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Research Article

Diet, Screen Time, Physical Activity, and Childhood Overweight in the General Population and in High Risk Subgroups: Prospective Analyses in the PIAMA Birth Cohort

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Objective. To prospectively identify behavioral risk factors for childhood overweight and to assess their relevance in high risk sub groups (children of mothers with overweight or low education). *Methods*. In the PIAMA birth cohort ($n = 3963$), questionnaire data were obtained at ages 5 and 7 on "screen time", walking or cycling to school, playing outside, sports club membership, fast food consumption, snack consumption and soft drink consumption. Weight and height were measured at age 8 years. *Results*. Screen time, but none of the other hypothesized behavioral factors, was associated with overweight (aOR 1.4 (CI: 1.2–1.6)). The adjusted population attributable risk fraction for screen time >1 hr/day was 10% in the high risk and 17% in the low risk sub groups. *Conclusion*. Reduction of screen time to <1 hr/day could result in a reduction of overweight prevalence in the order of 2 percentage points in both high and low risks sub groups.

1. Introduction

Putting a halt to the rising trend in overweight prevalence has high priority in public health policy all over the developed world. Prevention, preferably starting at an early age, is considered as the key strategy to achieve this goal [1], and considerable effort is put into the design of preventive measures [2]. Whereas we know in general terms that overweight is the result of an unbalance between energy intake and energy expenditure, development of effective preventive measures requires a much more specific understanding. Specific dietary habits and (in)activities associated with overweight risk in specific age groups need to be identified and their quantitative contribution to the overweight prevalence in the population needs to be assessed. In addition, we need to know whether the importance of specific behaviors for the development of overweight differs between sub groups in the population. It is well established that children from families with a low socio-economic status and children with overweight parents are at increased risk to develop overweight [3–9]. It is therefore particularly important to assess the role of behavioral risk factors specifically in these children, since they are the priority target groups for interventions to prevent and reduce overweight.

The aim of this study was to identify specific behavioral risk factors for overweight in young children and to assess their quantitative contribution to the prevalence of overweight in the general population and in high risk sub groups. In a large population-based birth cohort, we prospectively investigated associations between dietary habits, screen time and physical activity when the children were 5 and 7 years old and overweight at the age of 8 years. We also assessed the role of these behavioral factors separately in high risk sub groups: children of mothers with overweight and children of mothers with low education. We estimated the reduction of overweight prevalence that could be achieved if the prevalence of risk factors would be reduced.

2. Materials and Methods

2.1. Study Design and Study Population. The study population consisted of children who participated in the Dutch Prevention and Incidence of Asthma and Mite Allergy (PIAMA) birth cohort study. A detailed description of the study design has been published previously [10]. The baseline study population consisted of 4146 pregnant women, recruited from the general population in 1996-1997. Postal questionnaires, including questions on the child's lifestyle and health, were sent to the parents during pregnancy, at the child's ages of 3 and 12 months, and yearly thereafter up to the age of 8 years. At the age of 8 years, the children were invited for a medical examination which included measurement of weight and height. The study protocol was approved by the medical ethics committees of the participating institutes, and all parents gave written informed consent. Of the baseline population of 4146 pregnant women, 183 (5%) were lost to follow-up before any data on the child had been collected. The study therefore started with 3963 newborns. Parental completed questionnaires from age 3 months to 8 years were available for 3934, 3817, 3694, 3563, 3518, 3473, 3373, and 3269 children, respectively. When the medical examination of 8-year-old children was planned, 3668 children (93% of 3963) were still in the study, 3522 children were invited and 2214 participated (63% of those invited) and had their weight and height measured. 146 of the 3668 children were not invited for the medical examination, although they were still participating in the study. In the majority of cases the reason for this was that their families had moved and were now living too far away from the study centers where the medical examination was conducted. Complete data on overweight and risk factors were available for 1871 children (47% of the 3963 children in the study at birth).

2.2. Outcome Variables. During the medical examination of the 8-year-old children,They were weighed and measured in their underwear. Weight was measured to 0.1 kg and height to 0.1 cm by trained research staff using calibrated measuring equipment. From the weight and height measurements BMI (body mass index: weight (kg)/height $(m)^2$) was calculated. "Overweight" and "obesity" were defined according to age and gender-specific international standards that use cutoff points equivalent to the 25 kg/m^2 and 30 kg/m^2 cut-offs that are commonly used for adults [11]. The term "overweight" is used for the total group of children who were overweight, including those who were obese.

2.3. Exposure Variables: Physical Activity, Screen Time, and Diet. For physical activity, 3 indicators were selected: time spent walking or cycling to school (3 categories), membership of a sports club (yes/no), and time spent playing outside (3 categories). "Screen time" (4 categories) included time spent watching television, video's, or at the computer. For dietary intake, 3 indicators were used: fast food consumption, snack consumption, and soft drink consumption. Data on these exposures were obtained from the questionnaires administered at the ages of 5 and 7 years. These questionnaires contained a food frequency questionnaire with 40 different items and 5 answering categories per item (ranging from "never in the last month" to "on 6-7 days per week"), which was used to construct the dietary exposure variables. For "fast food consumption" a score was constructed based on the consumption frequencies of chips/French fries and of foods like hamburgers and hot dogs. "Snack consumption" was based on the reported consumption frequencies of 7 different foods/food groups including pie/cake, muffins, candy bars, sweets, chocolate, biscuits, and crisps. "Soft drink consumption" was based on the reported frequencies of consumption of 4 types of soft drinks. Each of these variables was based on a number of different items, which differed with respect to their energy content. To be able to "add up" the different items, total weekly energy intake from each item was calculated based on the reported frequencies, assuming average portion sizes and average energy content per portion. Data on maternal education and maternal weight and height were obtained from the questionnaire completed when the child was 1 year old. Maternal BMI was calculated from reported weight and height and overweight and was defined as a BMI $\geq$25 kg/m^2.

2.4. Data Analysis. The associations between the exposure variables and overweight at the age of 8 years were analysed by logistic regression, adjusted for gender and birth weight. Exposure variables were constructed using the data collected at both the age of 5 and at the age of 7 years in order to obtain a more stable estimate of exposure during the years preceding the measurement of weight and height. Walking/cycling to school, playing outside and screen time were recorded in categories, numbered 1, 2, and 3 for walking/cycling to school, 1, 2, and 3 for playing outside, and 1, 2, 3, and 4 for screen time (see Table 1). The data collected at the ages of 5 and 7 years, were combined by taking the mean of the numbers of the categories reported at the ages of 5 and 7 years respectively. This resulted in ordinal variables with 5 categories for walking/cycling to school (ranging from never at ages 5 and 7 to >1/2 an hour per day at both ages), 5 categories for playing outside (ranging from <1 x per week at ages 5 and 7 to >3 x per week at both ages) and 7 categories for screen time (ranging from <1/2 an hour per day at ages 5 and 7 to >2 hours per day at both ages). After having checked for nonlinearity, these variables were included as continuous variables in the regression models. Fast food, snack and soft drink consumption at age 5–7 (the mean of the consumption scores at age 5 and at age 7), were included in the regression analyses as linear variables, but are shown in categories (tertiles) in Table 1. Overweight

Table 1: Characteristics of the study population and prevalence of overweight (including obesity) and obesity at the age of 8 years in sub groups of the population.

	n (%)	Overweight at age 8%	Obesity at age 8%
Age 0-1			
Gender			
Boy	2055 (51.8%)	12.1	2.5
Girl	1908 (48.2%)	15.5	3.0
Maternal education[1]			
Low	934 (23.6%)	18.3	4.1
Intermediate	1651 (41.7%)	14.0	3.3
High	1378 (34.8%)	10.5	1.2
Maternal overweight			
BMI<25 kg/m^2	2960 (74.7%)	10.0	1.5
BMI $\geq$ 25 kg/m^2	1003 (25.3%)	25.0	6.8
Birth weight			
<2500 g	134 (3.4%)	10.0	2.3
2500–4000 g	3119 (78.7%)	12.5	2.3
$\geq$ 4000 g	710 (17.9%)	20.1	5.1
Breast feeding			
None	710(17.9 %)	18.7	4.0
0–16 weeks	1861 (47.0%)	13.4	2.8
$\geq$ 16 weeks	1392 (35.1%)	11.7	2.0
Age 5 years			
Fast food consumption[2]			
Low (523 kJ/wk)	1427 (36.0 %)	12.1	1.6
Intermediate (1549 kJ/wk)	1583 (40.0%)	14.0	2.7
High (2596 kJ/wk)	953 (24.0%)	15.8	4.4
Snack consumption[2]			
Low (2253 kJ/wk)	1314 (33.2%)	13.7	3.0
Intermediate (3350 kJ/wk)	1327 (33.5%)	14.1	2.0
High (5100 kJ/wk)	1322 (33.4%)	13.5	3.1
Soft drink consumption[2]			
Low (1436 kJ/wk)	1351 (34.1%)	12.5	1.7
Intermediate (2064 kJ/wk)	1342 (33.9%)	15.0	3.2
High (3132 kJ/wk)	1270 (32.1%)	13.7	3.0
Member sport club			
Yes	2441 (61.6 %)	14.1	3.0
No	1522 (38.4%)	13.3	2.4
Walking/cycling to school			
Cat.1 never	1449 (36.6%)	13.7	3.2
Cat.2 < 1/2 hr p. day	2105 (53.1%)	13.8	2.4
Cat.3 $\geq$ 1/2 hr p. day	409 (10.3%)	13.8	3.0
Screen time			
Cat.1 $\leq$ 1/2 hr p. day	935 (23.6%)	9.9	2.2
Cat.2 1/2–1 hr p. day	1873 (47.3%)	13.2	2.1
Cat.3 1-2 hrs p. day	1020 (25.7%)	17.5	4.1
Cat.4 > 2 hrs p. day	135 (3.4%)	19.7	5.1
Playing outside			
Cat.1 $\leq$1 x p. wk	179 (4.5%)	17.1	6.2
Cat.2 1–3 x p. wk	901 (22.8%)	14.5	3.0
Cat.3 > 3 x p. wk	2883 (72.7%)	13.3	2.4

Table 1: Continued.

	n (%)	Overweight at age 8%	Obesity at age 8%
Age 7 years			
Fast food consumption[2]			
Low (523 kJ/wk)	1410 (35.6%)	12.6	2.7
Intermediate (1549 kJ/wk)	1550 (39.1%)	13.4	2.1
High (2596 kJ/wk)	1003 (25.3%)	15.9	3.8
Snack consumption[2]			
Low (2492 kJ/wk)	1331 (33.6%)	15.1	3.8
Intermediate (3643 kJ/wk)	1311 (33.1%)	14.1	2.4
High (5465 kJ/wk)	1321 (33.3%)	12.0	1.9
Soft drink consumption[2]			
Low (1436 kJ/wk)	1393 (35.1%)	14.8	2.5
Intermediate (2010 kJ/wk)	1254 (31.7%)	13.2	3.1
High (2986 kJ/wk)	1316 (33.2%)	13.2	2.6
Member sport club			
Yes	3414 (86.2%)	14.0	2.8
No	549 (13.9%)	12.1	2.1
Walking/cycling to school			
Cat.1 never	683 (17.2%)	14.3	2.6
Cat.2 < 1/2 hr p. day	2758 (69.6%)	13.3	2.6
Cat.3 ≥ 1/2 hr p. day	522 (13.2%)	15.5	3.7
Screen time			
Cat.1 ≤ 1/2 hr p. day	548 (13.8%)	12.5	3.1
Cat.2 1/2–1 hr p. day	1683 (42.5%)	12.0	2.7
Cat.3 1-2 hrs p. day	1504 (38.0%)	15.1	2.6
Cat.4 > 2 hrs p. day	108 (5.7%)	20.5	2.8
Playing outside			
Cat.1 ≤ 1 x p. wk	152 (3.9%)	19.8	4.7
Cat.2 1–3 x p. wk	943 (23.8%)	14.0	3.2
Cat.3 > 3 x p. wk	2868 (72.4%)	13.4	2.5

[1]Low = primary, lower vocational and lower general; Intermediate = senior high school and intermediate vocational; High = higher vocational and university.
[2]For each category (Low, Intermediate, and High) the median energy intake (kJ/week) from this food group is shown in brackets.

(including obesity) was used as the outcome measure in the regression analyses. The number of obese children was too small for analyses with fully adjusted regression models, and obesity was therefore not used as outcome measure in these analyses. In previous studies in the PIAMA cohort, breast feeding was investigated in relation to overweight risk and was found to be associated with reduced overweight risk [12, 13]. Although breastfeeding is not the subject of this study, results on breast feeding are shown in the tables for completeness. In additional analyses, the associations of physical activity and diet with overweight were also assessed separately for the exposures at age 5 and at age 7.

Thirteen percent of all the data potentially in the study (3963 participants × 20 variables = 79260) were missing and 2092 children (53%) had a missing value on at least 1 of the variables. If data are not "missing completely at random" (MCAR), complete case analysis may lead to biased results [14, 15]. In our dataset several variables (including maternal education and breast feeding) were associated with the probability of a subject having one or more missing values. We therefore used multiple imputation to deal with missing data. Missing data were multiple times imputed, using the "Multivariate Imputation by Chained Equations" (MICE) procedure [16, 17], that runs under the statistical program R version 2.5.0 [18]. For the multiple imputation we used all the data that were used in the analyses, as well as data on the children's weight and height that were measured and reported by the parents in the yearly questionnaires. All analyses were performed on the complete case data and on the imputed data. The results shown are those from the analyses in the imputed data set.

Maternal education and maternal overweight could be confounders of the associations studied but could also be factors in causal pathways. The analyses were therefore conducted with and without these two variables in the models. In addition, the analyses were repeated, stratified for maternal education, maternal overweight and gender. Differences between the associations observed in the different sub

Table 2: Adjusted odds ratios (95% CI) for the associations of behavioral risk factors, low maternal education, and maternal overweight with overweight (including obesity) at the age of 8 years.

	Model 1 aOR (95% CI)	Model 2 aOR (95% CI)	Model 3 aOR (95% CI)	Model 4 aOR (95% CI)
Breastfeeding				
0–16 wks	0.66 (0.50–0.86)	0.68 (0.52–0.90)	0.72 (0.55–0.94)	0.70 (0.53–0.92)
>16 wks	0.54 (0.41–0.73)	0.60 (0.45–0.81)	0.65 (0.48–0.89)	0.65 (0.48–0.88)
Fast food consumption	1.47 (1.05–2.09)	1.29 (0.88–1.87)	1.15 (0.77–1.72)	1.14 (0.77–1.67)
Snack consumption	0.83 (0.61–1.11)	0.70 (0.52–0.95)	0.68 (0.50–0.93)	0.71 (0.52–0.98)
Soft drink consumption	0.77 (0.39–1.55)	0.91 (0.45–1.83)	0.92 (0.46–1.86)	0.91 (0.44–1.88)
Sportsclub	1.18 (0.83–1.68)	1.14 (0.80–1.61)	1.18 (0.83–1.66)	1.16 (0.81–1.65)
Active transport to school	0.98 (0.80–1.20)	1.02 (0.83–1.25)	1.03 (0.84–1.26)	1.01 (0.82–1.24)
Playing outside	0.84 (0.68–1.03)	0.94 (0.76–1.16)	0.94 (0.76–1.16)	0.95 (0.77–1.17)
Screen time	1.45 (1.26–1.66)	1.39 (1.21–1.61)	1.37 (1.18–1.58)	1.36 (1.17–1.58)
Low maternal education	1.65 (1.28–2.12)		1.46 (1.10–1.94)	
Maternal overweight	2.92 (2.38–3.57)			2.78 (2.25–3.43)

Model 1: each variable separately, adjusted only for gender and birth weight.
Model 2: each variable adjusted for gender, birth weight, breast feeding, and for all (other) behavioral risk factors.
Model 3: model 2 + including low maternal education.
Model 4: model 2 + including maternal overweight.

groups were tested by inclusion of interaction terms in the regression models.

For the behavioral risk factors that were found to be statistically significantly associated with overweight, adjusted population attributable risk percentages (PAR%) were calculated, using the Mantel-Haenszel approach, as described by Benichou [19].

3. Results

3.1. Characteristics of the Study Population. Table 1 shows characteristics of the study population and the prevalence of overweight and obesity in different sub groups. Children with incomplete data on either risk factors or on measured weight and height at 8 years were compared to the children with complete data, with respect to a number of characteristics assessed during the first year of the study (data not shown). Children with incomplete data had, compared to children with complete data, a relatively high prevalence of low maternal education (27.5% versus 19.4%) and of no breast feeding (19.7% versus 15.9%). As expected, in the imputed data the prevalence of these characteristics was somewhat higher (23.6% and 17.9%, see Table 1) than in the children with complete data. The prevalence of maternal overweight was similar in children with incomplete data and in children with complete data (24.1% and 26.1%, resp.). The prevalence of overweight in the children was almost the same in the imputed data and in the complete cases (13.8% and 14.4%, resp.) and the prevalence of obesity was the same in both datasets (2.7%).

3.2. Associations between Diet, Physical Activity, Screen Time, and Overweight. Table 2 shows the associations between diet, physical activity, screen time and overweight. In the analyses adjusted for gender and birth weight only (model 1), fast food consumption and screen time, were associated with increased overweight risk. Sports club membership, active transport to school, playing outside, snack consumption, and soft drink consumption were not associated with overweight. When all risk factors (including breast feeding) were included in the same regression model (model 2), the associations with overweight became somewhat weaker for most factors, indicating some association between the individual risk factors. The association of fast food consumption with overweight lost statistical significance in this analysis whereas the association with screen time remained statistically significant. Surprisingly, an inverse association between snack consumption and overweight was observed.

In additional analyses, the analyses shown in Table 2 were repeated with the behavioral risk factors measured at age 5 and (separately) with those factors measured at age 7 instead of the variables combining the exposures measured at age 5 and age 7. For the physical activity indicators and for screen time, results of these analyses were similar to those shown in Table 2, showing associations between screen time and overweight (aOR (95% CI) at age 5 : 1.35 (1.19–1.53) and aOR (95% CI) at age 7 : 1.22 (1.08–1.39)) but not between the physical activity indicators and overweight. Snack consumption at age 5 was not associated with overweight at the age of 8 years (aOR (95% CI): 0.87 (0.66–1.14)), but there was a significant inverse association between snack consumption at age 7 and overweight at the age of 8 years (aOR (95% CI) 0.70 (0.54–0.91)).

3.3. The Role of Maternal Education and Maternal Overweight. Low maternal education and especially maternal overweight were strong predictors of childhood overweight (see Table 2, model 1). The association between low maternal

Table 3: Prevalence of dietary habits and activities at ages 5 and 7 years, stratified by maternal education and by maternal overweight.

	Maternal education				Maternal overweight			
	High/Intermediate $n = 3029$		Low $n = 934$		BMI <25 $n = 2960$		BMI ≥25 $n = 1003$	
	5 yrs	7 yrs	5 yrs	7 yrs	5 yrs	7 yrs	5 yrs	7 yrs
Consumption in highest tertile (%)								
Fast food	20.5	22.4	35.5**	34.7**	21.9	23.8	30.5**	29.9**
Snacks	31.0	31.2	41.0**	40.3**	33.2	33.2	33.7	33.8
Soft drinks	32.1	32.9	31.9	34.3	31.5	34.2	33.8	30.4*
Member sport club (% no)	37.4	12.6	41.5*	17.9**	38.1	13.5	39.2	14.9
Walking/cycling school (% never)	36.1	17.0	38.0	18.1	36.4	17.1	37.0	17.6
Screen time (% >2 hrs/day)	2.3	4.6	7.0**	9.6**	2.9	5.8	4.9**	5.6
Playing outside (% ≤1 x/wk)	4.1	3.6	6.0	4.8	4.2	3.9	5.4	3.6

*$P < .05$ for difference in prevalence of the 2 sub groups at the same age.
**$P < .01$ for difference in prevalence of the 2 sub groups at the same age.

Table 4: Adjusted[1] odds ratios (95% CI) for the associations of behavioral risk factors with overweight (incl. obesity) at the age of 8 years, stratified by maternal education and by maternal overweight.

	Maternal education		Maternal overweight	
	High/Intermediate aOR (95% CI)	Low aOR (95% CI)	BMI <25 aOR (95% CI)	BMI ≥25 aOR (95% CI)
Breastfeeding				
0–16 wks	0.67 (0.44–1.03)	0.78 (0.48–1.28)	0.61 (0.44–0.85)	0.85 (0.53–1.34)
> 16 wks	0.60 (0.42–0.85)	0.78 (0.41–1.46)	0.59 (0.39–0.88)	0.78 (0.49–1.27)
Fast food consumption	1.13 (0.66–1.93)	1.14 (0.59–2.17)	1.14 (0.69–1.89)	1.14 (0.60–2.20)
Snack consumption	0.71 (0.48–1.06)	0.64 (0.39–1.05)	0.78 (0.51–1.18)	0.63 (0.37–1.07)
Soft drink consumption	0.92 (0.41–2.07)	0.93 (0.33–2.64)	0.66 (0.27–1.63)	1.49 (0.54–4.06)
Sportsclub	1.20 (0.79–1.79)	1.16 (0.57–2.37)	1.16 (0.70–1.92)	1.22 (0.70–2.12)
Active transport to school	1.02 (0.80–1.31)	1.02 (0.70–1.49)	1.01 (0.74–1.38)	0.98 (0.71–1.35)
Playing outside	0.96 (0.75–1.24)	0.90 (0.61–1.34)	0.78 (0.58–1.05)	1.30 (0.88–1.90)
Screen time	1.45 (1.20–1.76)	1.19 (0.88–1.63)	1.41 (1.15–1.72)	1.28 (1.02–1.61)

[1]adjusted for gender, birth weight, and all other risk factors in the table.

education and overweight weakened substantially in the model including the behavioral risk factors (an almost 25% change in the regression coefficient from 0.50 to 0.38), indicating that these specific factors explain at least part of the excess overweight prevalence in children of mothers with low education (see Table 2, model 3). The association between maternal overweight and overweight in the child weakened only marginally in the model including behavioral risk factors (5% change in regression coefficient from 1.07 to 1.02), indicating that the association between maternal overweight and overweight of the child is only to a limited extent mediated by the behavioral factors studied (see Table 2, model 4).

3.4. Stratification for Maternal Education, Maternal Overweight, and Gender. The analyses were repeated after stratification for low maternal education, maternal overweight and gender, respectively. In the sub groups with low maternal education and with maternal overweight the prevalence of overweight was relatively high (see Table 1). Children of mothers with a low level education had a higher prevalence of high fast food and snack intakes, of >2 hours screen time per day and of not being member of a sport club than children of more highly educated mothers (see Table 3). Children of overweight mothers had a higher prevalence of high fast food intake and of >2 hours screen time per day (at the age of 5, but not at 7 years) than children of normal weight mothers (see Table 3).

Girls had a slightly higher prevalence of overweight and slightly less screen time than boys (data not shown). The results suggest that the associations between screen time and overweight were weaker in children of mothers with overweight or low education than in children of mothers with a normal weight or higher level of education (Table 4). Interactions between the exposure variables and low maternal education and maternal overweight were not statistically significant,however. For boys and girls these associations were very similar (data not shown).

3.5. The Contribution of Screen Time to the Prevalence of Overweight. Of the behavioral risk factors studied, only screen time was statistically significantly associated with overweight. Based on the prevalence and adjusted odds ratios

Table 5: Screen time >1 hr/day at age 5 and/or age 7, stratified by maternal education and by maternal overweight: Prevalence; association with overweight (incl. obesity) at age 8 (with <1 hr/day at ages 5 and 7 as the reference); adjusted[1] Population Attributable Risk (PAR%); achievable reduction in overweight prevalence if risk factor was removed.

Screen time > 1 hr/day at age 5 and/or age 7	Maternal education		Maternal overweight	
	High/Intermediate	Low	BMI <25	BMI ≥25
Prevalence (%)	47.5	62.6	48.6	57.8
Association with overweight at age 8 (aOR (95% CI))	1.54 (1.16–2.06)	1.20 (0.78–1.83)	1.52 (1.12–2.04)	1.22 (0.84–1.76)
PAR %	16.7	10.2	16.6	10.4
Achievable reduction in overweight prevalence (%)	from 12.4 to 10.3	from 18.3 to 16.4	from 10.0 to 8.3	from 25.0 to 22.4

[1]adjusted for gender, birth weight, breast feeding and all behavioral risk factors included in the study.

for screen time >1 hr per day (see Table 5), we estimated how much screen time contributed to the total prevalence of overweight. Table 5 shows the adjusted population attributable risk percentage (PAR%) for a screen time of more than 1 hour per day at age 5 and/or age 7 as compared to less than 1 hour at both ages. Of the total overweight prevalence in the low risk sub groups an estimated 17% could be attributed to screen time of >1 hour per day as compared to 10% in the high risk sub groups. This means that, if all children would reduce their screen time to less than 1 hour per day, the following reductions in overweight prevalence could be achieved: from 18.3% to 16.4% in children of mothers with low education; from 12.4% to 10.3% in children of mothers with higher education from 25.0% to 22.4% in children of overweight mothers and from 10.0% to 8.3% in children of normal weight mothers.

3.6. Sensitivity Analysis in Complete Cases Only. All analyses were conducted in a data set containing only complete cases as well as in the imputed data. Results were similar. The odds ratios (95% CI) for screen time, for example, were 1.47 (1.24–1.75) and 1.41 (1.17–1.70) in model 1 and model 2, respectively, in the complete case analysis, compared to 1.45 (1.26–1.66) and 1.39 (1.21–1.61) in the analysis in the imputed data set.

4. Discussion

We evaluated the role of behavioral risk factors in the development of childhood overweight. Of 8 different potential behavioral risk factors, only screen time showed consistent and significant associations with overweight. In high risk sub groups of the population, screen time was higher than in low risk sub groups, but the associations between screen time and overweight were weaker (although not significantly weaker) in the high risk sub groups.

4.1. Strengths and Limitations. Important strengths of the study were the prospective design, the large study population, the repeated measurements (at ages 5 and 7) of different behavioral risk factors and the availability of measured (rather than parental reported) data on weight and height.However, a number of limitations have to be considered.

Thirteen percent of our data were missing and 53% of the study population had a missing value on 1 or more of the variables used in the analyses. We used multiple imputation to deal with missing data in our study in order to avoid bias due to selective missing of data and to make more efficient use of the available data. In addition, we also conducted a complete case analysis. Results of the complete case analysis and the analyses in the imputed data sets were similar.

Information on the behavioral risk factors was obtained from parental completed questionnaires and we therefore need to address the possibility of misreporting. The questions asked ranged from simple matter-of-fact items (like sports club membership yes/no) to items that are more difficult to observe and recall accurately (like the consumption frequency of a range of different food items). We expect that recalling or reporting problems will not have substantially influenced the data on sports club membership or transport to school and that any misreporting on these items will not have been systematically associated with overweight development. The data on foods and drinks consumption may well have been influenced by reporting bias. Many of the foods included in the dietary variables have a bad reputation in relation to overweight, and selective underreporting by parents of children who were developing overweight may have occurred.

Another problem with respect to the diet variables is that data were available on the consumption frequencies of food items, but not on portion sizes. Estimates of the intakes of fast food, snacks and soft drinks and the ranking of children according to their intakes were therefore based on reported consumption frequencies only, and the possibility of misclassification of food intake cannot be excluded.

4.2. Physical Activity and Overweight. Physical activity was investigated in relation to overweight, using 3 different indicators. Membership of a sports club and active transportation to school were not associated with overweight in this population. The reason that we did not observe the hypothesized associations might be that in young children the duration and intensity of these activities are usually too low to have a sizeable impact on total activity. If this would be confirmed in further studies, it may have potentially important implications for the allocation of budgets for the prevention of overweight in this age group. In older children and adolescents active transport to school and sports club membership may well be more important factors in relation to overweight [17]. We found some evidence for an inverse relation between playing outside and overweight, but the associations were weak and not statistically significant. Children who played outside ≤1 x per week seemed to have a higher overweight risk, but such children were a small minority in the study population.

4.3. Screen Time and Overweight. Screen time was consistently and significantly associated with overweight and the association was largely independent of other lifestyle factors. A dose-response relationship was observed when it was included as a categorical variable in the regression analysis. Our results thus suggest that, among the indicators of active and sedentary behavior that we studied, screen time is the most important risk factor for overweight in the age group studied. This result is in agreement with the conclusion of a recent study in which the evidence was summarized for six different strategies to prevent or treat pediatric overweight [20]. Our findings on screen time and overweight risk are also in line with the results of a comprehensive meta-analysis on the subject, which observed a statistically significant relationship between TV viewing and body fatness among children and youth [21]. We estimated that a reduction in overweight prevalence of up to 2 percentage points could be achieved if all children would reduce their screen time to less than 1 hour per day. This is very similar to the "maximum achievable reduction of prevalence (MARP)" of 1.5 percentage points that was estimated for watching television >1 hr/day in a study on 5-6 year old German children [22].

4.4. Diet and Overweight. Consumption of soft drinks and fast food at ages 5–7 was not associated with overweight whereas an unexpected inverse association between snack consumption and overweight was observed. Snack consumption at the age of 5 years was not associated with overweight at age 8, but snack consumption at age 7 was inversely associated with overweight at age 8. As indicated previously, these results may have been influenced by selective underreporting of snack consumption by parents of children who were becoming overweight. Besides selective underreporting, reverse causation may also have played a role, in the sense that parents of children who were becoming overweight really have reduced their children's consumption of specific foods and drinks. The results on fast food, snack and soft drink intakes seem to indicate that in particular the items included in our snack, variable are the kind of foods that come to parents' minds when they think of trying to limit excessive weight gain in their child. The selective underreporting and reverse causation that are likely to be present in our dietary data, make it impossible to judge from our results how diet influences the development of overweight. We hypothesize that these mechanisms might play a role also in other epidemiological studies on diet and overweight. Whereas, on theoretical grounds, it is hard to imagine that food intake is unrelated to weight status, observational studies have generally not produced consistent evidence for the expected associations [20, 23–27]. Our results do not provide an answer to the question whether consumption of soft drinks, fast food, and snacks causes overweight but seem to indicate that parents may see reduction of snack consumption as a method to counteract the development of overweight. With respect to screen time, we found no such evidence. Further studies into the strategies that parents themselves use to influence their children's weight gain might provide insights that could be useful for the design of preventive strategies.

4.5. Physical Activity, Screen Time, Diet, and Overweight in High Risk Subgroups. Low maternal education and maternal overweight were found to be strongly associated with overweight in the child. The association between low maternal education and overweight weakened substantially when the behavioral risk factors were included in the model, indicating that these factors explain part of the association. The behavioral risk factors had little influence on the association between maternal overweight and overweight in the child, indicating that other factors, possibly genetic factors, play a more important role in this association.

We repeated the regression analyses in sub groups stratified by maternal weight status and maternal education. Whereas in the high risk sub groups, screen time was higher than in low risk sub groups, the associations between screen time and overweight were weaker (although not statistically significantly) in these groups, and the population attributable risk percentage was lower than in the low risk sub groups. As the children of mothers with overweight and/or low education are the children at highest risk to develop overweight, this observation is potentially important for the development of preventive strategies and needs to be clarified in future observational as well as intervention studies.

5. Conclusions

Reduction of screen time should be part of interventions to prevent or reduce overweight in young children and could result in a reduction of overweight prevalence in the order of 2 percentage points in both high and low risk sub groups. Our results also suggest however that interventions aimed to promote sports club membership, active transport to school, and playing outside may have little impact on the prevalence of overweight in this age group. The possibility that, due to reverse causation, associations between food intake and overweight cannot be assessed in observational studies, needs further study.

References

[1] T. Lobstein, L. Baur, and R. Uauy, "Obesity in children and young people: a crisis in public health," *Obesity Reviews*, vol. 5, supplement 1, pp. 4–104, 2004.

[2] H. Oude Luttikhuis, L. Baur, H. Jansen, et al., "Interventions for treating obesity in children," *Cochrane Database of Systematic Reviews*, no. 1, Article ID CD001872, 2009.

[3] J. J. Reilly, J. Armstrong, A. R. Dorosty, et al., "Early life risk factors for obesity in childhood: cohort study," *British Medical Journal*, vol. 330, no. 7504, pp. 1357–1359, 2005.

[4] N. J. Blair, J. M. D. Thompson, P. N. Black, et al., "Risk factors for obesity in 7-year-old European children: the Auckland Birthweight Collaborative Study," *Archives of Disease in Childhood*, vol. 92, no. 10, pp. 866–871, 2007.

[5] S. S. Hawkins and C. Law, "A review of risk factors for overweight in preschool children: a policy perspective," *International Journal of Pediatric Obesity*, vol. 1, no. 4, pp. 195–209, 2006.

[6] C. Semmler, J. Ashcroft, C. H. M. van Jaarsveld, S. Carnell, and J. Wardle, "Development of overweight in children in relation to parental weight and socioeconomic status," *Obesity*, vol. 17, no. 4, pp. 814–820, 2009.

[7] G. K. Singh, M. D. Kogan, P. C. Van Dyck, and M. Siahpush, "Racial/ethnic, socioeconomic, and behavioral determinants of childhood and adolescent obesity in the United States: analyzing independent and joint associations," *Annals of Epidemiology*, vol. 18, no. 9, pp. 682–695, 2008.

[8] E. Stamatakis, P. Primatesta, S. Chinn, R. Rona, and E. Falascheti, "Overweight and obesity trends from 1974 to 2003 in English children: what is the role of socioeconomic factors?" *Archives of Disease in Childhood*, vol. 90, no. 10, pp. 999–1004, 2005.

[9] M. Wake, P. Hardy, L. Canterford, M. Sawyer, and J. B. Carlin, "Overweight, obesity and girth of Australian preschoolers: prevalence and socio-economic correlates," *International Journal of Obesity*, vol. 31, no. 7, pp. 1044–1051, 2007.

[10] B. Brunekreef, J. Smit, J. de Jongste, et al., "The prevention and incidence of asthma and mite allergy (PIAMA) birth cohort study: design and first results," *Pediatric Allergy and Immunology*, vol. 13, supplement 15, pp. 55–60, 2002.

[11] T. J. Cole, M. C. Bellizzi, K. M. Flegal, and W. H. Dietz, "Establishing a standard definition for child overweight and obesity worldwide: international survey," *British Medical Journal*, vol. 320, no. 7244, pp. 1240–1243, 2000.

[12] S. Scholtens, U. Gehring, B. Brunekreef, et al., "Breastfeeding, weight gain in infancy, and overweight at seven years of age: the prevention and incidence of asthma and mite allergy birth cohort study," *American Journal of Epidemiology*, vol. 165, no. 8, pp. 919–926, 2007.

[13] S. Scholtens, B. Brunekreef, H. A. Smit, et al., "Do differences in childhood diet explain the reduced overweight risk in breastfed children?" *Obesity*, vol. 16, no. 11, pp. 2498–2503, 2008.

[14] D. B. Rubin, *Multiple Imputation for Non Response in Surveys*, John Wiley & Sons, New York, NY, USA, 1987.

[15] J. L. Schafer, *Analysis of Incomplete Multivariate Data*, Chapman & Hall, London, UK, 1997.

[16] S. van Buuren and K. Oudshoorn, "Flexible multi-variate imputation by mice," Tech. Rep., TNO Preven-tion and Health, Leiden, The Netherlands, 1999, http://web.inter.nl.net/users/S.van.Buuren/mi/docs/rapport99054.pdf.

[17] S. van Buuren and K. Oudshoorn, "MICE: Multivariate Imputation by Chained Equations," R package version 1.15, 2005, http://web.inter.nl.net/users/S.van.Buuren/mi/hmtl/mice.htm.

[18] R Development Core Team, *R: A Language and Environment for Statistical Computing*, R Foundation for Statistical Computing, Vienna, Austria, 2005.

[19] J. Benichou, "A review of adjusted estimators of attributable risk," *Statistical Methods in Medical Research*, vol. 10, no. 3, pp. 195–216, 2001.

[20] B. Sherry, "Food behaviors and other strategies to prevent and treat pediatric overweight," *International Journal of Obesity*, vol. 29, supplement 2, pp. 116–126, 2005.

[21] S. J. Marshall, S. J. H. Biddle, T. Gorely, N. Cameron, and I. Murdey, "Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis," *International Journal of Obesity and Related Metabolic Disorders*, vol. 28, no. 10, pp. 1238–1246, 2004.

[22] A. M. Toschke, S. Rückinger, E. Böhler, and R. Von Kries, "Adjusted population attributable fractions and preventable potential of risk factors for childhood obesity," *Public Health Nutrition*, vol. 10, no. 9, pp. 902–906, 2007.

[23] P. K. Newby, "Are dietary intakes and eating behaviors related to childhood obesity? A comprehensive review of the evidence," *Journal of Law, Medicine and Ethics*, vol. 35, no. 1, pp. 35–60, 2007.

[24] R. A. Forshee, P. A. Anderson, and M. L. Storey, "Sugar-sweetened beverages and body mass index inchildren and adolescents: a meta-analysis," *American Journal of Clinical Nutrition*, vol. 87, no. 6, pp. 1662–1671, 2008.

[25] R. A. Forshee, P. A. Anderson, and M. L. Storey, "Erratum in "Sugar-sweetened beverages and body mass index in children and adolescents: a meta-analysis"," *American Journal of Clinical Nutrition*, vol. 89, no. 1, pp. 441–442, 2009.

[26] V. S. Malik, M. B. Schulze, and F. B. Hu, "Intake of sugar-sweetened beverages and weight gain: a systematic review," *American Journal of Clinical Nutrition*, vol. 84, no. 2, pp. 274–288, 2006.

[27] L. R. Vartanian, M. B. Schwartz, and K. D. Brownell, "Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis," *American Journal of Public Health*, vol. 97, no. 4, pp. 667–675, 2007.