about child feeding and child weight status among socioeconomically diverse white, Hispanic, and African-American mothers.* J Am Diet Assoc, 2004. **104**(2): p. 215-21.
26. Blissett, J. and C. Bennett, *Cultural differences in parental feeding practices and children's eating behaviours and their relationships with child BMI: a comparison of Black Afro-Caribbean, White British and White German samples.* Eur J Clin Nutr, 2013. **67**(2): p. 180-4.
27. Brug, J., et al., *Differences in beliefs and home environments regarding energy balance behaviors according to parental education and ethnicity among schoolchildren in Europe: the ENERGY cross sectional study.* BMC Public Health, 2014. **14**: p. 610.
28. Evans, A., et al., *Parental feeding practices and concerns related to child underweight, picky eating, and using food to calm differ according to ethnicity/race, acculturation, and income.* Matern Child Health J, 2011. **15**(7): p. 899-909.
29. Cardel, M., et al., *Parental feeding practices and socioeconomic status are associated with child adiposity in a multi-ethnic sample of children.* Appetite, 2012. **58**(1): p. 347-53.
30. Varela, R.E., et al., *Parenting style of Mexican, Mexican American, and Caucasian-non-Hispanic families: social context and cultural influences.* J Fam Psychol, 2004. **18**(4): p. 651-7.
31. Loth, K.A., et al., *Eat this, not that! Parental demographic correlates of food-related parenting practices.* Appetite, 2013. **60**(1): p. 140-7.
32. Lora, K.R., et al., *African-American and Hispanic children's beverage intake: Differences in associations with desire to drink, fathers' feeding practices, and weight concerns.* Appetite, 2016. **107**: p. 558-567.
33. van de Gaar, V.M., et al., *Effects of an intervention aimed at reducing the intake of sugar-sweetened beverages in primary school children: a controlled trial.* Int J Behav Nutr Phys Act, 2014. **11**: p. 98.
34. Jansen, W., et al., *A school-based intervention to reduce overweight and inactivity in children aged 6-12 years: study design of a randomized controlled trial.* BMC Public Health, 2008. **8**: p. 257.
35. Swertz O, D.P., Thijssen J. , *Statistics Netherlands. Migrants in the Netherlands 2004.* Voorburg/Heerlen, Netherlands: Statistics Netherlands, 2004.
36. Netherlands, S., *Dutch standard classification of education 2003.* Voorburg/Heerlen, Netherlands: Statistics Netherlands, 2004.
37. Bulk-Bunschoten AMW, R.C., Leerdam FJM, Hirasing RA, *Protocol for detection of overweight in preventive youth health care.* VUMC: Amsterdam, 2004.
38. Cole, T.J., et al., *Establishing a standard definition for child overweight and obesity worldwide: international survey.* BMJ, 2000. **320**(7244): p. 1240.
39. Veldhuis, L., et al., *Parenting style, the home environment, and screen time of 5-year-old children; the 'be active, eat right' study.* PLoS One, 2014. **9**(2): p. e88486.
40. De Bourdeaudhuij, I., et al., *General parenting styles are not strongly associated with fruit and vegetable intake and social-environmental correlates among 11-year-old children in four countries in Europe.* Public Health Nutr, 2009. **12**(2): p. 259-66.
41. Lamborn, S.D., et al., *Patterns of competence and adjustment among adolescents from authoritative, authoritarian, indulgent, and neglectful families.* Child Dev, 1991. **62**(5): p. 1049-65.
42. van der Horst, K., et al., *The ENDORSE study: research into environmental determinants of obesity related behaviors in Rotterdam schoolchildren.* BMC Public Health, 2008. **8**: p. 142.
43. Veldhuis, L., et al., *'Be active, eat right', evaluation of an overweight prevention protocol among 5-year-old children: design of a cluster randomised controlled trial.* BMC Public Health, 2009. **9**: p. 177.

44. Rosnow, R.L. and R. Rosenthal, *Statistical procedures and the justification of knowledge in psychological science.* American Psychologist, 1989. **44**(10): p. 1276.
45. Greenland, S. and W.D. Finkle, *A critical look at methods for handling missing covariates in epidemiologic regression analyses.* Am J Epidemiol, 1995. **142**(12): p. 1255-64.
46. Dekker, L.H., et al., *Socio-economic status and ethnicity are independently associated with dietary patterns: the HELIUS-Dietary Patterns study.* Food Nutr Res, 2015. **59**: p. 26317.
47. Raaijmakers, L.G.M., et al., *Emotional and instrumental feeding practices of Dutch mothers regarding foods eaten between main meals.* BMC Public Health, 2014. **14**: p. 171.
48. Birch, L.L., et al., *Effects of instrumental consumption on children's food preference.* Appetite, 1982. **3**(2): p. 125-34.
49. Burrows, T.L., R.J. Martin, and C.E. Collins, *A Systematic Review of the Validity of Dietary Assessment Methods in Children when Compared with the Method of Doubly Labeled Water.* Journal of the American Dietetic Association, 2010. **110**(10): p. 1501-1510.

Table 1. Characteristics of children and parents in the overall sample and according to the ethnic background of the child (n=644).

	Overall sample (n=644)	Dutch (n=195)	Surinamese/ Antillean (n=142)	Moroccan/ Turkish (n=186)	Other ethnic background (n=121)	*p-value**
Child characteristics						
Age, mean (SD) (*missing, n=6*)	9.4 (1.8)	8.7 (1.8)	9.4 (1.8)	9.6 (1.5)	10.4 (1.6)	<0.001
Gender, girl, n (%) (*missing n=12*)	342 (54.1)	107 (55.2)	76 (53.9)	89 (50.0)	70 (58.8)	0.50
Number of siblings, n>1 (%) (missing n=2)	530 (82.6)	157 (80.5)	114 (80.3)	167 (90.3)	92 (76.7)	<0.001
Overweight or obese†, n (%) (*missing n=45*)	138 (23.0)	25 (13.8)	35 (26.1)	54 (31.8)	24 (21.1)	0.002
Unhealthy snacks daily, n (%) (*missing n=12*)	92 (14.6)	32 (16.8)	20 (14.2)	21 (11.4)	19 (16.2)	0.45
Unhealthy snacks per day, n (%) (*missing n=17*)						0.37
>1 snack per day	186 (29.7)	55 (28.8)	37 (26.1)	56 (30.4)	38 (32.8)	
Parental characteristics						
Gender, female, n (%) (*missing n=47*)	522 (87.4)	166 (88.8)	127 (94.8)	140 (82.4)	89 (84.0)	0.007
Age, mean (SD) (*missing, n*=6)	37.0 (8.9)	37.3 (8.6)	36.7 (7.7)	36.4 (9.4)	37.6 (10.0)	0.66
Education level of the parent (*missing n=21*)						<0.001
Low	137 (22.0)	20 (10.6)	16 (11.4)	75 (41.2)	26 (23.2)	
Mid-low	156 (25.0)	58 (30.7)	33 (23.6)	46 (25.3)	19 (17.0)	
Mid-high	215 (34.5)	61 (32.3)	66 (47.1)	45 (24.7)	43 (38.4)	
High	115 (18.5)	50 (26.5)	25 (17.9)	16 (8.8)	24 (21.4)	
Single parent, n(%) (missing, n=5)	171(26.76)	45(23.4)	59(41.5)	29(15.6)	38(31.9)	<0.001

* *p-value* derived from Chi-square test (categorical variables) or ANOVA (continuous variables).

†Weight status of the child was categorized according to the BMI cut-off points published by the International Obesity Task Force.

Table 2. Average scores on feeding style dimensions, parenting style dimensions and parenting style categories according to the children's ethnic background (n=644).

	Dutch (n=195)	Surinamese/ Antillean (n=142)	Moroccan /Turkish (n=186)	Other ethnic background (n=121)	*p-value*
Feeding style dimensions, mean (SD)					
Control over eating	4.03 (0.55)	3.72 (0.63)	3.76 (0.58)	3.56 (0.72)	<0.001
Emotional feeding	1.58 (0.66)	1.58 (0.60)	2.02 (0.87)	2.03 (0.94)	<0.001
Encouragement to eat	3.86 (0.62)	3.80 (0.69)	3.74 (0.66)	3.72 (0.67)	0.03
Instrumental feeding	1.93 (0.78)	1.90 (0.77)	2.56 (0.91)	2.28 (0.93)	<0.001
Parenting style dimensions, mean (SD)					
Involvement	4.58 (0.33)	4.65 (0.36)	4.55 (0.42)	4.48 (0.51)	0.02
Strictness	4.58 (0.58)	4.52 (0.63)	4.50 (0.57)	4.41 (0.71)	0.03
Parenting style categories, n (%)					
Authoritative	70 (37.63)	66 (47.83)	67 (37.43)	40 (34.78)	0.007
Authoritarian	36 (19.35)	8 (5.80)	16 (8.94)	15 (13.04)	
Indulgent	25 (13.44)	21 (15.22)	27 (15.08)	13 (11.30)	
Neglectful	55 (29.57)	43 (31.16)	69 (38.55)	47 (40.87)	

* *p-value* derived from Kruskal-Wallis test (feeding style dimensions and parenting style dimensions) or *Chi*-square test (parenting style categories).

Table 3. Results of the logistic regression analyses for the associations of feeding style dimensions, parenting style dimensions and parenting style categories with children's unhealthy snacking behavior (n=644).

Variables	Unhealthy snacks every day (Yes vs No)		Unhealthy snack frequency per day (>1 vs ≤1)	
	Unadjusted * OR (95% Cl)	Adjusted † OR (95% Cl)	Unadjusted * OR (95% Cl)	Adjusted † OR (95% Cl)
Feeding style dimensions				
Control over eating	**0.63 (0.45, 0.88)**	**0.63 (0.44, 0.91)**	**0.54 (0.41, 0.71)**	**0.57 (0.42, 0.76)**
Emotional feeding	0.92 (0.69, 1.23)	0.95 (0.69, 1.30)	**1.24 (1.01, 1.53)**	1.18 (0.93, 1.48)
Encouragement to eat	0.80 (0.57, 1.11)	0.73 (0.52, 1.04)	0.87 (0.67, 1.13)	0.97 (0.73, 1.28)
Instrumental feeding	0.92 (0.71, 1.19)	0.92 (0.69, 1.22)	1.10 (0.90, 1.33)	0.99 (0.80, 1.23)
Parenting style dimensions				
Involvement	**0.56 (0.33, 0.93)**	0.60 (0.35, 1.04)	0.68 (0.45, 1.04)	0.78 (0.50, 1.21)
Strictness	1.23 (0.83, 1.82)	1.43 (0.92, 2.21)	0.80 (0.61, 1.05)	0.89 (0.66, 1.20)
Parenting style categories				
Authoritative	Ref	Ref	Ref	Ref
Authoritarian	1.14 (0.57, 2.27)	1.10 (0.53, 2.28)	1.20 (0.68, 2.11)	1.31 (0.72, 2.38)
Indulgent	**0.26 (0.09, 0.76)**	**0.25 (0.09, 0.73)**	0.90 (0.51, 1.60)	0.87 (0.48, 1.56)
Neglectful	0.94 (0.57, 1.57)	0.84 (0.48, 1.46)	1.33 (0.89, 1.98)	1.21 (0.78, 1.87)

* Results from separate logistic regression models for each independent variable, without adjusting for potential confounders.

† Results from separate logistic regression models for each independent variable, adjusted for the child's age, weight status, ethnic background, and the responding parent's education level.

Note: numbers printed in **bold** represent a significant association at $p<0.05$ between the independent variable and children's unhealthy snacking behavior.

Table 4. Results of the logistic regression analyses for the associations feeding style dimensions, parenting style dimensions and parenting style categories with the children's unhealthy snacking behavior, stratified by the children's ethnic background.

	Dutch n=195	Surinamese/ Antillean n=142	Moroccan/ Turkish n=186	Other ethnic background n=121
	OR (95% CI) †	OR (95% CI) †	OR (95% CI) †	OR (95% CI) †
Unhealthy snacks every day				
Feeding style dimensions				
Control over eating*	**0.41 (0.21, 0.79)**	1.17 (0.52, 2.64)	**0.40 (0.19, 0.88)**	0.66 (0.33, 1.31)
Emotional feeding	1.13 (0.64, 2.00)	0.50 (0.18, 1.35)	1.01 (0.60, 1.71)	0.93 (0.53, 1.61)
Encouragement to eat	**0.48 (0.25, 0.90)**	1.17 (0.56, 2.47)	1.05 (0.52, 2.11)	0.71 (0.35, 1.45)
Instrumental feeding	1.10 (0.68, 1.80)	0.79 (0.40, 1.56)	1.13 (0.69, 1.85)	0.71 (0.40, 1.28)
Parenting style dimensions				
Involvement*	1.00 (0.32, 3.17)	1.74 (0.39, 7.86)	0.51 (0.18, 1.41)	**0.25 (0.09, 0.67)**
Strictness*	2.04 (0.86, 4.85)	2.60 (0.84, 8.09)	0.92 (0.41, 2.06)	0.67 (0.35, 1.29)
Parenting style categories*				
Authoritative	Ref	Ref	Ref	Ref
Authoritarian	1.25 (0.48, 3.22)	0.58 (0.07, 5.16)	1.77 (0.31, 10.09)	0.49 (0.05, 4.54)
Indulgent	-‡	0.20 (0.03, 1.66)	1.55 (0.34, 6.99)	-‡
Neglectful	0.53 (0.20, 1.40)	0.31 (0.08, 1.18)	2.01 (0.68, 6.51)	2.33 (0.74, 7.33)
Unhealthy snacks >1 times per day				
Feeding style dimensions				
Control over eating*	**0.37 (0.20, 0.68)**	1.02(0.56, 1.85)	**0.44 (0.25, 0.77)**	**0.44 (0.24, 0.79)**
Emotional feeding	1.18 (0.74, 1.89)	0.84 (0.44, 1.59)	1.29 (0.93, 1.70)	**1.56 (1.02, 2.39)**
Encouragement to eat	0.64 (0.38, 1.02)	0.97 (0.56, 1.67)	1.20 (0.73, 1.96)	0.74 (0.41, 1.32)
Instrumental feeding*	1.10 (0.74, 1.64)	0.84 (0.51, 1.38)	**1.43 (1.01, 2.04)**	0.80 (0.52, 1.25)
Parenting style dimensions				
Involvement	1.26 (0.48, 3.29)	0.88 (0.31, 2.49)	0.65 (0.31, 1.37)	0.45 (0.20, 1.02)
Strictness	1.13 (0.64, 2.00)	0.77 (0.43, 1.38)	0.83 (0.48, 1.44)	0.58 (0.33, 1.00)
Parenting style categories				
Authoritative	Ref	Ref	Ref	Ref
Authoritarian	1.79 (0.77, 4.14)	-‡	1.15 (0.35, 3.75)	0.94 (0.21, 4.14)
Indulgent	0.97 (0.35, 2.68)	0.83 (0.27, 2.61)	0.46 (0.14, 1.51)	2.68 (0.67, 10.73)
Neglectful	0.64 (0.28, 1.48)	1.03 (0.44, 2.44)	1.62 (0.79, 3.33)	**2.78 (1.05, 7.33)**

*Interaction term between ethnic background of the child and the noted independent variable was significant (*P*<0.10).

† Results from separate logistic regression model adjusted for the child's age and weight status, and the parent's education level.

‡ Not available due to low sample size in these groups (see supplemental Table S2.)

Note: numbers printed in **bold** represent a significant association between the independent variable and unhealthy snacking behavior of the child.

Table S1. Descriptive results of feeding style dimensions, parenting style dimensions, parenting style categories according to children's snacking behavior.

	Eating unhealthy snacks every day			Unhealthy snacks frequency per day		
	Yes	No	*p-value**	<=1	<=1	*p-value**
Feeding style dimensions (mean (SD))						
Control over eating	3.82(0.60)	3.62(0.78)	0.006	3.87(0.60)	3.61(0.68)	<0.001
Emotional feeding	1.75(0.85)	1.78(0.79)	0.784	1.73(0.75)	1.88(0.91)	**0.048**
Encouragement to eat	3.72(0.7)	3.8(0.65)	0.296	3.8(0.68)	3.75(0.62)	0.362
Instrumental feeding	2.11(0.94)	2.16(0.88)	0.636	2.13(0.87)	2.2(0.94)	0.370
Parenting style dimensions (mean (SD))						
Involvement	4.47(0.53)	4.59(0.38)	**0.011**	4.59(0.39)	4.53(0.45)	0.170
Strictness	4.57(0.58)	4.5(0.62)	0.317	4.53(0.59)	4.45(0.65)	0.139
Parenting style category (n (%))						
Authoritative	38(17.27)	182(82.73)	**0.032**	159(71.95)	62(28.05)	0.123
Authoritarian	11(15.71)	59(84.29)		50(71.43)	20(28.57)	
Indulgent	4(5.26)	72(94.74)		57(76)	18(24)	
Neglectful	33(17.19)	159(82.81)		132(69.11)	59(30.89)	

* *p-value* derived from Wilcoxon test (feeding and parenting style dimensions) or Chi-square test (parenting style categories).

Table S2. The number of missing items for each dimensions of feeding style and parenting style according to ethnic background.

	Number of Missing items	Total (n=644) %	Dutch (n=195) %	Surinamese/ Antillean (n=142) %	Moroccan/ Turkish (n=186) %	Other ethnic background (n=121) %	*p-value*[*]
Feeding style dimensions							
Control over eating (10 items)	1	4.50	3.59	6.34	4.84	3.31	0.19
	>1	2.64	2.56	0.7	2.15	5.79	
Emotional feeding (4 items)	1	4.04	6.15	4.23	3.76	0.83	0.09
	>1	2.02	2.05	0	2.15	4.13	
Encouragement to eat (5 items)	1	6.37	6.15	4.23	6.99	8.26	0.39
	>1	3.37	4.62	1.41	3.23	5.79	
Instrumental feeding (8 items)	1	2.64	3.08	2.11	3.76	0.83	0.19
	>1	2.02	2.56	0	1.61	4.13	
Parenting style dimensions							
Involvement (9 items)	1	3.57	3.59	3.52	3.76	3.31	0.92
	>1	3.57	3.08	2.11	4.3	4.96	
Strictness (6 items)	1	2.64	3.08	2.82	2.69	1.65	0.08
	>1	7.45	12.31	6.34	3.76	6.61	

**p-value* derived from Chi-square test.

CHAPTER 8

Associations between family and home-related factors and child's snack consumption in a multi-ethnic population

Journal of Public Health. 2018 Jul 18.

Amy van Grieken, Lu Wang, Vivian M van de Gaar, Wilma Jansen, Hein Raat

Abstract

Background

Energy-dense snacks are considered unhealthy due to their high concentrations of fat and sugar and low concentrations of micronutrients. The present study aimed to evaluate associations between family and home-related factors and children's snack consumption. We explored associations within subgroups based on ethnic background of the child.

Methods

Cross-sectional data of 644 primary school children (mean age: 9.4 years, 53 % girls) from the population-based 'Water Campaign' study conducted in the Netherlands were used. Logistic regression analyses were used to evaluate the associations between family and home-related factors and child's snack intake.

Results

Of the children, 28.7% consumed more than one snack per day. Children of parents who expressed more restrictive parenting practices towards the child's snack consumption (odds ratio(OR)=2.5, $p<0.001$), and who modelled snack eating less often (OR=2.2, $p<0.001$) had lower snack intake. Restrictive parenting practices and parental modelling of healthy snacking were significant for children with a Dutch or Moroccan/Turkish ethnic background, but not for children with Surinamese/Antillean ethnic background.

Conclusions

We observed that parenting practices and parental modelling were independently associated with the child's snack intake. Also, the relationships between these factors and the child's snack consumption differed for children with distinct ethnic backgrounds.

Introduction

Energy-dense snacks are considered unhealthy due to their high concentrations of fat and sugar and low concentrations of micronutrients [1]. Also, more frequent consumption of snacks is associated with higher total energy intake, sugars accounting for a larger proportion of the total energy intake [2]. Eating of snacks is also related to overweight and other health problems later in life [3, 4]. It is known that dietary behavior, healthy and unhealthy habits, may track from childhood into adulthood; therefore, childhood is a critical period for changes in health behavior [5].

In the USA, national data on snack intake among children aged 2 to 9 years old showed an average intake of three energy-dense snacks per day [6]. In the Netherland, the Dutch national food consumption survey showed that children have on average three energy-dense snack intakes per day [7]. Given the nature and extent of related health problems due to unhealthy dietary behaviors and childhood overweight, it is important to develop effective intervention programs for families and children that include the promotion of a low snack intake as part of a balanced and healthy dietary pattern [8].

To increase the effectiveness of such interventions, it is necessary to identify the factors that are associated with unhealthy snack consumption. In this study we apply the Environmental Research framework for weight Gain prevention (EnRG-framework) [9] to study factors that are associated with unhealthy snack consumption of school-aged children. According to the EnRG-framework, in addition to socio-demographic characteristics and cognitive factors such as attitude and self-efficacy, physical and social home environmental factors associated with child's snack intake are important for behavior changes [10, 11]. Parents may be important 'agents of change' with regard to the promotion of a healthy life style among children [12-14]. Additionally, it has been argued that habit strength and taste preferences are considered important factors that may affect the development of health behaviors in childhood [15, 16]. In our study we focus on parental attitudes, availability of snacks at home, restrictive parenting practices, parental modelling and the child's own preferences and habits. In this study, we refer to these factors as "family and home-related factors".

Studies thus far have yielded mixed results with regard to the associations between family and home-related factors and the child's snack consumption [17-19]. This may be partly explained by the preliminary finding that associations between family and home-related factors and dietary behaviors such as children's snack intake may differ between subgroups with various ethnic backgrounds [20-22]. However, studies that specifically focus on evaluating whether the association between family and home-related factors and children's snack behavior differ between subgroups are lacking. According to Wyse and colleagues, the social-cultural environment (e.g., family eating patterns) may be amendable to intervene and is therefore relevant to be studied [23].

In this study, our first objective is to assess the associations between family and home-related factors with children's snack intake, and the second objective is to explore these associations within different ethnic groups. We hypothesize that the home environment, especially parental attitudes and parental modelling, influence children's snack intake. Additionally, we hypothesize that the associations between family and home-related factors with children's snack intake are different within distinct ethnic groups.

Materials and Methods

Study population

Our cross-sectional study used data from the population-based 'Water Campaign' study, a controlled trial that assessed the effects of a combined school- and community-based intervention on children's sugar sweetened beverage consumption [24]. The Medical and Ethical Review Committee of the Erasmus Medical Centre issued a 'declaration of no objection' (i.e., formal waver) for this study (reference number MEC-2011-183). Four primary schools located in multi-ethnic, disadvantaged neighborhoods in Rotterdam, the Netherlands, were included in the study. The included schools resulted from a convenience sample of schools participating in a municipal overweight intervention program. Only schools in disadvantaged neighborhoods were eligible for this intervention [24].

All children of grades 2 to 8 (aged 6 to 13 years old) within each of the four included schools were invited to participate, resulting in a total of 1288 invited children. Passive parental consent was obtained, parents (and children) were informed about the intervention and the study and were free to refuse participation without giving any explanation [24]. Parents of all the invited children received the baseline questionnaires from the teachers. The parental questionnaire could be completed at home by the main caregiver of the child, within a period of maximum 4 weeks. Parents of 644 children returned the baseline questionnaire, and were available for this study. For our full analysis, children with missing data in the outcome variable (n=11), family and home-related factors (n=53), and age (n=5) were excluded, resulting in 575 (89.1%) subjects included.

Measurements

Socio-demographic characteristics child and parent

The child's gender (boy/girl), age (years), and ethnic background were assessed. Ethnic background was defined according to definitions given by Statistics Netherlands [25]. The child's ethnic background was defined as Dutch if both parents had been born in the Netherlands; if one of the parents had been born in another country, ethnic background was defined according to that country; and if both parents had been born in foreign countries, ethnic background was defined as the mother's country of birth. Ethnic background was categorized as 'Dutch'; 'Surinamese/Antillean'; 'Moroccan/Turkish'; or 'other/unknown'.

The responding parents' gender (mother/father), age (years) and educational level were also reported. Parents' highest achieved educational level was categorized as 'low' (no education; primary school); 'mid-low' (≤4 years of general secondary school, or lower professional training); 'mid-high' (>4 years of general secondary school or middle professional training); or 'high' (higher professional training or university) [26].

Family and home-related factors

Table 1 provides an overview of the scales (and example items) that were used to measure the family and home-related factors: (a) cognitive variables, (b) environmental variables, and (c) habitual variables. These factors were assessed with items derived from previously used questionnaires in the studies 'ENDORSE' and 'Be Active, Eat Right' [27, 28]. They were developed using the Theory of Planned Behavior (TPB) as proposed by Ajzen [29]. The items were tailored to the consumption of snacks by children as suggested by Oluka et al [30] and by Francis et al [31]. The items used to measure the construct 'habit' were derived from the Self-Report Behavioral Automaticity index [32]. All items measuring the family and home-related factors were assessed using a five-point response scale, except for the questions regarding restriction rules for the child's snack consumption (response scale 'yes'/'no'). All items were coded such that a higher score indicated a more 'favorable' behavior/situation (i.e., the child was expected to consume less snacks). Scales were only computed when there were no missing data on any of the items.

Snack consumption

The following definition of snacks was used: energy-dense snacks (snacks that are poor in nutrients and high in fat and/or sugar), which are consumed in between of the three main meals. Examples of snacks were provided, based on our definition of snacks.

Children's snack intake was assessed using the question 'On a day your child eats snacks, how many snacks does your child consume on average?'. Response categories ranged from 'none' to 'five or more'. This measure was dichotomized for analyzing purposes into ≤1 and >1 snacks per day.

Statistical analysis

Analyses were conducted using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Child and parental characteristics were analyzed using descriptive statistics. Logistic regression models were fitted, with the child's snack consumption as the dependent variable (≤1 vs >1 snacks per day). The family and home-related factors (cognitive, environmental and habitual variables) of snack consumption were used as independent variables in the model.

The independent variables were entered in the model as blocks, correcting for other variables within this block. The first block that was entered in the model contained the cognitive variables (parental attitude, and perceived behavioral control); the second block contained the environmental variables (availability, parenting practices, rules, and parental modelling); the third block contained the habitual variables (habit strength and child's taste preference).We tested the correlations between the independent variables, the results showed that none of the variables were highly correlated (all $r<0.6$). Finally, a full model was fitted with all independent variables. Odds ratio's with 95% confidence intervals (95% CI) were estimated. Results were considered significant at $p<0.05$ [33]. All analyses were controlled for socio-demographic characteristics (child's age, gender and ethnic background, and parental educational level) as potential confounders in the associations between family and home-related factors and snack consumption. For child gender and parental educational level, missing values were assigned to a separate category to be included in the models.

To evaluate whether there were differences in the associations between family and home-related factors and child's snacking behavior between the distinct ethnic subgroups children, an interaction term was added to the model. The interaction term of each family and home-related factor with child ethnic background was tested separately in the model with the adjustment for all the other family and home-related variables and the potential confounders. Table S1 in Supplement 1 shows that several interactions differed statistically (p<0.10) [33]. Therefore, the previously described analyses were also applied separately for the subgroups of children with a Dutch, Surinamese/Antillean, Moroccan/Turkish, and other/unknown ethnic background.

Results

Characteristics of the study population

Table 2 shows the socio-demographic characteristics and children's snack intake according to ethnic background of the children. Mean age of the children was 9.4 years (SD: 1.8), 53.1% were girls and 32.3% were Dutch. According to the parents, the average snack intake of the children was 1.24 snacks (SD: 0.7) per day; 28.7% of the children consumed more than one snack per day. The responding parents included 87.6% mothers, and 12.4% fathers. There was no significant difference in the reported average snack consumption and the family and home-related factors by gender of the responding parents (all *p*>0.05, see Table S2 for details), excepted for 'taste preference of the child towards snacks'(*p*<0.01, with fathers reported a higher taste preference of the child).

Family and home-related factors associated with the child's snack intake

Table 3 presents the results of the logistic regression analyses evaluating the association between the family and home-related factors and the child's snack intake per day (≤1 vs >1). A more positive parental attitudes towards reducing children's snack consumption (i.e., 'my child should eat less unhealthy snacks') was associated with a higher consumption of unhealthy snacks (*p*=0.03). Children of parents who express more restrictive parenting practices towards child's snack consumption (i.e., more monitoring, not allowing, not buying) (*p*=0.001), and who model a lower snack consumption (*p*=0.001) were reported to have a lower snack intake. All the family and home-related variables accounted in total for about 28% of the variance in children's snack intake.

Associations according to the ethnic background of the child

Table 4 presents the full model of the child's snack intake per day (≤1 vs >1) separately for the four subgroups based on ethnic background of the child. For children of all the ethnic backgrounds excepted for the Suriname/Antillean subgroup, restrictive parenting practices towards child's snack consumption and parental modelling of less snack consumption were associated with lower snack consumption of children (all $p<0.05$). In addition, for children with a Dutch ethnic background, a more positive attitude towards reducing child's snack intake (i.e., 'my child should eat less unhealthy snacks') was associated with higher snack consumption of children ($p=0.004$).

Discussion

Main finds of this study

In this paper, we assessed associations between family and home-related factors and children's snack intake. Overall, restrictive parenting practices towards child's snack consumption and parental modelling of less snack consumption were independently associated with lower snack intake of children. Associations between family and home-related factors with child's snack intake differed for children with a Dutch, Surinamese/Antillean, Moroccan/Turkish, and other/unknown background.

What is already known

Compared to the Dutch national food survey, parent reported snack consumption in our sample was relatively low (1.2 vs 3.3 snacks per day) [7]. The national food survey is based on a representative national sample, while this study concern a representative multi-ethnic inner-city population. We recommend future studies in varied populations to confirm or reject the current findings.

Previous research and review studies [1, 17, 34-39] have suggested that parental restrictive practices towards the unhealthy food is associated with lower consumption of unhealthy foods among children, while parental modelling of high unhealthy food consumption and home availability of unhealthy foods are strongly associated higher consumption of unhealthy foods among children. In line with previous research, our results suggest that children of parents who express restrictive parenting practices towards the child's snack intake (i.e., monitoring, not allowing, not buying) and children of parents who model snack consumption less often, are reported to have a lower snack intake. To increase interventions' effectiveness, intervention developers may include parents specifically as target of the intervention. In the present study, the reported availability of snacks in the home was associated with child's snack consumption in the univariate analyze only (data not shown). After adjusting for restrictive parenting practices towards child's snack consumption and parental modelling, the association was reduced to non-significant. This might be because parents who express more restrictive parenting practices towards child's snack consumption may also be less likely to make snacks available at home. Another possible explanation may be that children in our sample live in inner-city neighborhoods, where ample food shops and supermarkets are present; therefore the availability at home might be relatively less important.

What the study adds

This study examined the associations of a wide range of family and home-related factors with child's snack intake in an ethnically diverse population. Only few studies have investigated differences in factors associated with energy balance-related behaviors according to ethnic background [22, 40-43]. In line with previous research, this study provides some support for the hypothesis that the associations between home and family related factors and children's snack intake vary between subgroups of children with various ethnic backgrounds. However, due to different determinants investigated, and different ethnic groups included, comparisons with previous research are difficult.

We observed that restrictive parenting practices towards child's snack consumption and parental modelling of lower snack consumption were associated with lower snack consumption of children in all the ethnic subgroups, excepted for the 'Surinamese/Antillean' group. For the 'Surinamese/Antillean' subgroup, children's habitual strength might have an influence on their snack consumption ($p=0.06$). Possible reason for the observed differential association in the 'Surinamese/Antillean' group might be the different dietary pattern in the group. Previous studies have suggested that the group with Surinamese ethnic background in the Netherland compliant to a more traditional dietary pattern, which contains less unhealthy snack foods [44]. Further studies are expected to gain more insight in factors associated with children's snack consumption in the 'Surinamese/Antillean' group.

Differences in associations between family and home-related factors and child's snacking behavior per ethnic subgroups may have practical implications for developers of interventions. When the intervention population is diverse – e.g., ethnically or culturally diverse – there may be different factors relevant to be addressed in subgroups within the population.

Health promotion professionals should be aware of different subgroups within a population and gain knowledge about these subgroups in order to be able to better target their intervention; a certain degree of tailoring of interventions to population subgroups may be beneficial [45]. We recommend further quantitative studies to evaluate differences between ethnic subgroups in the population with regard to the factors associated with children's snacking behavior, ideally with a larger sample size and a longitudinal design. In addition, we recommend qualitative research to increase the understanding of the relevance of factors that are important for healthy lifestyles of children in varied ethnic subgroups in the population.

Limitation of this study

A limitation is the cross-sectional design, which precludes causal interpretation of our findings. It is recommended to explore and test our findings for causal inferences in longitudinal or experimental studies. Secondly, the study was conducted in multi-ethnic inner-city neighborhoods. The generalizability of our study findings might therefore be limited to children belonging to similar populations and settings. Thirdly, we relied on parental self-reports. It is possible that parents may have provided socially desirable answers; however, parent reports have shown to be an accurate method to estimate dietary intake in school-aged children [46]. Fourthly, we combined children of Surinamese and Antillean decent ('Caribbean'), and of Moroccan and Turkish decent ('Mediterranean') into a single subgroup, in order to avoid very small subgroups in the analyses. Still, in the study we had relatively small subgroups, which limited the power to detect significant associations within the subgroups. We recommend to interpret these results with caution.

Conclusions

This paper provided insight into factors related to children's snack consumption in a varied population. We observed that parenting practices and parental modelling were associated with the child's snack consumption. These findings provide support for interventions to focus on parents and improve their (family) lifestyle in order to promote healthy behaviors in children. We also observed some differences between ethnic subgroups with respect to the associations between family and home-related factors and child's snack consumption. Further quantitative and qualitative studies should address the differences between ethnic subgroups in the population with regard to the underlying factors of children's snack consumption, and whether it is beneficial to tailor interventions to promote healthy dietary behaviors.

References

1. van Ansem, W.J., et al., *Children's snack consumption: role of parents, peers and child snack-purchasing behaviour. Results from the INPACT study.* Eur J Public Health, 2015. **25**(6): p. 1006-11.
2. Field, A.E., et al., *Snack food intake does not predict weight change among children and adolescents.* Int J Obes Relat Metab Disord, 2004. **28**(10): p. 1210-6.
3. Daniels, S.R., *Complications of obesity in children and adolescents.* Int J Obes (Lond), 2009. **33 Suppl 1**: p. S60-5.
4. Reilly, J.J. and J. Kelly, *Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review.* Int J Obes (Lond), 2011. **35**(7): p. 891-8.
5. Craigie, A.M., et al., *Tracking of obesity-related behaviours from childhood to adulthood: A systematic review.* Maturitas, 2011. **70**(3): p. 266-84.
6. Piernas, C. and B.M. Popkin, *Trends in snacking among U.S. children.* Health Aff (Millwood), 2010. **29**(3): p. 398-404.
7. Gevers, D.W., et al., *Intake of energy-dense snack foods and drinks among Dutch children aged 7-12 years: how many, how much, when, where and which?* Public Health Nutr, 2016. **19**(1): p. 83-92.
8. Scholten, E.W., et al., *Relationship between impulsivity, snack consumption and children's weight.* PLoS One, 2014. **9**(2): p. e88851.
9. Kremers, S.P., et al., *Environmental influences on energy balance-related behaviors: a dual-process view.* Int J Behav Nutr Phys Act, 2006. **3**: p. 9.
10. Van Der Horst, K., et al., *A systematic review of environmental correlates of obesity-related dietary behaviors in youth.* Health Educ Res, 2007. **22**(2): p. 203-226.
11. Haerens, L., et al., *The contribution of psychosocial and home environmental factors in explaining eating behaviours in adolescents.* Eur J Clin Nutr, 2008. **62**(1): p. 51-59.
12. Golan, M. and S. Crow, *Parents are key players in the prevention and treatment of weight-related problems.* Nutr Rev, 2004. **62**(1): p. 39-50.
13. Rosenkranz, R.R. and D.A. Dzewaltowski, *Model of the home food environment pertaining to childhood obesity.* Nutr Rev, 2008. **66**(3): p. 123-40.
14. Conlon, B.A., et al., *The Role of Parenting Practices in the Home Environment among Underserved Youth.* Child Obes, 2015. **11**(4): p. 394-405.
15. Birch, L.L., *Development of food preferences.* Annu Rev Nutr, 1999. **19**: p. 41-62.
16. Nederkoorn, C., et al., *Control yourself or just eat what you like? Weight gain over a year is predicted by an interactive effect of response inhibition and implicit preference for snack foods.* Health Psychol, 2010. **29**(4): p. 389-93.
17. Verloigne, M., et al., *Family- and school-based correlates of energy balance-related behaviours in 10-12-year-old children: a systematic review within the ENERGY (EuropeaN Energy balance Research to prevent excessive weight Gain among Youth) project.* Public Health Nutr, 2012. **15**(8): p. 1380-95.
18. Larson, N. and M. Story, *A review of snacking patterns among children and adolescents: what are the implications of snacking for weight status?* Child Obes, 2013. **9**(2): p. 104-15.

19. Gubbels, J.S., et al., *Association between parenting practices and children's dietary intake, activity behavior and development of body mass index: the KOALA Birth Cohort Study.* Int J Behav Nutr Phys Act, 2011. **8**: p. 18.
20. Brug, J., et al., *Differences in weight status and energy-balance related behaviours according to ethnic background among adolescents in seven countries in Europe: the ENERGY-project.* Pediatr Obes, 2012. **7**(5): p. 399-411.
21. Skala, K., et al., *Ethnic differences in the home food environment and parental food practices among families of low-income Hispanic and African-American preschoolers.* J Immigr Minor Health, 2012. **14**(6): p. 1014-22.
22. Brug, J., et al., *Differences in beliefs and home environments regarding energy balance behaviors according to parental education and ethnicity among schoolchildren in Europe: the ENERGY cross sectional study.* BMC Public Health, 2014. **14**: p. 610.
23. Wyse, R., et al., *Associations between characteristics of the home food environment and fruit and vegetable intake in preschool children: a cross-sectional study.* BMC Public Health, 2011. **11**: p. 938.
24. van de Gaar, V.M., et al., *Effects of an intervention aimed at reducing the intake of sugar-sweetened beverages in primary school children: a controlled trial.* Int J Behav Nutr Phys Act, 2014. **11**: p. 98.
25. Swertz, O., P. Duimelaar, and J. Thijssen, *Statistics Netherlands. Migrants in the Netherlands 2004.* 2004, Statistics Netherlands: Voorburg/Heerlen, the Netherlands.
26. *Dutch Standard Classification of Education 2003*. 2004, Statistics Netherlands: Voorburg/Heerlen, Netherlands.
27. van der Horst, K., et al., *The ENDORSE study: research into environmental determinants of obesity related behaviors in Rotterdam schoolchildren.* BMC Public Health, 2008. **8**: p. 142.
28. Veldhuis, L., et al., *'Be active, eat right', evaluation of an overweight prevention protocol among 5-year-old children: design of a cluster randomised controlled trial.* BMC Public Health, 2009. **9**: p. 177.
29. Ajzen, I., *The Theory of Planned Behavior.* Organizational Behavior and Human Decision Processes, 1991. **50**(2): p. 179-211.
30. Oluka, O.C., S. Nie, and Y. Sun, *Quality assessment of TPB-based questionnaires: a systematic review.* PLoS One, 2014. **9**(4): p. e94419.
31. Francis, J., et al., *Constructing questionnaires based on the theory of planned behaviour: A manual for health services researchers.* . 2004, Centre for Health Services Research, University of Newcastle: Newcastle, United Kingdom.
32. Gardner, B., et al., *Towards parsimony in habit measurement: testing the convergent and predictive validity of an automaticity subscale of the Self-Report Habit Index.* Int J Behav Nutr Phys Act, 2012. **9**: p. 102.
33. Field, A., *Discovering Statistics Using SPSS*. Vol. Second Edition. 2005, London: SAGE Publications. 779.
34. Van Lippevelde, W., et al., *Associations between home- and family-related factors and fruit juice and soft drink intake among 10- to 12-year old children. The ENERGY project.* Appetite, 2013. **61**(1): p. 59-65.
35. van Grieken, A., et al., *Associations between the home environment and children's sweet beverage consumption at 2-year follow-up: the 'Be active, eat right' study.* Pediatr Obes, 2015. **10**(2): p. 126-33.
36. Verloigne, M., et al., *Family- and school-based predictors of energy balance-related behaviours in children: a 6-year longitudinal study.* Public Health Nutr, 2013. **16**(2): p. 202-11.
37. Pearson, N., K. Ball, and D. Crawford, *Predictors of changes in adolescents' consumption of fruits, vegetables and energy-dense snacks.* Br J Nutr, 2011. **105**(5): p. 795-803.
38. Yee, A.Z., M.O. Lwin, and S.S. Ho, *The influence of parental practices on child promotive and preventive food consumption behaviors: a systematic review and meta-analysis.* Int J Behav Nutr Phys Act, 2017. **14**(1): p. 47.

39. Hendrie, G., et al., *Change in the family food environment is associated with positive dietary change in children.* International Journal of Behavioral Nutrition and Physical Activity, 2013. **10**(1): p. 4.
40. Chuang, R.J., et al., *Ethnic differences in the home environment and physical activity behaviors among low-income, minority preschoolers in Texas.* Am J Health Promot, 2013. **27**(4): p. 270-8.
41. Varela, R.E., et al., *Parenting style of Mexican, Mexican American, and Caucasian-non-Hispanic families: social context and cultural influences.* J Fam Psychol, 2004. **18**(4): p. 651-7.
42. Lora, K.R., et al., *African-American and Hispanic children's beverage intake: Differences in associations with desire to drink, fathers' feeding practices, and weight concerns.* Appetite, 2016. **107**: p. 558-567.
43. Wang, L., et al., *Feeding styles, parenting styles and snacking behaviour in children attending primary schools in multiethnic neighbourhoods: a cross-sectional study.* BMJ open, 2017. **7**(7): p. e015495.
44. Dekker, L.H., et al., *Socio-economic status and ethnicity are independently associated with dietary patterns: the HELIUS-Dietary Patterns study.* Food Nutr Res, 2015. **59**: p. 26317.
45. Gubbels, J.S., et al., *The next step in health behavior research: the need for ecological moderation analyses - an application to diet and physical activity at childcare.* Int J Behav Nutr Phys Act, 2014. **11**: p. 52.
46. Burrows, T.L., R.J. Martin, and C.E. Collins, *A systematic review of the validity of dietary assessment methods in children when compared with the method of doubly labeled water.* J Am Diet Assoc, 2010. **110**(10): p. 1501-10.

Table 1. Descriptive results and scale information for the family and home-related factors (n=644).

	General information		Scale information		(Example of) Questionnaire item
	n (%)	mean (SD)	# items	Cronbach's α (stand.)	
Cognitive variables[1]					
Parental attitude towards child's snack intake *(range 1-5)*	630 (97.8%)	3.35(0.69)	2	0.8	e.g. "When my child eats snacks, I find it…" (pleasant – not so pleasant)
Parental attitude towards decreasing child's snack intake *(range 1-5)*	622 (91.6%)	2.64(0.82)	3	0.7	e.g. "I believe my child should consume less snacks." (disagree – agree)
Perceived behavioral control of parents towards having their child eat less snacks *(range 1-5)*	625 (97.4%)	3.87(0.84)	2	0.8	e.g. "Does it seem difficult or easy to let your child eat less snacks?" (difficult – easy)
Environmental variables[1]					
Availability of snacks at school, brought from home *(range 1-5)*	635 (98.6%)	4.43(0.99)	1	-	e.g. "Snacks - brought from home - are usually available for my child at school." (agree – disagree)
Availability of snacks at home *(range 1-5)*	632 (98.1%)	2.87(1.26)	1	-	e.g. "Snacks are usually available for my child at home." (agree – disagree)
Parenting practices towards child's snack intake *(range 1-5)*	621 (96.4%)	3.62(0.63)	4	0.7	e.g. "My child is allowed to eat unhealthy snacks when he/she wants?" (agree –disagree)
Rules at home with regard to child's snack intake *(range 1-2)*	623 (96.7%)	1.78(0.37)	2	0.8	e.g. "Are there in your home rules about how many snacks your child may consume?" (no– yes)
Modelling of snack intake by the parents *(range 1-5)*	623 (96.7%)	3.50(0.73)	2	0.6	e.g. "How often do you (or your partner) eat snacks together with your child? (every day, multiple times – never)
Habitual variables[1]					
Habit strength of the child's snack intake *(range 1-5)*	614 (95.3%)	3.55(0.95)	4	0.8	e.g. "My child often eats snacks without thinking about it." (agree – disagree)
Taste preference of child towards snack *(range 1-5)*	634 (98.4%)	1.88(1.04)	1	-	i.e. "My child likes the taste of snacks."(agree – disagree)

[1]Higher scores on the cognitive variables, environmental variables and habitual variables indicate the expectation of less unhealthy snack consumption.

Table 2. Child and parental characteristics for the overall sample and according to ethnic background of the child (n=644).

	Overall sample (n=644) **% or mean (SD)**	**Dutch (n=195)** **% or mean (SD)**	**Surinamese/ Antillean (n=142)** **% or mean (SD)**	**Moroccan/ Turkish (n=186)** **% or mean (SD)**	**Other/ unknown (n=121)** **% or mean (SD)**	***p-value***
Child characteristics						
Gender, % girl *missing, n=12*	53.1%	53.8%	50.9%	52.6%	55.3%	0.929
Age (in years), mean (SD) *missing, n=6*	9.4 (1.8)	8.7 (1.8)	9.4 (1.8)	9.6 (1.6)	10.3 (1.6)	0.000
Parental characteristic						
Gender, % female						
missing, n=48	87.6%	89.2%	94.8%	82.4%	84.0%	0.006
Educational level						0.000
missing, n=21						
% Low	22.0%	10.6%	11.4%	41.2%	23.2%	
% Mid-low	25.0%	30.7%	23.6%	25.3%	17.0%	
% Mid-high	34.5%	32.3%	47.1%	24.7%	38.4%	
% High	18.5%	26.5%	17.9%	8.8%	21.4%	
Snack intake child						
Average number of snacks per day, mean (SD) *missing, n=11*	1.24 (0.7)	1.26 (0.7)	1.16 (0.6)	1.23 (0.7)	1.32 (0.8)	0.398
Snacks per day, % >1 *missing, n=11*	28.7%	28.7%	23.2%	29.6%	34.0%	0.389

Note: The continuous variables were tested by one-way Anova, and the categorical variables were tested by Chi-square test (categorical variables).

Table 3. Results from the logistic regression models evaluating the associations between family and home-related factors and child's snack intake per day (≤1 vs >1) (n=575).

	Model 1	Model 2	Model 3	Model 4
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Cognitive variables[1]				
Parental attitude towards child's snack intake	2.07(1.49, 2.87) ***			1.06(0.72,1.56)
Parental attitude towards decreasing child's snack intake	0.67(0.52,0.86) **			0.75(0.56,1.01) *
Perceived behavioral control of parents towards having their child eat less snacks	1.41(1.12,1.78) *			0.90(0.68,1.18)
Environmental variables[1]				
Availability of snacks at school, brought from home		1.15(0.94,1.40)		1.12(0.92,1.37)
Availability of snacks at home		1.12(0.93,1.36)		1.07(0.87,1.31)
Parenting practices towards child's snack intake		2.51(1.66,3.80) ***		2.56(1.63,4.04) ***
Family and home rules with regard to child's snack intake		1.26(0.72,2.19)		1.25(0.71,2.22)
Parental modelling of snack intake		2.24 (1.59,3.14) ***		2.13(1.50,3.04) ***
Habitual variables[1]				
Habit strength of the child's snack intake			1.89(1.51,2.38) ***	1.09(0.80,1.48)
Taste preference of child towards snack			1.22(0.98,1.52)	1.12(0.88,1.44)
Nagelkerke R^2 (adjusted)[2]	**.144**	**.275**	**.164**	**.288**

[1] Higher scores indicate expectation of less snacks consumed/higher score on favorable behavior.
[2] Nagelkerke R square statistic represents the estimated level of variance explained by the regression model.
Note: Asterisks' represent the level of significance of the association between independent variable and outcome, corrected for all other variables within the model and adjusted for all confounders (child's gender, age and ethnic background and educational level of the parent): *: p <0.05, **: p <0.01, ***: p<0.001.

Table 4: Results from the full logistic regression model evaluating the associations between family and home-related factors and child's snack intake per day (≤1 vs >1) according to the ethnic background of the child.

	Dutch (n=178)	**Surinamese/ Antillean (n=127)**	**Moroccan/ Turkish (n=167)**	**Other/unknown (n=103)**
	OR (95%CI)	**OR (95%CI)**	**OR (95%CI)**	**OR (95%CI)**
Cognitive variables[1]				
Parental attitude towards child's snack intake	1.09(0.40,2.96)	0.64(0.22,1.85)	2.01(0.96,4.23)	0.36(0.10,1.24)
Parental attitude towards decreasing child's snack intake	0.34(0.16,0.70) **	0.54(0.26,1.13)	1.15(0.67,1.96)	1.37(0.46,3.72)
Perceived behavioral control of parents towards having their child eat less snacks	0.54(0.29,1.04)	1.10(0.52,2.31)	1.28(0.74,2.21)	0.96(0.46,2.04)
Environmental variables1				
Availability of snacks at school, brought from home	0.88(0.56,1.40)	1.40(0.90,2.20)	1.21(0.83,1.78)	1.05(0.51,2.17)
Availability of snacks at home	1.49(0.94,2.36)	0.83(0.51,1.37)	0.92(0.60,1.40)	1.02(0.53,1.97)
Parenting practices towards child's snack intake	4.89(1.70,14.08) **	1.46(0.43,4.95)	2.62(1.14,6.05) *	5.17(1.17,22.88) *
Family and home rules with regard to child's snack intake	3.36(0.76,14.91)	1.36(0.32,5.84)	1.61(0.54,4.85)	0.41(0.07,2.30)
Parental modelling of snack intake	3.75(1.66,8.45) ***	1.09(0.40,3.08)	2.19(1.05,4.55) *	2.64(1.04,6.71) *
Habitual variables1				
Habit strength of the child's snack intake	1.14(0.59,2.23)	2.22(0.97,5.08)	0.71(0.41,1.25)	1.56(0.60,4.09)
Taste preference of child towards snack	1.29(0.68,2.47)	0.87(0.51,1.48)	1.08(0.69,1.68)	2.08(0.84,5.16)
Nagelkerke R^2 (adjusted)[2]	**.502**	**.404**	**.335**	**.529**

[1] Higher scores indicate expectation of less snacks consumed/higher score on favorable behavior.
[2] Nagelkerke R square statistic represents the estimated level of variance explained by the regression model.
Note: Asterisks' represent the level of significance of the association between independent variable and outcome, corrected for all other variables within the model and adjusted for all confounder (child's gender, age and ethnic background and educational level of the parent): *: p<0.05, **: p<0.01, ***: p<0.001.

Table S1. *P-value*s for interaction between ethnic background and the determinants on child's snack intake per day (≤1 vs >1)* (n=575).

	Snack intake per day (≤1 vs >1)			
	*p-value*s Overall	*p-value*s Dutch vs Surinamese/Antillean	*p-value*s Dutch vs Moroccan/Turkish	*p-value*s Dutch vs Other/unknown
Cognitive variables[1]				
Parental attitude towards child's snack intake (range 1-5)	0.091	NS	NS	NS
Parental attitude towards decreasing child's snack intake (range 1-5)	0.098	NS	0.013	NS
Perceived behavioral control of parents towards having their child eat less snacks (range 1-5)	NS	NS	NS	NS
Environmental variables[1]				
Availability of snacks at school, brought from home (range 1-5)	NS	NS	NS	NS
Availability of snacks at home (range 1-5)	0.040	0.005	0.055	0.069
Parenting practices towards child's snack intake (range 1-5)	NS	0.022	NS	NS
Family and home rules with regard to child's snack intake (range 1-2)	NS	NS	NS	NS
Parental modelling of snack intake (range 1-5)	0.022	0.003	NS	NS
Habitual variables[1]				
Habit strength of the child's snack intake (range 1-5)	NS	NS	0.085	NS
Taste preference of child towards snack (range 1-5)	NS	0.095	NS	NS

*The interaction terms of family and home-related factors with ethnic background were tested in the full model, with the adjustment for all the other family and home-related variables and socio-demographic variables.
NS = not significant (p>0.10).
[1]Higher scores indicate the expectation of less snacks consumption.

Table S2. The reported child snack consumption and family and home-related factors according to responding parents' gender.

	Mother reported % or mean (SD)	**Father reported % or mean (SD)**	***p-value***
	N=522	N=74	
Average number of snacks per day, mean (SD) *missing, n=11*	1.14 (0.65)	1.27 (0.72)	0.131
Snacks per day, % >1 *missing, n=11*	20.5%	30.3%	0.086
Cognitive variables[1]			
Parental attitude towards child's snack intake	3.32(0.67)	3.41(0.70)	0.345
Parental attitude towards decreasing child's snack intake	3.65(0.84)	3.59(0.85)	0.576
Perceived behavioral control of parents towards having their child eat less snacks	3.85(0.83)	3.93(0.77)	0.462
Environmental variables[1]			
Availability of snacks at school, brought from home	4.43(1.01)	4.48(0.90)	0.712
Availability of snacks at home	2.85(1.25)	2.99(1.28)	0.405
Parenting practices towards child's snack intake	3.61(0.63)	3.69(0.58)	0.324
Family and home rules with regard to child's snack intake	1.79(0.37)	1.74(0.41)	0.270
Parental modelling of snack intake	3.48(0.72)	3.65(0.66)	0.078
Habitual variables[1]			
Habit strength of the child's snack intake	3.52(0.95)	3.72(0.84)	0.095
Taste preference of child towards snack	**1.81(0.98)**	**2.18(1.18)**	**0.004**

[1]Higher scores indicate the expectation of less snack consumption/a higher score on more favorable behavior

Table S3. Description of the family and home-related factors according to child ethnic backgrounds (n=644).

	Dutch (n=178)	Surinamese/ Antillean (n=127)	Moroccan/ Turkish (n=167)	Other/unknown (n=103)	
	mean (SD)	mean (SD)	mean (SD)	mean (SD)	*Over-all p-value*
Cognitive variables[1]					
Parental attitude towards child's snack intake *(range 1-5)*	3.15(0.60)	3.21(0.56)	3.57(0.74) *	3.48(0.75) *	<0.000
Parental attitude towards decreasing child's snack intake *(range 1-5)*	3.52(0.83)	3.56(0.80)	3.77(0.79) *	3.69(0.88)	0.03
Perceived behavioral control of parents towards having their child eat less snacks *(range 1-5)*	3.85(0.81)	3.97(0.88)	3.87(0.85)	3.81(0.79)	0.46
Environmental variables[1]					
Availability of snacks at school, brought from home *(range 1-5)*	4.47(1.00)	4.28(1.19)	4.38(1.00)	4.59(0.75)	0.10
Availability of snacks at home *(range 1-5)*	2.65(1.29)	2.78(1.20)	3.10(1.20) *	2.99(1.25) *	0.004
Parenting practices towards child's snack intake *(range 1-5)*	3.70(0.59)	3.52(0.62)	3.68(0.68)	3.56(0.60)	0.04
Rules at home with regard to child's snack intake *(range 1-2)*	1.82(0.35)	1.77(0.40)	1.78(0.36)	1.71(0.41) *	0.15
Modelling of snack intake by the parents *(range 1-5)*	3.36(0.72)	3.46(0.68)	3.57(0.71) *	3.68(0.73) *	0.002
Habitual variables[1]					
Habit strength of the child's snack intake *(range 1-5)*	3.68(0.95)	3.48(1.00)	3.54(0.91)	3.51(0.92)	0.26
Taste preference of child towards snack *(range 1-5)*	1.66(0.91)	2.02(1.06)*	1.96(1.09) *	1.83(0.99)	0.01

[1]Higher scores indicate the expectation of less snack consumption/a higher score on more favourable behavior.
* Significantly different compared to the Dutch group.

CHAPTER 9

General Discussion

Overweight and obesity among children remains a global public health issue due to its high prevalence and negative physical and psychological consequences for health [1, 2]. Individual behaviors such as increased intake of energy-dense nutrition-poor foods, a decreasing physical activity level, and increased sedentary time are the main factors that contribute to the increased prevalence of childhood overweight and obesity [3]. In addition, inadequate sleep duration has been associated with increased risk of childhood overweight [4-6]. Knowledge on the determinants of childhood overweight and overweight related lifestyle behaviors is useful for the development of evidence-based interventions and policies to prevent childhood overweight and obesity.

The following research questions are addressed in the studies presented in this thesis:

Part 1: Socioeconomic differences in risk of childhood overweight

7. What are the socioeconomic differences on weight gain during infancy (0-12 months), and if there are, what factors can explain these differences (chapter 2)?

Part 2: Health behaviors and childhood overweight

8. What are the clustering patterns of diet, physical activity, and sedentary behaviors among children aged 3 years, what are the parental and child characteristics associated with the clustering patterns, and what is the association between the clustering patterns and child BMI and weight status (chapter 3)?
9. What is the cross-sectional and longitudinal association between sleep and child BMI during infancy and early childhood (6-36 months) (chapter 4)?

Part 3: Factors associated with health behaviors

10. What are the family and child characteristics associated with early introduction of complementary feeding and the consumption of non-recommended foods during infancy (chapter 5)?
11. What are the cross-sectional and longitudinal associations between parental bedtime practices during in and child sleep outcomes in infancy and early childhood (chapter 6)?
12. What are the family characteristics associated with snack intake in school-aged children, and do the associations differ by child ethnic background (chapter 7, chapter 8)?

In this chapter, the main findings of the studies presented in this thesis and the interpretation of the findings are discussed, the methodological considerations are discussed, and implications for public health practice and future research are given. Finally, an overall conclusion is provided.

1. Main findings and interpretation

Part 1 Assessing the socioeconomic differences in childhood overweight risk

Socioeconomic differences in infant weight gain

In chapter 2, we explored the association between socioeconomic status and the weight gain trajectory during infancy (child age 0-12 months), and examined factors mediating the socioeconomic gradients in weight gain during infancy in a sample of children from the BeeBOFT study. Our study showed low maternal educational level was associated with lower birth weight and more rapid weight gain of the child between the age of 0 to 6 months. Factors explaining the association between maternal educational level and infancy weight gain included birth weight, gestational age, and infant feeding practices including breastfeeding duration and age at introduction of complementary feeding. After adjusting for all the potential mediators, maternal educational level was no longer associated with infant weight gain.

The finding that children with low educated mothers have lower birthweight than those with high educated mothers is in line with previous studies from developed countries [7-10]. Children with lower birthweight tend to catch-up in the first few months after birth [11]. Both low birthweight, and increased infant weight gain are associated with increased risk of overweight and cardiovascular risk factors at later ages [12-17]. Whether the socioeconomic divergence in infant weight gain can explain the socioeconomic inequalities in obesity and cardiovascular risk factors in later life requires further investigation. In addition to infant birth weight, infant feeding practices including breastfeeding duration and age at introduction of complementary food explained the remaining associations between low maternal education level and increased infant weight gain. Consistent with previous studies [18-21], we found that low educated mothers were less likely to initiate breastfeeding, breastfed for a shorter period, and introduced complementary food at an earlier age. Both formula feeding [22, 23] and early introduction of complementary foods [24] have been associated with increased weight gain during infancy. Higher protein and energy content from formula and complementary feeding [25] may stimulate the secretion of insulin-like growth factor which enhances growth in the first 6 months of infancy [26]. In addition, breastfed infants may learn to self-regulate their intake better than formula fed infants [27]. It should be noted that reverse causalities might exist for the associations of breastfeeding duration and age at introduction of complementary feeding with infant weigh gain. Parents of infants experiencing more rapid growth may stop breastfeeding early and introduce complementary feeding early [21, 28, 29].

Part 2. Assessing the health behaviors related to childhood overweight

Clustering patterns of children's diet, physical activity, and sedentary behaviors.

Chapter 3 examined the clustering patterns of diet, physical activity, and sedentary behaviors among children three years of age using latent class analysis. Although it has been repeatedly shown that certain lifestyle behaviors may co-occur or cluster within subgroups of children [30], little evidence exists on children under the age of four. Latent class analysis identified three subgroups of children with distinct lifestyle patterns: the "unhealthy lifestyle" pattern (36% of the children), characterized by high sugar-containing drink and unhealthy snack consumption, low fruit and vegetable consumption, high screen time, and a low physical activity level; the "low snacking and low screen time" pattern (48% of the children), characterized by low consumption of sugar-containing drinks and unhealthy snacks and low screen time; and the "active, high fruit and vegetable, high snacking, high screen time" pattern (16%), characterized by a high physical activity level, high consumption of fruit and vegetable as well as high consumption of sugar-containing drinks and unhealthy snacks, and high screen time. Our findings confirmed that the occurrence of unhealthy lifestyle behaviors can already be observed in children as young as three years. Lower maternal educational level and a permissive parenting style were associated with higher risks for the children of having an "unhealthy lifestyle" pattern or an "active, high fruit and vegetable, high snacking, high screen time" pattern.

In contrast to our hypothesis, children with the "unhealthy lifestyle" pattern did not have a higher BMI or a higher risk of being overweight compared to children with a healthier lifestyle pattern (those with a "low snacking and low screen time" pattern). The lack of association could be due to our cross-sectional design. It is also possible that children in our study (aged 3 years) have not been exposed to the unhealthy lifestyles for a long period, due to their young age, and this might present an opportunity for the primary prevention of overweight. At this young age, we could intervene to prevent the accumulation of unhealthy lifestyle behaviors. Also, as BMI is an indicator for both fat mass and fat free mass, it could be that children in the unhealthy lifestyle group had lower muscle mass and higher fat mass compared to children with relatively healthier lifestyles [31, 32].

Relationship between sleep and child BMI during infancy and early childhood

In chapter 4, we examined the cross-sectional association and bi-directional longitudinal association between sleep duration and BMI in infancy and early childhood. Our results suggest that a negative cross-sectional association between sleep duration and BMI z-score already occurs during early childhood (i.e. age 14 and 36 months). Prospectively, shorter sleep duration at the age of 6 or 14 months did not predict BMI z-score at later ages (i.e. at 14 and 36 months). A higher BMI z-score at the age of 6 months did predict shorter sleep duration at the age of 14 months after adjusting for baseline sleep. We found no association between sleep problems (night awakenings or prolonged sleep onset latency) and child BMI.

The magnitude of the cross-sectional associations we found was modest (e.g., the BMI z-score was 0.045 higher per 1 hour longer sleep duration at the age of 36 months), and is comparable to previous studies [33, 34]. The observed cross-sectional associations could be a result of reverse-causality, as we observed that higher BMI z-score at age 6 months predict shorter sleep duration of the child at age 14 months. It is also possible that unobserved confounding factors have contributed to both a reverse association and cross-sectional association. The lack of a longitudinal association between sleep duration and child BMI could be due to a longer total sleep duration of children in our population (compared to the previous studies which found a longitudinal association) [35]. Sleep duration might have minimal effect on child's weight development when the child gets longer sleep. Another possible explanation for the lack of a longitudinal association is a low intra-individual stability of sleep duration in early childhood [36], which may have reduced the predictive value of sleep duration. Variability in sleep duration might be induced by, for instance developmental spurts, illnesses or seasonal effects and changes in parental rearing attitudes [36].

Part 3. Assessing the determinants of health behaviors related to childhood overweight

Family and child related factors associated with inappropriate complementary feeding

Chapter 5 describes the family and child related factors associated with early introduction of complementary feeding (i.e. introducing complementary foods before child age 4 months) and the consumption of non-recommended foods among infants 6 months old. In total, 21.4% of the infants were introduced to complementary foods before the recommended age [37-39] (i.e. 4 months of age). At child age 6 months, 20.2% of the infants consumed sweet beverages on a daily basis and 16.5% of the infants consumed snack foods on a daily basis. The family and child related factors associated with both early introduction of complementary feeding and the consumption of non-recommended foods included younger maternal age, lower maternal educational level, absence or shorter duration of breastfeeding, parental conviction that "my child always wants to eat when he/she sees someone eating", and not attending day-care. Higher maternal pre-pregnancy BMI and infant postnatal weight gain were associated only with early introduction of complementary feeding.

Our results suggest that both timing and types of complementary feeding should be addressed when developing intervention programs targeting on the high-risk mothers (i.e. mothers who are younger, lower educated, and not breastfeeding or having a shorter duration of breastfeeding). We identified several parental cognitive factors associated with inappropriate complementary feeding practices, such as parental beliefs that "my child always wants to eat when he/she sees someone eating" and that "fruit and vegetables can be given to the baby freely earlier than 4 months". As cognitive factors tend to be more modifiable than demographical and biological factors, targeting these psychosocial contributors to inappropriate complementary feeding might be useful in future intervention programs.

Association between parental bedtime practices and child sleep outcomes

Chapter 6 describes the cross-sectional and longitudinal association of parental bedtime practices at child's age of 6 months with children's sleep outcomes at 6, 14 and 36 months reported by parents.

Our cross-sectional analyses suggest that room-sharing at child age 6 months was independently associated with shorter night sleep duration and more night awakenings of the child. Parental presence in the room while the child falls asleep was independently associated with shorter total and night sleep duration, more night awakenings, longer sleep onset latency, and more frequent bedtime difficulties of the child. Putting the child to bed awake was independently associated with shorter total sleep duration of the child. A more regular bedtime routine was independently associated with shorter sleep onset latency and less bedtime difficulties of the child. Furthermore, parental presence at child sleep onset at 6 months was longitudinally associated with shorter total and night sleep duration, more night awakenings, shorter sleep onset latency and less bedtime difficulties of the child at 36 months, independent of child sleep outcomes at 6 months. Overall, among all the parental bedtime practices, parental presence at child sleep onset was the factor most strongly associated with unfavorable child sleep outcomes (i.e. shorter sleep duration, more night awakenings, and more sleep onset problems) both cross-sectional and longitudinally. Our finding is in line with previous research [40-43], which has consistently showed that parental involvement in child sleep initiation is associated with less consolidated sleep of the child. In addition, our study provides evidence on the longitudinal associations of parental presence at child sleep onset at 6 months and child sleep outcomes at 36 months, after adjusting for prior sleep duration and sleep problems. The results of our study support the recommendation encourage independent sleep initiation in the middle of infancy. However, it is not known whether the associations of room-sharing and parental presence at sleep onset with child sleep outcomes were due to higher parental awareness of children's true sleep duration, night awakenings and sleep onset latency. Despite this limitation, our findings might still be useful for developing guidelines for preventing child sleep problems, as parental perception of child sleep problems are mainly determined by the insufficient sleep duration, excessive night awakenings, and sleep onset difficulties of children that are aware by parents. We recommend future research incorporating objectively measured sleep outcomes of children to confirm our findings.

Family related factors associated with children's unhealthy snack consumption

Chapter 7 describes the association of parenting style and feeding style with children's unhealthy snack consumption. In line with previous research [44-46] and our hypothesis, the results suggest that 'control over eating' was associated with less unhealthy snack consumption among children. Contrary to our hypothesis, we did not observe significant association between 'instrumental feeding' and 'emotional feeding' and children's intake of unhealthy snacks. Further, our findings do not support our hypothesis that an authoritative parenting style is associated with less unhealthy snack consumption among children, although previous studies have suggested that an authoritative parenting style is associated with healthier dietary intake among children [47-51]. Our results also suggest that the associations of feeding style with children's unhealthy snack consumption differed according to the ethnic background of the child. For example, stratified analysis showed that 'control over eating' was associated with lower unhealthy snack consumption in most of the ethnic subgroups, except for the subgroup of children with a 'Surinamese/Antillean' ethnic background.

In chapter 8, we examined the association of family and home-related factors with children's unhealthy snack consumption. We also examined whether the associations differ between subgroups based on ethnic background of the child. The family and home-related factors included cognitive variables including parental attitude towards children' snack intake, parental perceived behavioral control towards having their child eating less snacks, and environmental variables including availability of snacks at home, parenting practices towards child's snack consumption, rules at home with regard to child's snack consumption, and parental modelling of snack intake, and habitual variables including children's habit strength of snack intake, and taste preference of the child towards snacks. We observed that more restrictive parenting practices towards the child's snack consumption and parental modelling of healthy snacking were associated with less snack consumption of the children, independent of other home and family-related factors. These findings are in line with previous research [52-59]. Although previous studies have universally shown that home availability is associated with children's food consumption [55, 56, 60], we found no independent association between home availability of snacks with children's unhealthy snack consumption. With regard to the subgroup analyses, we found that the association of restrictive parenting practices and parental modelling of healthy snacking with child's snacking behavior were significant for children with a Dutch or Moroccan/Turkish ethnic background, but not for children with a Surinamese/Antillean ethnic background. A possible reason for the observed differential association in the 'Surinamese/Antillean' group for both chapter 7 and chapter 8 might be the different dietary pattern in the group. Previous studies have suggested that the group with Surinamese ethnic background in the Netherlands are compliant to a more traditional dietary pattern, which contains less unhealthy snack foods [61].

2 Methodological issues

2.1 Study design and study population

Study design

Chapters 2-6 in this thesis used data from the BeeBOFT study, which is a cluster randomized controlled trial involving 10 Youth Health Care (YHC) organizations from different regions of the Netherlands. The participating parents/child dyads were invited and recruited by 51 YHC teams from the 10 YHC organizations. In the 'BBOFT+' intervention group, parents received advices on child rearing skills to promote children's health behaviors (breastfeeding, less sugar containing beverages, breakfast daily, less TV viewing, and more physical activity) at each YHC routine visit (scheduled at child age 0.5, 1, 2, 3, 4, 6, 9, 11, 14, 18, 24 and 36 months). In the ‘E-health4Uth’ Healthy Toddler intervention group, parents received tailored advice on children’s health behaviors after they finished an online survey at child age 18 and 24 months, respectively.

For multilevel data, e.g. clustered data, observations on individuals in the same cluster tend to be correlated (non-independent) [62]. Whether multilevel analysis is needed depends on the degrees of correlation within clusters, known as intra-cluster correlation coefficient (ICC) [63]. The ICC is the proportion of variance in the outcome variable that is explained by the grouping variable (clusters), and is calculated as the ratio of group-level error variance over the total error variance [63]. For each study presented in this thesis which used data from the BeeBOFT study, we have checked the ICC for the outcomes variables. The ICC values were all below 0.02, suggesting very low degrees of correlation within clusters [64]. Therefore, we did not apply multi-level modelling for the studies presented in this thesis.

The intervention conditions, i.e. the ‘BBOFT+’ intervention and the ‘E-health4Uth’ intervention, may have influenced children’s health-related lifestyle behaviors and BMI or weight status. In the studies using the data from the BeeBOFT study presented in this thesis, intervention condition was adjusted for as a potential confounding factor for the association between the determinant and outcome variables. Furthermore, the potential influence of the intervention condition on the associations between the determinants and outcomes that we investigated were examined. In chapter 2, we examined the interaction term of intervention condition and maternal educational level in the models predicting infant weight gain, of which the results suggest no significant influence of the ‘BBOFT’ intervention on the association between maternal educational level and infant weight gain. In chapter 3, sensitivity analysis suggests that the lifestyle patterns identified by latent class models among children from the control condition were comparable to those identified in the total study population. In chapter 4, we examined the interaction terms of intervention condition and child sleep (including sleep duration, and sleep problems) in the models predicting child BMI, and the results suggest that the associations between child sleep and BMI do not differ by the intervention conditions. In chapter 5, we repeated the multivariate models predicting the early introduction of complementary feeding and the frequent consumption of non-recommended foods using data from the group of children allocated to the control condition, and the results are similar to the findings in the total population. In chapter 6, we repeated the models using parental bedtime practices to predict child sleep outcomes using data for the control group, and similar associations of parental bedtime practices with child sleep outcomes were found as in the total study population.

For chapter 7 and chapter 8, data from the Water campaign study were used. As we only used the baseline data from the Water campaign study, no design effect was expected to influence our results.

Study population

The initial participation rate of the BeeBOFT study was 37% (3003/7985), which is similar to the participation rate in large birth cohorts (around 30-40%) [65]. However, it has been shown that a low participation rate may not necessarily influence the association between exposure and outcome variables [65, 66]. Selection bias may only occur when the participation is related to both the exposure and the outcome variables. Higher educated parents are more likely to participate in health-related research [67]. Furthermore, parents with a higher education are more likely to participate in follow-up measures [68]. Therefore, the sample may not perfectly represent the general population in the Netherlands. The associations found in the present study should be interpreted with caution.

For the Water campaign study, the initial participation rate was 50% (644/1288). The study was conducted in multi-ethnic inner-city neighborhoods. The findings based on the Water campaign study are therefore limited to children belonging to similar populations and settings.

2.2 Assessment issues

Socioeconomic status

Family socioeconomic status is an important factor considered in the present thesis influencing child overweight risk and child health behaviors. Socioeconomic status refers to "a broad concept that refer to the placement of persons, families, households with respect to the capacity to create or consume goods that are valued in our society" [69]. The most commonly used indicators for family socioeconomic status include educational level, income, and occupation/employment status [69].

In chapter 3, maternal educational level was chosen as the main indicator of family socioeconomic status in the present thesis. Firstly, educational level is easy to measure through questionnaires and has a high response rate. Secondly, educational level is a relatively stable variable accomplished in early adult life compared to income and working circumstances. We performed sensitivity analysis using paternal educational level, parental educational level (the highest attained educational level for parents), and paternal and maternal employment status as indicators of family socioeconomic status, and comparable results were observed.

For chapter 2, maternal educational level was chosen as the main indicator of family socioeconomic status as healthy infant weight development is mainly related to maternal related factors, such as child birthweight, maternal BMI, and infant feeding [11, 70]. In addition, we repeated our analysis using other family socioeconomic indicators, including paternal educational level, maternal employment status and paternal employment status. It is a limitation that family income was not available to study.

Children's health behaviors

In this thesis, parent-reported questionnaires were used to measure children's health behaviors including dietary, physical activity, and sedentary behavior (chapter 2), sleep behaviors (chapter 4 and chapter 6), and children's unhealthy snack consumption (chapter 7 and chapter 8). All the questions were adapted from Dutch questionnaires that have been used in previous research [71, 72]. Parental-report is the most commonly used method to collect data on health behaviors of children in large epidemiological studies [73-75]. However, previous validation studies have suggested that parental-reported behavioral data are prone to reporting error [76]. Parents may provide social desirable answers, resulting in over or underestimation of certain health behaviors. For example, some studies suggest that parents may over-estimate children's physical activity level, and underestimate their sedentary time [77]. In addition, parents may not be aware of children's dietary intake, physical activity, sedentary behavior, and sleep behaviors outside the home, e.g., at day-care or at schools [76]. As no validation study has been performed for the questions on children's health behaviors used in the present study, the magnitude and direction of the reporting bias is not known.

For dietary assessment, accurate objective measures that can be applied to large epidemiological studies are lacking [75, 78]. We recommend future research investigating children's dietary intake to use food frequent questionnaires (FFQ) that is validated using the gold standard measure, the method of doubly labeled water, to measure children's dietary intake. To our best knowledge, no validated FFQ specifically developed for children under the age of 4 years is available [75]. We recommend future research to develop validated FFQ for children of different age groups, including children under the age of 4 years.

The development of portable motion sensing technologies (e.g. pedometers, accelerometer) have made it possible to determine children's physical activity, sedentary behaviors, and sleep behaviors objectively in real time [78, 79]. In addition, the combination of accelerometer with heart rate monitoring or additional movement measures have been shown to remarkably improve the accuracy of physical activity compared with doubly labeled water technique [78, 80]. However, these methods are not without limitations: the cost for the research could be much higher, and data from the portable sensing devices in a short period may not be able to provide reliable estimate for a habitual physical activity, sedentary behavior, and sleep behaviors of children [80]. Parent-report questionnaires may be used as complementary measure to the objectively measured data.

2.3 Statistical analysis

Mediation analysis

In chapter 2, we examined factors mediating the association between low maternal educational level and infant weight gain. Factors that were associated with both maternal educational level and infant weight gain in our study sample were considered as potential mediators [81]. We used path analysis to examine the mediating effect of multiple potential mediators for the association between low maternal educational level and infant weight gain. The indirect effect of maternal educational level for each of the pathways was calculated as the product of regression coefficients on that pathway [81, 82]. The proportion of the effect of maternal educational level on infant weight gain mediated by each mediator was determined by dividing the corresponding absolute indirect effect by the total effect [83]. By using path analysis, correlations between mediators were taken into account, and we were able to calculate the independent effect mediated by multiple mediators [83].

Clustering pattern of lifestyle behaviors

In chapter 3, we used a latent class model to identify the clustering or co-occurring patterns of lifestyle behaviors among children. Latent class analysis allows for the simultaneous modelling of covariates to determine the optimal number of latent classes [84]. In addition, latent class analysis uses model-based posterior membership probabilities to determine class membership for each individual, which accounts for the fact that an individual does not perfectly belong to a latent class. While cluster analysis assigns each individual into only one cluster, which may not be conceptually reasonable when the clusters overlap [84]. However, it should be noted that the cluster patterns observed by both cluster analysis and latent class analysis may only be specific to the population studied and caution is needed when generalizing results to other populations.

3 Implications for public health practices

This thesis revealed that infants from families with lower social economic status (SES) have lower birth weight and gain weight more rapidly during the first half of infancy than those from higher SES families. The association between lower SES and more rapid weight gain during infancy can be explained by lower birthweight, shorter gestational age, shorter duration of breastfeeding, and early introduction of complementary foods. Promotion of a healthy pregnancy, optimizing duration of breastfeeding and timing of complementary feeding, in particular among low educated women, may contribute to normalizing infant growth and reduce adverse consequences of increased infant weight gain.

In chapter 3, three distinct concurrence patterns of lifestyle behavior were identified using latent class analysis among children aged 3 years. The findings of this study emphasize the need to take into account the different lifestyle patterns existing in the population when developing interventions aimed at improving children's lifestyle behaviors. By grouping children into subgroups sharing different behavioral patterns, findings of the present study may assist in developing targeted interventions aimed at improving children's lifestyle behaviors and combating childhood overweight and obesity.

In chapter 4, we found a modest association between higher BMI and shorter sleep duration among toddlers (e.g., the BMI z-score was 0.045 higher per 1 hour longer sleep duration at the age of 36 months). Despite the small effect size in this study, contributions to a healthy weight in early life may be important, given the fact that adiposity may persist into later life. Youth health care providers and general practitioners should inform parents, especially parents of overweight children about the relevance of healthy sleep in addition to healthy eating and physical exercise.

Our results in chapter 6 showed that room-sharing and parental presence at bedtime during infancy were associated with unfavorable sleep outcomes of the child, while bedtime routine and putting the child to bed awake were associated with more favorable sleep outcomes of the child. Our findings support the recommendations on encouraging independent sleep initiation of the infants for the prevention of sleep problems [85]. In addition, our findings support the Dutch guideline regarding the prevention of sleep problems among infants, including regular bedtime routine, and putting the child to bed awake [86].

The results shown in chapter 7 and chapter 8 confirm the association of family related factors with children's unhealthy snacking behavior. The family related factors significantly associated with children's unhealthy snack consumption included feeding style ("control over eating"), restrictive parenting practices, and parental modelling of snacking behaviors. These findings suggest that intervention developers may target parents to increase the effectiveness of interventions for improving children's health behaviors. In addition, we found that the associations between family related factors and children's unhealthy snack consumption differ by child ethnic background. Therefore, intervention developers should be aware that that there may be different factors relevant to be addressed in different ethnic subgroups within a community when developing health promotion interventions.

4 Recommendations for future research

We confirmed that lower socioeconomic status was associated with more rapid infant weight gain during infancy. Rapid infant weight gain has been suggested to be associated with increased risk of obesity and cardiovascular risk factors in later life. We recommend research with a long follow-up period to investigate the association between early infant weight gain and long term risk of overweight and cardiovascular diseases. In addition, we recommend further research to investigate whether the socioeconomic divergence in weight gain during infancy can play a role in the socioeconomic inequalities in obesity and cardiovascular risk factors in later life.

To accurately assess the dietary intake/food habits of children, use of validated food frequency questionnaires and other dietary intake assessment instruments is recommended. We recommend future research to develop validated dietary intake assessment tools for children of different age groups, including children under the age of 4 years. To investigate children's physical activity, sedentary behavior, and sleep behaviors (sleep duration, and night awakenings), objective measures such as accelerometers in combination with parental questionnaires are recommended.

We recommend further research with repeated assessment of sleep duration using more accurate measurement methods, for example by combining sleep diary and objective measures like accelerometer, to confirm our finding regarding the longitudinal association between higher BMI during infancy and shorter sleep duration at later age. In addition, further research is recommended to explore the potential mechanism explaining the influence of higher BMI on sleep duration. It has been proposed that children with higher BMI z-scores are less active [87], and therefore need less sleep [88]. It has also been proposed that the association between higher BMI and curtailed sleep may be mediated by poorer general health and physiological disorders such as sleep apnea [34, 89, 90].

Our findings support the relevance of the ecological model for prediction of childhood overweight [91], indicating that a wider environment, such as ethnic and cultural background, may have moderating effects on the association between home environmental determinants and children's dietary behaviors. Future research should examine the effect of the home environment on children's health behaviors within a broader context of community, and cultural background. The ecological model for prediction of childhood overweight also suggests that studies should examine the interaction between environment and individual characteristics.

5 General conclusion

In this thesis, we demonstrated that socioeconomic differences exist with regard to infant weight gain. We confirmed that certain overweight related lifestyle behaviors may occur within subgroups of children as young as 3 years, and that maternal educational level and parenting style are associated with these occurring patterns. We found a cross-sectional association between shorter sleep duration and higher BMI z-score during early childhood, and longitudinal association between higher BMI z-score (at age 6 months) and shorter sleep duration of the child (at age 14 months). We identified several family environmental factors associated with child's snack consumption, and demonstrated that the association between family environmental factors and child's snack consumption may differ between ethnic groups. Overall, our findings support the relevance of social, family environmental and child related factors in predicting childhood overweight and overweight related health behaviors. The findings of the present study will be useful to support the development of evidence-based prevention programs regarding childhood overweight and obesity.

References

1. Organization, W.H. *Report of the commision on ending childhood obesity*. 2016 [cited 2018; Available from: http://apps.who.int/iris/bitstream/handle/10665/204176/9789241510066_eng.pdf?sequence=1.
2. Sahoo, K., et al., *Childhood obesity: causes and consequences.* Journal of family medicine and primary care, 2015. **4**(2): p. 187.
3. te Velde, S.J., et al., *Energy balance-related behaviours associated with overweight and obesity in preschool children: a systematic review of prospective studies.* Obes Rev, 2012. **13 Suppl 1**: p. 56-74.
4. Felső, R., et al., *Relationship between sleep duration and childhood obesity: Systematic review including the potential underlying mechanisms.* Nutrition, Metabolism and Cardiovascular Diseases, 2017. **27**(9): p. 751-761.
5. Ash, T. and E.M. Taveras, *Associations of short sleep duration with childhood obesity and weight gain: summary of a presentation to the National Academy of Science's Roundtable on Obesity Solutions.* Sleep Health, 2017. **3**(5): p. 389-392.
6. Taylor, R.W., et al., *Sleep, nutrition, and physical activity interventions to prevent obesity in infancy: follow-up of the Prevention of Overweight in Infancy (POI) randomized controlled trial at ages 3.5 and 5 y.* The American journal of clinical nutrition, 2018. **108**(2): p. 228-236.
7. Morgen, C.S., et al., *Socioeconomic disparities in birth weight and body mass index during infancy through age 7 years: a study within the Danish National Birth Cohort.* BMJ Open, 2017. **7**(1): p. e011781.
8. Jansen, P.W., et al., *Explaining educational inequalities in birthweight: the Generation R Study.* Paediatr Perinat Epidemiol, 2009. **23**(3): p. 216-28.
9. Mortensen, L.H., et al., *Social inequality in fetal growth: a comparative study of Denmark, Finland, Norway and Sweden in the period 1981-2000.* J Epidemiol Community Health, 2008. **62**(4): p. 325-31.
10. Mortensen, L.H., et al., *Income-related and educational inequality in small-for-gestational age and preterm birth in Denmark and Finland 1987-2003.* Scand J Public Health, 2010. **38**(1): p. 40-5.
11. Kupers, L.K., et al., *Determinants of Weight Gain during the First Two Years of Life--The GECKO Drenthe Birth Cohort.* PLoS One, 2015. **10**(7): p. e0133326.
12. Jornayvaz, F.R., et al., *Low birth weight leads to obesity, diabetes and increased leptin levels in adults: the CoLaus study.* Cardiovasc Diabetol, 2016. **15**.
13. Taine, M., et al., *Rapid Early Growth May Modulate the Association Between Birth Weight and Blood Pressure at 5 Years in the EDEN Cohort StudyNovelty and Significance.* Hypertension, 2016. **68**(4): p. 859-865.
14. Curhan, G.C., et al., *Birth weight and adult hypertension, diabetes mellitus, and obesity in US men.* Circulation, 1996. **94**(12): p. 3246-50.
15. Eriksson, J.G., et al., *Catch-up growth in childhood and death from coronary heart disease: longitudinal study.* Bmj, 1999. **318**(7181): p. 427-31.
16. Leunissen, R.W., et al., *Timing and tempo of first-year rapid growth in relation to cardiovascular and metabolic risk profile in early adulthood.* Jama, 2009. **301**(21): p. 2234-42.
17. Dulloo, A.G., et al., *The thrifty 'catch-up fat' phenotype: its impact on insulin sensitivity during growth trajectories to obesity and metabolic syndrome.* Int J Obes (Lond), 2006. **30 Suppl 4**: p. S23-35.
18. Gibbs, B.G. and R. Forste, *Socioeconomic status, infant feeding practices and early childhood obesity.* Pediatr Obes, 2014. **9**(2): p. 135-46.

19. van Rossem, L., et al., *Are starting and continuing breastfeeding related to educational background? The generation R study.* Pediatrics, 2009. **123**(6): p. e1017-27.
20. Lin, S.L., et al., *Timing of solid food introduction and obesity: Hong Kong's "children of 1997" birth cohort.* Pediatrics, 2013. **131**(5): p. e1459-67.
21. van Rossem, L., et al., *Weight change before and after the introduction of solids: results from a longitudinal birth cohort.* Br J Nutr, 2013. **109**(2): p. 370-5.
22. van Rossem, L., et al., *Is the association of breastfeeding with child obesity explained by infant weight change?* Int J Pediatr Obes, 2011. **6**(2-2): p. e415-22.
23. Klag, E.A., et al., *Associations Between Breast Milk Feeding, Introduction of Solid Foods, and Weight Gain in the First 12 Months of Life.* Clin Pediatr (Phila), 2015. **54**(11): p. 1059-67.
24. Grote, V., et al., *The introduction of solid food and growth in the first 2 y of life in formula-fed children: analysis of data from a European cohort study.* Am J Clin Nutr, 2011. **94**(6 Suppl): p. 1785S-1793S.
25. Inostroza, J., et al., *Low-Protein Formula Slows Weight Gain in Infants of Overweight Mothers.* J Pediatr Gastroenterol Nutr, 2014. **59**(1): p. 70-7.
26. Socha, P., et al., *Milk protein intake, the metabolic-endocrine response, and growth in infancy: data from a randomized clinical trial.* Am J Clin Nutr, 2011. **94**(6 Suppl): p. 1776s-1784s.
27. Singhal, A. and J. Lanigan, *Breastfeeding, early growth and later obesity.* Obes Rev, 2007. **8 Suppl 1**: p. 51-4.
28. Jobe, A.H., *Age of weaning and infant growth.* The Journal of pediatrics, 2015. **167**(2): p. 219-221.
29. Wright, C.M., K.N. Parkinson, and R.F. Drewett, *Why are babies weaned early? Data from a prospective population based cohort study.* Arch Dis Child, 2004. **89**(9): p. 813-6.
30. Leech, R.M., S.A. McNaughton, and A. Timperio, *The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review.* Int J Behav Nutr Phys Act, 2014. **11**: p. 4.
31. Stevens, J., J.E. McClain, and K.P. Truesdale, *Selection of measures in epidemiologic studies of the consequences of obesity.* Int J Obes (Lond), 2008. **32 Suppl 3**: p. S60-6.
32. van der Sluis, M.E., et al., *Longitudinal associations of energy balance-related behaviours and cross-sectional associations of clusters and body mass index in Norwegian adolescents.* Public Health Nutr, 2010. **13**(10 A): p. 1716-1721.
33. Bolijn, R., et al., *Daytime sleep duration and the development of childhood overweight: the KOALA B irth C ohort S tudy.* Pediatric obesity, 2016. **11**(5): p. e1-e5 %@ 2047-6302.
34. Collings, P.J., et al., *Sleep Duration and Adiposity in Early Childhood: Evidence for Bidirectional Associations from the Born in Bradford Study.* Sleep, 2017. **40**(2).
35. Taveras, E.M., et al., *Short sleep duration in infancy and risk of childhood overweight.* Arch Pediatr Adolesc Med, 2008. **162**(4): p. 305-11.
36. Jenni, O.G., et al., *Sleep duration from ages 1 to 10 years: variability and stability in comparison with growth.* Pediatrics, 2007. **120**(4): p. e769-76.
37. Agostoni, C., et al., *Complementary feeding: a commentary by the ESPGHAN Committee on Nutrition.* Journal of pediatric gastroenterology and nutrition, 2008. **46**(1): p. 99-110.
38. Fewtrell, M., et al., *Complementary feeding: A position paper by the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) committee on nutrition.* Journal of pediatric gastroenterology and nutrition, 2017. **64**(1): p. 119-132.
39. Verbrugge, H.P., *Youth health care in The Netherlands: a bird's eye view.* Pediatrics, 1990. **86**(6 Pt 2): p. 1044-7.
40. Adair, R., et al., *Night waking during infancy: role of parental presence at bedtime.* Pediatrics, 1991. **87**(4): p. 500-4.
41. Yu, X.T., et al., *Parental behaviors and sleep/wake patterns of infants and toddlers in Hong Kong, China.* World J Pediatr, 2017. **13**(5): p. 496-502.

42. Touchette, É., et al., *Factors associated with fragmented sleep at night across early childhood.* Archives of pediatrics & adolescent medicine, 2005. **159**(3): p. 242-249.
43. Mindell, J.A., et al., *Parental behaviors and sleep outcomes in infants and toddlers: a cross-cultural comparison.* Sleep Med, 2010. **11**(4): p. 393-9.
44. Rodenburg, G., et al., *Associations of parental feeding styles with child snacking behaviour and weight in the context of general parenting.* Public Health Nutr, 2014. **17**(5): p. 960-9.
45. Sleddens, E.F., et al., *Relationship between parental feeding styles and eating behaviours of Dutch children aged 6-7.* Appetite, 2010. **54**(1): p. 30-6.
46. Lo, K., et al., *Associations between Parental Feeding Styles and Childhood Eating Habits: A Survey of Hong Kong Pre-School Children.* PLoS One, 2015. **10**(4): p. e0124753.
47. Boots, S.B., et al., *Managing young children's snack food intake. The role of parenting style and feeding strategies.* Appetite, 2015. **92**: p. 94-101.
48. Sleddens, E.F., et al., *General parenting, childhood overweight and obesity-inducing behaviors: a review.* Int J Pediatr Obes, 2011. **6**(2-2): p. e12-27.
49. Vollmer, R.L. and A.R. Mobley, *Parenting styles, feeding styles, and their influence on child obesogenic behaviors and body weight. A review.* Appetite, 2013. **71**: p. 232-241.
50. Pearson, N., et al., *Parenting styles, family structure and adolescent dietary behaviour.* Public Health Nutr, 2010. **13**(8): p. 1245-53.
51. Blissett, J., *Relationships between parenting style, feeding style and feeding practices and fruit and vegetable consumption in early childhood.* Appetite, 2011. **57**(3): p. 826-31.
52. Van Lippevelde, W., et al., *Associations between home- and family-related factors and fruit juice and soft drink intake among 10- to 12-year old children. The ENERGY project.* Appetite, 2013. **61**(1): p. 59-65.
53. van Grieken, A., et al., *Associations between the home environment and children's sweet beverage consumption at 2-year follow-up: the 'Be active, eat right' study.* Pediatr Obes, 2015. **10**(2): p. 126-33.
54. Verloigne, M., et al., *Family- and school-based predictors of energy balance-related behaviours in children: a 6-year longitudinal study.* Public Health Nutr, 2013. **16**(2): p. 202-11.
55. Pearson, N., K. Ball, and D. Crawford, *Predictors of changes in adolescents' consumption of fruits, vegetables and energy-dense snacks.* Br J Nutr, 2011. **105**(5): p. 795-803.
56. van Ansem, W.J., et al., *Children's snack consumption: role of parents, peers and child snack-purchasing behaviour. Results from the INPACT study.* Eur J Public Health, 2015. **25**(6): p. 1006-11.
57. Verloigne, M., et al., *Family- and school-based correlates of energy balance-related behaviours in 10-12-year-old children: a systematic review within the ENERGY (EuropeaN Energy balance Research to prevent excessive weight Gain among Youth) project.* Public Health Nutr, 2012. **15**(8): p. 1380-95.
58. Yee, A.Z., M.O. Lwin, and S.S. Ho, *The influence of parental practices on child promotive and preventive food consumption behaviors: a systematic review and meta-analysis.* Int J Behav Nutr Phys Act, 2017. **14**(1): p. 47.
59. Hendrie, G., et al., *Change in the family food environment is associated with positive dietary change in children.* International Journal of Behavioral Nutrition and Physical Activity, 2013. **10**(1): p. 4.
60. Larson, N. and M. Story, *A review of snacking patterns among children and adolescents: what are the implications of snacking for weight status?* Child Obes, 2013. **9**(2): p. 104-15.
61. Dekker, L.H., et al., *Socio-economic status and ethnicity are independently associated with dietary patterns: the HELIUS-Dietary Patterns study.* Food Nutr Res, 2015. **59**: p. 26317.
62. Steenbergen, M.R. and B.S. Jones, *Modeling multilevel data structures.* american Journal of political Science, 2002: p. 218-237.

63. Julian, M.W., *The consequences of ignoring multilevel data structures in nonhierarchical covariance modeling.* Structural Equation Modeling, 2001. **8**(3): p. 325-352.
64. Killip, S., Z. Mahfoud, and K. Pearce, *What is an intracluster correlation coefficient? Crucial concepts for primary care researchers.* Ann Fam Med, 2004. **2**(3): p. 204-8.
65. Nohr, E.A., et al., *Does low participation in cohort studies induce bias?* Epidemiology, 2006. **17**(4): p. 413-8.
66. Pizzi, C., et al., *Sample selection and validity of exposure-disease association estimates in cohort studies.* J Epidemiol Community Health, 2011. **65**(5): p. 407-11.
67. Berra, S., et al., *Methods and representativeness of a European survey in children and adolescents: the KIDSCREEN study.* BMC Public Health, 2007. **7**(1): p. 182.
68. van Grieken, A., et al., *Personalized Web-Based Advice in Combination With Well-Child Visits to Prevent Overweight in Young Children: Cluster Randomized Controlled Trial.* J Med Internet Res, 2017. **19**(7): p. e268.
69. Shavers, V.L., *Measurement of socioeconomic status in health disparities research.* J Natl Med Assoc, 2007. **99**(9): p. 1013-23.
70. Woo Baidal, J.A., et al., *Risk Factors for Childhood Obesity in the First 1,000 Days: A Systematic Review.* Am J Prev Med, 2016. **50**(6): p. 761-79.
71. van Grieken, A., et al., *Population-based childhood overweight prevention: outcomes of the 'Be active, eat right'study.* PloS one, 2013. **8**(5): p. e65376.
72. Horst, K.v.d., et al., *The ENDORSE study: Research into environmental determinants of obesity related behaviors in Rotterdam schoolchildren.* BMC Public Health, 2008. **8**(1): p. 142.
73. Sirard, J.R. and R.R. Pate, *Physical activity assessment in children and adolescents.* Sports Med, 2001. **31**(6): p. 439-54.
74. Lubans, D.R., et al., *A systematic review of the validity and reliability of sedentary behaviour measures used with children and adolescents.* Obes Rev, 2011. **12**(10): p. 781-99.
75. Burrows, T.L., R.J. Martin, and C.E. Collins, *A systematic review of the validity of dietary assessment methods in children when compared with the method of doubly labeled water.* J Am Diet Assoc, 2010. **110**(10): p. 1501-10.
76. Livingstone, M.B., P.J. Robson, and J.M. Wallace, *Issues in dietary intake assessment of children and adolescents.* Br J Nutr, 2004. **92 Suppl 2**: p. S213-22.
77. Colley, R.C., et al., *Physical activity, sedentary behaviour and sleep in Canadian children: parent-report versus direct measures and relative associations with health risk.* Health Rep, 2012. **23**(2): p. 45-52.
78. Dhurandhar, N.V., et al., *Energy balance measurement: when something is not better than nothing.* Int J Obes (Lond), 2015. **39**(7): p. 1109-13.
79. Wijtzes, A.I., et al., *Correlates of physical activity in 2-year-old toddlers: the generation R study.* The Journal of pediatrics, 2013. **163**(3): p. 791-799. e2.
80. Cliff, D.P., J.J. Reilly, and A.D. Okely, *Methodological considerations in using accelerometers to assess habitual physical activity in children aged 0–5 years.* Journal of Science and Medicine in Sport, 2009. **12**(5): p. 557-567.
81. Baron, R.M. and D.A. Kenny, *The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations.* Journal of personality and social psychology, 1986. **51**(6): p. 1173.
82. MacKinnon, D., *Introduction to Statistical Mediation Analysis* 2008: Lawrence Erlbaum Associates.
83. Ditlevsen, S., et al., *The mediation proportion: a structural equation approach for estimating the proportion of exposure effect on outcome explained by an intermediate variable.* Epidemiology, 2005. **16**(1): p. 114-120.
84. Magidson, J. and J. Vermunt, *Latent class models for clustering: A comparison with K-means.* Canadian Journal of Marketing Research, 2002. **20**(1): p. 36-43.

85. Mindell, J.A., *Sleeping Through the Night, Revised Edition: How Infants, Toddlers, and Parents can get a Good Night's sleep*. 2010: Zondervan.
86. Vlasblom E, S.B.v., L'Hoir MP, Beltman M. . *JGZ-Richtlijn: Gezonde slaap en slaapproblemen bij kinderen. [JGZ- guideline: Healthy sleep and sleep problems in children]*. 2017; Available from: https://www.ncj.nl/richtlijnen/alle-richtlijnen/richtlijn/gezonde-slaap-en-slaapproblemen-bij-kinderen.
87. Trost, S.G., et al., *Physical activity in overweight and nonoverweight preschool children.* Int J Obes Relat Metab Disord, 2003. **27**(7): p. 834-9.
88. Wu, Y., et al., *Effect of leisure-time aerobic exercise and muscle strength activity on sleep duration: results from the 2012 National Health Interview Survey.* Journal of Public Health, 2016. **24**(2): p. 117-124.
89. Katz, E.S., R.B. Mitchell, and C.M. D'ambrosio, *Obstructive sleep apnea in infants.* American journal of respiratory and critical care medicine, 2012. **185**(8): p. 805-816.
90. Lumeng, J.C. and R.D. Chervin, *Epidemiology of pediatric obstructive sleep apnea.* Proceedings of the American Thoracic Society, 2008. **5**(2): p. 242-252.
91. Davison, K.K. and L.L. Birch, *Childhood overweight: a contextual model and recommendations for future research.* Obes Rev, 2001. **2**(3): p. 159-71.

CHAPTER 10

Summary and samenvatting

Summary

Overweight and obesity among children is one of the major public health issues worldwide due to its high prevalence and negative physical and psychological consequences. This thesis aims to provide insight in the determinants of childhood overweight, and health behaviors related to childhood overweight (i.e., infant feeding practices, dietary intake, sedentary behavior, physical activity, and sleep duration). The following research questions are addressed in the studies of this thesis:

Part 1: Socioeconomic differences in risk of childhood overweight

1. What are the socioeconomic differences on weight gain during infancy (0-12 months), and if there are, what factors can explain these differences (chapter 2)?

Part 2: Health behaviors and childhood overweight

2. What are the clustering patterns of diet, physical activity, and sedentary behaviors among children aged 3 years, what are the parental and child characteristics associated with the clustering patterns, and what is the association between the clustering patterns and child BMI and weight status (chapter 3)?
3. What is the cross-sectional and longitudinal association between sleep and child BMI during infancy and early childhood (6-36 months) (chapter 4)?

Part 3: Factors associated with health behaviors

4. What are the family and child characteristics associated with early introduction of complementary feeding and the consumption of non-recommended foods during infancy (chapter 5)?
5. What are the cross-sectional and longitudinal associations between parental bedtime practices and child sleep outcomes in infancy and early childhood (chapter 6)?
6. What are the family characteristics associated with snack intake in school-aged children, and do the associations differ by child ethnic background (chapter 7, chapter 8)?

These research questions were addressed using data from two population based studies in the Netherlands: the BeeBOFT study and the Water Campaign study.

Chapter 2 describes that low maternal educational level was associated with lower birth weight of the child, and more rapid weight gain during the first half of infancy (0-6 months). The main mediating factors explaining the association between maternal educational level and

infancy weight gain included birth weight, gestational age, and infant feeding practices including breastfeeding duration and age at introduction of complementary feeding.

In chapter 3, latent class analysis identified three distinct cooccurrence patterns of lifestyle behaviors among children: the “unhealthy lifestyle” pattern (36%), the “low snacking and low sedentary” pattern (48%), and the “active, high fruit and vegetable consumption, high snacking and high sedentary” pattern (16%). Lower maternal educational level and a permissive parenting style of the parents were associated with having an “unhealthy lifestyle” pattern among children. We found no association between the lifestyle patterns and children’s BMI or weight status.

In chapter 4, we observed a negative cross-sectional association between sleep duration and BMI z-score during early childhood (i.e. age 14 and 36 months). Prospectively, shorter sleep duration at the age of 6 or 14 months did not predict BMI z-score at later ages (i.e. at 14 and 36 months). A higher BMI z-score at the age of 6 months did predict shorter sleep duration at the age of 14 months after adjusting for baseline sleep. We found no association between sleep problems (including excessive night awakenings and extended sleep onset latency) and child BMI.

In chapter 5, we identified several demographical, biological, behavioral, psychosocial, and social factors associated with early introduction of complementary feeding and the consumption of non-recommended foods (i.e. unhealthy snacks and sugar-sweetened beverages). Specifically, younger maternal age, lower maternal educational level, shorter duration of breastfeeding, parental conviction that “my child always wants to eat when he/she sees someone eating” and not using daycare were associated with both early introduction of complementary feeding and frequent consumption of non-recommended foods. These findings are relevant for designing intervention programs aimed at educating parents.

Chapter 6 reveals that parental bedtime practices at child age 6 months are closely related to child sleep outcomes reported by parents cross-sectionally. More specifically, parent-child room-sharing was independently associated with shorter night sleep duration and more night awakenings of the child; parental presence at sleep onset was the factor most strongly associated with unfavorable sleep outcomes of the child, including shorter total and night sleep duration, more night awakenings, longer sleep onset latency, and more bedtime difficulties; a more regular bedtime routine was independently associated shorter sleep onset latency and less bedtime difficulties. Further, we found that parental presence at child sleep onset at child age 6 months was longitudinally associated with shorter total and night sleep duration, more night awakenings, longer sleep onset latency, and more bedtime difficulties of the child at 36 months, independent of child sleep outcomes at baseline. The results of chapter 6 support the recommendation to encourage independent sleep initiation in infancy.

Chapter 7 shows that 'control over eating' was associated with lower unhealthy snack consumption among children. In addition, the associations of feeding style and parenting style with children's unhealthy snack consumption differed according to the ethnic background of the child. Chapter 8 shows that more restrictive parenting practices towards the child's snack consumption and parental modelling of healthy snacking were associated with fewer snack consumption of the children, independent of other home and family-related factors. Further subgroup analysis shows that the association of restrictive parenting practices and parental modelling of healthy snacking with child's snacking behavior were significant for children with a Dutch or Moroccan/Turkish ethnic background, but not for children with a Surinamese/Antillean ethnic background.

Overall, our findings support the relevance of socio-economic, family environmental and child related factors for the development childhood overweight and overweight related lifestyle behaviors. The findings of the present study are useful for the development of evidence-based prevention programs regarding childhood overweight and obesity.

Samenvatting

Wereldwijd is overgewicht en obesitas bij kinderen één van de grootste volksgezondheidsproblemen vanwege de hoge prevalentie en de negatieve fysieke en psychologische gevolgen. Dit proefschrift heeft als doel inzicht te verschaffen in determinanten van overgewicht en gerelateerd gezondheidsgedrag bij kinderen, met specifieke aandacht voor voedingspraktijken van ouders, voeding, sedentair gedrag, lichaamsbeweging en slaapduur. De volgende onderzoeksvragen worden beantwoord in dit proefschrift:

Deel 1: Sociaaleconomische verschillen in risico op overgewicht bij kinderen

1. Wat zijn de sociaaleconomische verschillen in gewichtstoename tijdens de kindertijd (0-12 maanden), en welke factoren kunnen de verschillen verklaren (Hoofdstuk 2)?

Deel 2: Gezondheidsgedrag en overgewicht bij kinderen

2. Wat is het patroon van clustering van voedingsgewoonten, fysieke activiteit en sedentair gedrag van 3-jarige kinderen? Welke ouder- en kind factoren zijn geassocieerd met deze patronen? In welke mate zijn de patronen geassocieerd met BMI en de gewichtsstatus van het kind? (Hoofdstuk 3).

3. Wat is de cross-sectionele en longitudinale associatie tussen slaap en de BMI van het kind (6-36 maanden) (Hoofdstuk 4)?

Deel 3: Factoren die verband houden met gezondheidsgedrag

4. Welke gezins- en kind factoren kunnen in verband worden gebracht met de vroege introductie van bijvoeding en het geven van niet-aanbevolen voedingsmiddelen aan jonge kinderen? (Hoofdstuk 5)

5. Wat zijn de cross-sectionele en longitudinale associaties tussen bed-rituelen die ouders hanteren en slaapduur en slaapkwaliteit van het kind (Hoofdstuk 6)?

6. Welke gezinsfactoren zijn geassocieerd met snacken bij schoolgaande kinderen, en verschillen deze associaties voor kinderen met een verschillende etnische achtergrond (Hoofdstuk 7, Hoofdstuk 8)?

Bovenstaande onderzoeksvragen zijn beantwoord met behulp van gegevens van twee in Nederland uitgevoerde studies: de BeeBOFT-studie (Hoofdstukken 1-6) en de Water Campagne-studie (Hoofdstukken 7-8).

Hoofdstuk 2 beschrijft dat een laag opleidingsniveau van de moeder geassocieerd was met een lager geboortegewicht van het kind en een snellere gewichtstoename tijdens de eerste helft van de kindertijd (0-6 maanden). De belangrijkste mediërende factoren die de associatie tussen het opleidingsniveau van de moeder en de toename van het lichaamsgewicht verklaren, waren

geboortegewicht, zwangerschapsduur en voedingspraktijken van ouders, waaronder de duur van borstvoeding en de leeftijd van het kind bij de introductie van bijvoeding.

In hoofdstuk 3 zijn met latente klasse analyse drie verschillende patronen van leefstijlgedragingen bij kinderen geïdentificeerd: een patroon van "ongezonde leefstijl" (36%), een "weinig snacks en weinig sedentair gedrag" patroon (48%) en een "actief, hoge fruit- en groenteconsumptie, veel snacks en veel sedentair gedrag "patroon (16%). Een lager opleidingsniveau van de moeder en een toegeeflijke opvoedingsstijl van de ouders werden geassocieerd met het hebben van het "ongezonde leefstijl" patroon bij kinderen. We vonden geen verband tussen de leefstijlpatronen en de BMI of gewichtsstatus van het kind.

In hoofdstuk 4 beschrijven we onze bevinding van een negatieve cross-sectionele associatie tussen slaapduur en BMI-z-score op de leeftijd van 14 en 36 maanden. Een kortere slaapduur op de leeftijd van 6 of 14 maanden voorspelde prospectief niet de BMI-z-score op latere leeftijden (d.w.z. na 14 en 36 maanden). Een hogere BMI-score op de leeftijd van 6 maanden voorspelde een kortere slaapduur op de leeftijd van 14 maanden rekening houdend met slaapduur bij de beginmeting. We vonden geen verband tussen slaapproblemen (waaronder nachtelijke doorslaapproblemen en inslaapproblemen) en BMI van het kind.

In hoofdstuk 5 hebben we verschillende demografische, biologische, gedrags-, psychosociale en sociaaleconomische factoren geïdentificeerd die samenhangen met vroege introductie van bijvoeding en de consumptie van niet-aanbevolen voedingsmiddelen (zoals ongezonde snacks en suikerhoudende dranken). In het bijzonder jongere leeftijd van de moeder, lager opleidingsniveau van de moeder, kortere duur van de borstvoeding, ouderlijke overtuiging dat "mijn kind altijd wil eten wanneer hij / zij iemand ziet eten" en niet gebruiken van dagopvang voor het kind, werden geassocieerd met zowel vroege introductie van bijvoeding als een frequente consumptie van niet-aanbevolen voedingsmiddelen. Deze bevindingen zijn relevant voor het ontwikkelen van interventieprogramma's voor het vergroten van kennis van ouders.

Hoofdstuk 6 laat zien dat de rituelen die ouders toepassen bij het naar bed brengen van hun kind op de leeftijd van 6 maanden cross-sectioneel nauw gerelateerd zijn aan de door ouders gerapporteerde slaap van hun kind. Het delen van een kamer tussen ouder en kind was onafhankelijk geassocieerd met een kortere slaapduur 's nachts en meer doorslaapproblemen bij het kind. Aanwezigheid van de ouder bij het in slaap vallen van het kind was de factor die het sterkst was geassocieerd met een ongunstige slaap van het kind, waaronder een kortere totale en nachtelijke slaapduur, meer nachtelijke doorslaapproblemen, meer inslaapproblemen en meer moeilijkheden met het naar bed gaan. Een regelmatig bed-ritueel was onafhankelijk geassocieerd met minder inslaapproblemen en minder moeilijkheden met naar bed gaan. Verder vonden we dat de ouderlijke aanwezigheid bij het in slaap vallen op de leeftijd van 6 maanden was geassocieerd met een kortere totale en nachtelijke slaapduur, meer doorslaapproblemen, meer inslaapproblemen en meer moeilijkheden met naar bed gaan van het kind op 36 maanden, onafhankelijk van de situatie bij de beginmeting. De resultaten van hoofdstuk 6 ondersteunen de aanbeveling om kinderen zelf in slaap te laten vallen.

Hoofdstuk 7 laat zien dat 'controle van ouders over het eten van hun kind' verband hield met minder ongezonde snackconsumptie bij kinderen. Verder verschilden de associaties tussen ouderlijke voedingsstijl en opvoedingsstijl enerzijds en ongezonde snackconsumptie van kinderen anderzijds naar etnische herkomst van het kind. Hoofdstuk 8 laat zien dat een meer restrictieve opvoedingsstijl ten opzichte van de snackconsumptie van het kind, en het model gedrag van de ouders met betrekking tot gezonde tussendoortjes, verband hielden met een lagere consumptie van snacks door het kind. Dit verband was onafhankelijk van andere gezinsfactoren. Verdere subgroep analyses toonden aan dat de associatie tussen een restrictieve opvoedingsstijl en model gedrag van de ouder enerzijds en het snackgedrag van kinderen anderzijds significant was voor kinderen met een Nederlandse of Marokkaanse / Turkse etnische achtergrond, maar niet voor kinderen met een Surinaamse / Antilliaanse etnische achtergrond.

Al met al ondersteunen onze bevindingen de relevantie van sociaaleconomische, gezins- en kind-gerelateerde factoren voor de groei, de ontwikkeling van overgewicht en gerelateerd gezondheidsgedrag in de kindertijd. De bevindingen van de huidige studie zijn nuttig voor de ontwikkeling van “evidence-based” preventieprogramma's voor het voorkomen van overgewicht en obesitas bij kinderen.

Appendices

About the author

List of publications

PhD portfolio

Words of Gratitude

About the author

Lu Wang was born on December 10th, 1989 in Dezhou, in the province of Shandong, P.R. China. After graduating from secondary school in 2007, she started to study Preventive Medicine in the School of Public Health at Shandong University. In June 2012, she graduated with a Bachelor degree in Preventive Medicine. In the same year, she continued to study at Shandong University as a Master student. She did her master project in the Division of Biostatistics in the School of Public Health, Shandong University. In June 2015, she obtained her Master of Public Health. In September 2015, she started her PhD project at Erasmus University Medical Center in Rotterdam, the Netherlands. Lu received a fellowship from the China Scholarship Council (CSC) to perform her PhD project in the Netherlands. From 2015 to 2019, she worked under the supervision of Prof. Hein Raat and Dr. Amy van Grieken and Dr. Wilma Jansen in the Department of Public Health. Her research mainly focused on factors associated with growth, overweight and overweight related health behaviors in children, the results of which are presented in the present thesis. In the future, Lu would like to develop her career in academia and devote herself to the research to improve population health, especially maternal and child health. To start with that, she would like to pursue a Postdoc Position in the field of maternal and child health in the United States after obtaining her PhD degree.

List of publications

Published

Wang L, van Grieken A, Yang-Huang J, Vlasblom E, Beltman M, L'Hoir MP, Boere-Boonekamp MM, Raat H. Relationship between socioeconomic status and weight gain during infancy. PLOS One.2018 Nov 2;13(11):e0205734. (*This thesis*)

Wang L, Jansen W, Vlasblom E, L'Hoir MP, Boere-Boonekamp MM, van Grieken A, Raat H. Sleep and BMI in infancy and early childhood (6-36 months): A longitudinal study. Pediatric obesity, 2019: e12506. (*This thesis*)

Wang L, van Grieken A, van der Velde LA, Vlasblom E, Beltman M, L'Hoir MP, Boere-Boonekamp MM, Raat H. Factors associated with complementary feeding and consumption of non-recommended food types among Dutch infants: the BeeBOFT study. BMC public health, 2019 19(1):388. (*This thesis*)

Wang L, van de Gaar VM, Jansen W, Mieloo CL, van Grieken A, Raat H. Feeding styles, parenting styles and snacking behaviour in children attending primary schools in multiethnic neighbourhoods: a cross-sectional study. BMJ Open 2017;7:e015495. (*This thesis*)

van Grieken A, **Wang L**, Vivian M van de Gaar, Wilma Jansen Raat H. Associations between family and home-related factors and child's snack consumption in a multi-ethnic population. J Public Health (Oxf). 2018 Jul 18. (*This thesis*)

van Grieken A, Vlasblom E, **Wang L**, Beltman M, Boere-Boonekamp M M, Monique P L'Hoir, Raat H. Personalized Web-Based Advice in Combination With Well-Child Visits to Prevent Overweight in Young Children: Cluster Randomized Controlled Trial. Journal of medical internet research. 2017; 19(7):e268.

Yang-Huang J, van Grieken A, **Wang L**, Jaddoe VWV, Jansen W, Raat H. Ethnic background and children's television viewing trajectories: The Generation R Study. PLOS ONE 2018; 13(12).

Submitted

Wang L, Jansen W, Vlasblom E, L'Hoir MP, Boere-Boonekamp MM, van Grieken A, Raat H. Identifying patterns of diet, physical activity, and sedentary behaviors in preschool children. (*This thesis*)

Wang L, van Grieken A, Jansen W, Vlasblom E, Boere-Boonekamp M M, L'Hoir M P, Raat H, Parental bedtime practices in infancy and children's sleep outcomes in infancy and early childhood. (*Submitted*

Franse C, **Wang L**, Constant F, Fries L R, Raat H, Factors associated with water consumption among children: a systematic review. *accepted*

PhD PORTFOLIO

Name PhD student	Lu Wang
Department	Public Health, Erasmus Medical Center Rotterdam
Research school	Netherlands Institute for Health Sciences (NIHES), Rotterdam
PhD period	September 2015-September 2019
Promotor	Prof. dr. Hein Raat
Co-promotor	Dr. Amy van Grieken, Dr. Wilma Jansen

	Year	Workload (ETCS)
Courses		
Biostatistical Methods I: Basic Principles	2015	5.7
Systematic Review	2015	0.7
Quality of Life Measurement	2016	0.7
Introduction to Global Public Health	2016	0.7
Introduction to Bayesian Methods in Clinical Research	2016	1.4
Genome-wide Association Studies	2016	0.7
Endnote	2016	0.7
Scientific Integrity	2016	0.3
Scientific Writing	2017	1.1
Dutch Language	2017	1.1
Seminars and workshops		
Seminars, Department of Public health	2015-2018	5.0
Youth section research meeting	2015-2018	2.5
Generation R research Meeting	2015-2018	0.3
R workshop, Department of Public Health	2016	0.3
Workshop in Meta-cart	2017	0.3
Symposium: Catalyst for Change	2018	0.3
Symposium: Implementation Science	2018	0.3
Youth Section Research colloquium	2018	0.5
PhD Day, Erasmus MC	2015-2018	0.5

Career Guidance Program	2015-2018	0.5
Inter(national) conferences		
Swiss Public Health Congress, Neuchatel, Switzerland	2017	0.5
2018 Annual Meeting of the International Society of Behavioral Nutrition and Physical Activity, Hongkong, China	2018	1.0
10th Annual Workshop of International Network of Research on Inequalities in Child Health, Bradford, United Kingdom	2018	0.5
Other activities		
Peer review for scientific journals	2018	0.5
Systematic Review on determinants of water consumption	2018	1.0
Peer consultant for statistical questions in Youth section	2015-2018	1.0

1 ECTS (European Credit Transfer System) is equal to a workload of 28 hours

WORDS OF GRATITUDE

I would like to thank everyone who has been involved in the realization of this thesis, and in my wonderful PhD journey at Erasmus MC.

First of all, I would like to thank my promotor Professor Dr. Hein Raat, for offering me the opportunity to conduct my PhD research in the Youth section, in the Department of Public health at Erasmus MC. Thank you for all the support and supervision during the four years PhD journey. You have helped me to make the mindset transition from a statistician to a scientist. I enjoyed the inspiring discussions related to our research with you. You always stimulated me to think deeper on the scientific questions and public health importance when generating each paper. I highly appreciate your time and energy that you have spent in preparing me to be a more independent and mature researcher. I am very lucky to have you as my promoter.

Dr. Amy Van Grieken, thank you for being my co-promoter and daily supervisor. Thank you very much for all the supervision, and for all the insightful and in-depth discussions on each steps of my research work on our Tuesday meetings. Thank you for always checking my manuscripts very carefully and giving me helpful suggestions. You contribution to the completion of this thesis is invaluable. By role modeling, you have taught me to become a more professional, efficient, rigorous, and organized researcher.

Dear Dr. Wilma Jansen, thank you for being my second co-promoter. You always provided me insightful perspectives on the questions I met in my research, and gave me prompt and intelligent inputs on my manuscripts. You contribution to the completion of this thesis is invaluable.

Dear Dr. Cathelijne L. Mieloo, thank you for supervised my research temporally when Amy was on maternity leave. You were really helpful with my first research article.

I would like to send my sincere gratitude to the members of my inner committee, Dr. E.L.T. van den Akker, Dr. VWV. Jaddoe, and Dr. J.C. Seidell, for taking time to read and assess my thesis. I also kindly thank Dr. Paul Kocken, Dr. Paulin Jansen, Dr. Lenie van Rossem, Dr. Matty Crone, Dr. Anke Onema for agreeing to be the members of the plenary committee of my PhD defense.

Dear co-authors, Dr. Eline Vlasblom, Dr. Monique P L'Hoir, Dr. Magda M Boere-Boonekamp, Dr. Maaike Beltman, Dr. Vivian M van der Gaar, Dr. Cathelijne L. Mieloo, thank you for your fruitful collaboration. Thank you very much for your critical review of our manuscripts, and for your intelligent input.

Dear colleagues in the Youth section, Guannan, Junwen, Xuxi, Yuan, Jie, Lizi, Raquel, Anne, Suzanne, Carmen, Minke, Dafna, Siok, Diana, Irene, Mirte, Laura, it is great to work with you together. I really enjoyed time we gathered in our youth section meeting to discuss about the research work of each other, and to discuss about cutting edge research articles. It is great to be a team with you.

Special thanks to my lovely and helpful paranymphs Junwen and Xuxi, thank you for all the time and efforts in helping me to prepare this defense.

My dearest friends, Guannan, Junwen, Xuxi, thank you for all the friendships, helps, trusts and companion. The most happy moments I spent in the Netherlands were always with you together.

Thank you for the other colleagues and friends I met in Erasmus MC, Xiaona, Yannan, Qing Wu, JinLuan Chen, Manzhi Zhao, Cherry, Zhangling Chen, Bruna, Kevin, Adi, Jega, Soraya, Caroline (Bonareri Osora), Sophie (Hurif). Thank you for your friendship and giving me positive energy!

Dear Klaas and Rinske, my Dutch grandpapa and grandmama, I really enjoyed the time spend in your house. I learned a lot of life wisdom from you. You are living in a way that I would like to become!

Dear Parents, Dear husband, thank you for your unconditional love, trust, support, and encouragement. Dear Olivia, I love you so much!