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Prospective associations between energy balance-related behaviors at 2 years of age and subsequent adiposity: the EDEN mother-child cohort

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Conflict of interest

None of the authors had a conflict of interest.

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Short running head: Early obesogenic energy balance-related behaviors

Abbreviations: bioelectrical impedance analysis (BIA); Body mass index (BMI); Energy balance-related behaviors (EBRBs); Food frequency questionnaire (FFQ); Percentage of body fat (%BF); Principal component analysis (PCA); Socio-economic position (SEP).

1 **Abstract**

2 **Background/Objectives** Sedentary behavior, physical activity and dietary behavior are formed
3 early during childhood and tend to remain relatively stable into later life. No longitudinal studies
4 have assessed the independent influence of these three energy balance-related behaviors during
5 toddlerhood on later adiposity. We aimed to analyze the associations between screen time, outdoor
6 play time, and dietary patterns at age 2 years and child adiposity at age 5, in boys and girls
7 separately.

8 **Subjects/Methods** This study included 883 children from the French EDEN mother-child cohort.
9 Screen time, outdoor play time and dietary intakes were reported by parents in questionnaires when
10 the child was aged 2. Two dietary patterns, labelled “Guidelines” and “Processed, fast-foods”, were
11 identified in a previous study. Percentage of body fat (%BF) based on bioelectrical impedance
12 analysis and body mass index were measured at age 5.

13 **Results** In boys, screen time at age 2 was positively associated with %BF at age 5 ($\beta= 0.51$ (95%
14 confidence interval (CI): 0.02, 1.01) for those boys with ≥ 60 min/day of screen time vs. those with
15 ≤ 15 min/day, P for trend 0.045). In girls, outdoor play was inversely associated with %BF ($\beta= -0.93$
16 (95%CI: -1.58, -0.28) for those in the highest tertile of outdoor play time vs. those in the lowest
17 tertile, $P= 0.002$). Overall, at age 2, dietary patterns were associated with both screen time and
18 outdoor play time, but no significant and independent association was observed between dietary
19 patterns and later adiposity.

20 **Conclusion** This study shows longitudinal and gender differentiated relations between both screen
21 time and outdoor play time in toddlerhood and later adiposity, while evidence for a relation between
22 dietary patterns and subsequent fat development was less conclusive. Early childhood - by age 2 -
23 should be targeted as a critical time for promoting healthy energy balance-related behaviors.

24

25

26 INTRODUCTION

27 Childhood overweight and obesity have reached epidemic proportions worldwide.¹ In 2010, the
28 estimated prevalence among preschool children was as high as 11.7% in developed countries and
29 6.1% in developing countries.² This epidemic has reached the whole pediatric population, with
30 secular trends towards higher fat mass in both obese and non-obese children. Beyond any
31 predisposition due to genetic susceptibility or programming of later adiposity by the intrauterine
32 environment, the rapid increase in adiposity in recent decades in young children may also indicate
33 that obesogenic energy balance-related behaviors (EBRBs), namely high levels of sedentary
34 behaviors, low levels of physical activity and unhealthy dietary behaviors, come into play at an
35 early age.^{3,4}

36 Early childhood (< 5 years) is critical for the setting of EBRBs for a number of reasons. Early
37 exposure to active play stimulates motor skills, which predict later physical activity.⁵ Early food
38 experiences influence the development of taste and food preferences, which in turn affect
39 subsequent eating habits.⁶⁻⁸ Furthermore, there is some evidence that sedentary behaviors, physical
40 activity and dietary intakes track (the concept of tracking relates to the stability, or relative ranking
41 within a cohort, of behaviors over time) from early childhood into later childhood, adolescence and
42 even adulthood.⁹⁻¹³ The early establishment of obesogenic EBRBs, which are maintained once
43 habits are formed, is therefore hypothesized to lead to a cumulative increase of positive energy
44 balance over the life course, favoring the development of body fat.⁴ Hence, identifying the specific
45 early behaviors that are most predictive of later body fat development, especially those that are
46 modifiable, is a necessary step for developing effective interventions and public health policies
47 aimed at reducing childhood overweight and obesity.

48 Accumulating evidence from longitudinal studies in preschoolers (roughly aged 3-5 years at
49 baseline) indicates that sedentary behavior - mainly television viewing - is deleterious and physical
50 activity protective for later adiposity.^{4,14} Inconsistent evidence characterizes the prospective

51 relations between early dietary behaviors and overweight.¹³⁻¹⁵ There is however a dearth of research
52 examining these longitudinal associations among children younger than 3,^{13 16} despite growing
53 evidence that toddlers are already engaging in high levels of screen time¹⁷ and that suboptimal
54 dietary patterns are already established by age 2.^{12 18} Moreover, despite a careful search, we have
55 been unable to find any longitudinal studies among toddlers that have taken the three EBRBs into
56 account simultaneously, nor have we found any that have studied boys and girls separately,
57 although both body composition¹⁹ and physical activity^{20 21} differ between preschool boys and girls.
58
59 We aimed to analyze the independent associations between screen time, outdoor play time, and
60 dietary patterns at age 2 and child adiposity at age 5, assessed by comprehensive and specific
61 measurements, including bioelectrical impedance analysis. We hypothesized that outdoor play time
62 and healthy dietary patterns would be protective against the development of adiposity, while screen
63 time and non-healthy dietary patterns would not be. We assumed that the effects might be modified
64 by gender and therefore conducted the analysis separately in boys and girls.

65

66 **SUBJECTS AND METHODS**

67 **Subjects**

68 The EDEN mother-child study is a prospective cohort designed to assess pre- and postnatal
69 determinants of child health and development; it has been described in detail elsewhere.²² In brief,
70 between 2003 and 2006, 2002 pregnant women (< 24-weeks' gestation) aged 18-44 years were
71 recruited in two university hospital maternity clinics, in Nancy and Poitiers, France. Exclusion
72 criteria were multiple pregnancies, diabetes history, French illiteracy, and plans to move out of the
73 region within the next three years. Approval for the study was obtained from the relevant ethics
74 committee (ID 0270 of 12 December 2012) and the French Data Protection Authority (CNIL, ID
75 902267 of 12 December 2012). Written consents were obtained from each participant.

76 There were 1903 live born children; 1266 sets of parents returned the questionnaire with complete
77 or imputed data for the child EBRBs at age 2; the participants selected for this study are the 883 for
78 whom data were available for both anthropometric and bioelectrical impedance analysis (BIA)
79 measurements at age 5 (**Figure 1**). The current sample thus comprised 473 boys and 410 girls with
80 both behavioral and adiposity measurements.

81

82 **Adiposity measurements at age 5**

83 Anthropometric and bioelectrical impedance data were collected during the clinical examination
84 that took place at the Nancy and Poitiers university hospitals when the child was 5 (mean 5.65
85 years, SD 0.16). Measurements were performed by trained investigators, using standard procedures.

86 *Anthropometric measurements.* Height and weight were measured twice, then averaged. The
87 children's heights were measured to the nearest 0.1 cm with wall-mounted stadiometers (Model
88 208, SECA, Hamburg, Germany) as they stood barefoot, and their weights to the nearest 0.2 kg
89 with an electronic scale (Model 888, SECA, Hamburg, Germany), while they wore light underwear.
90 Body mass index (BMI) was calculated as weight (kg)/height² (m²). Skinfold thickness was taken
91 three times, then averaged, to the nearest 0.2 mm at the left triceps and subscapular sites, with a
92 Holtain skinfold caliper (Chasmors Ltd, London, UK).

93 *Bioelectrical impedance analysis (BIA) measurements.* All children underwent BIA twice (and the
94 two measurements were averaged), with a single-frequency impedance analyzer (Model BIA 101,
95 Akern-RJL, Italy) after 5 minutes of rest and with an empty bladder.

96 *Percentage of body fat.* The estimated percentage of body fat (%BF) was based on the
97 anthropometric and BIA measures and used three different equations: from Houtkooper et al.,²³
98 Slaughter et al.²⁴ and Goran et al.²⁵ The latter, which takes body resistance and all anthropometric
99 measures listed above (height, weight, and skinfold thickness) into account, was developed among

100 white children aged 4-9 years. Because it was considered the most suitable for our study population,
101 it was prioritized in the analysis.

102

103 **Energy balance-related behaviors at age 2**

104 *Sedentary behavior and physical activity.* Postal questionnaires were sent to parents and completed,
105 primarily by mothers, when the children were aged 2 (mean 2.03 years, SD 0.09). Sedentary
106 behavior was assessed from the responses to three questions regarding the time (in min/day) that the
107 child spent watching television or playing video or computer games, on a typical weekday
108 (excluding Wednesday), Wednesday (which was a day off school at the time of the study), and
109 weekend days; there was one question for each type of day. Similarly, physical activity was
110 assessed from three questions about the time the child usually spent playing outdoors (e.g., in a
111 backyard, a park, a playground) for each type of day. An average daily time was calculated and
112 weighted for both types of activity. Sedentary screen time was split into three categories, i.e., ≤ 15
113 min/day, >15 min/day to <1 h/day, and ≥ 1 h/day, which corresponded to tertiles in our population.
114 Given the children's age and the period of data collection (2005-2008), we can reasonably think that
115 television (and DVDs) accounted for most of the screen time in our study.²⁶ There is evidence of
116 seasonal variations in physical activity, especially for the time children spend playing outdoors.²⁷
117 Hence, the daily time spent playing outdoors was categorized into season-specific tertiles (low,
118 intermediate, and high). Imputations were done for 187 children when one or two items of the three
119 (i.e., weekday, Wednesday, weekend day) were missing for a given activity, based on the values
120 available for any other day.

121 *Dietary patterns.* Children dietary intake at age 2 was collected with a food frequency questionnaire
122 (FFQ) included in the postal questionnaire and described in detail elsewhere.¹² In brief, the food
123 classification was established based on similarities in food type and context of consumption and
124 was designed to be able to describe the patterns of the child's diet. The FFQ included 26 food

125 groups along with seven possible responses, ranging from “Never” to “Several times per day”; all
126 were converted into weekly frequencies. A previous analysis of these data¹² using principal
127 component analysis (PCA), identified two dietary patterns, which accounted for 19.8% of the
128 explained variance. The first pattern, labelled “Processed, fast-food”, was positively correlated with
129 intake of French fries, processed meat, carbonated soft drinks, crisps, biscuits, pizzas, fruit juices,
130 dairy puddings and ice cream, legumes, and bread (by descending order of factor loadings) and
131 inversely correlated with the intake of cooked vegetables. The second pattern, labelled
132 “Guidelines”, was mainly characterized by high consumption frequency of cooked vegetables, rice,
133 fruits, raw vegetables, low fat fish, potatoes, ham, compotes, meat, and bread. Scores for each
134 pattern were calculated at the individual level by summing the observed standardized frequencies of
135 consumption per food group, weighted according to the PCA loadings.

136

137 **Covariates**

138 *Baseline BMI.* Using the Jenss-Bayley nonlinear model and measurements collected from the
139 child’s health care booklet (birth to 5 years) and at the clinical examinations undertaken at the
140 university clinics at ages 1, 3, and 5, we fitted individual weight and height growth trajectories.²⁸

141 The resulting equation allowed us to predict both weight and height and therefore BMI at age 2.

142 *Socio-economic position (SEP).* Since SEP is a recognized covariate of diet in early childhood,^{18 29}
143 the analysis adjusted for maternal education (the highest diploma obtained: less than high-school,
144 high school diploma, 2-year university degree and ≥ 3 year university degree) and monthly
145 household income (in €) at inclusion (categorized as ≤ 1500 , 1501 to 2300, 2301 to 3000, 3001 to
146 3800, > 3800).

147

148 **Statistical analysis**

149 The study population was compared to the EDEN population not selected for this study (that is, the
150 initially included families with live born children for whom any of behavioral variables at age 2 or
151 adiposity measurements at age 5 were not available) for infant birth characteristics, parental
152 demographic characteristics and SEP. Within the study population, boys and girls were compared
153 for EBRBs, adiposity outcomes, and covariates. Chi-square tests were used for categorical variables
154 and Student t-tests for continuous variables. The relations between the EBRBs at age 2 were also
155 assessed, adjusting for SEP and study center, with multivariable linear and ordinal logistic
156 regression analyses.

157 Multivariable linear regression analysis was used to assess the association between EBRBs at age 2
158 and adiposity at age 5. For each of the four outcomes (i.e., BMI and %BF with each of the three
159 equations described above), the analysis was conducted in two steps. First, screen time, outdoor
160 play time, and dietary patterns were each included in separate models. Then the three EBRBs were
161 included simultaneously along with the SEP variables in a single model, referred as the fully-
162 adjusted model. All models were run for boys and girls separately, and adjusted for center (Poitiers
163 or Nancy), baseline BMI, and exact age at the 5-year clinical examination. Finally, sensitivity
164 analyses were carried out for the sample excluding children with imputed data (complete case
165 sample, n=756).

166 SAS 9.3 was used for the statistical analyses, and the level of significance set at $P < 0.05$.

167

168 **RESULTS**

169 **Characteristics of the study population**

170 **Table 1** summarizes the characteristics of boys and girls in the study sample. At age 2, the boys
171 spent more time playing outdoors and had a slightly lower mean BMI than girls. There was no
172 significant difference between genders for either dietary pattern scores or screen time. Overall,
173 12.2% of the 2-year-old children spent no time on screen activities, 54.7% less than 1 h/day, and

174 33.1% 1 h/day or more. At age 5, %BF and prevalence of overweight (including obesity) were both
175 significantly lower among boys than girls.

176 Compared to non-selected children, children selected for the current study were less likely to have
177 been born to a young mother (28.9 years *vs.* 30.2, $P < 10^{-4}$), to have a mother with a lower education
178 level (42% with education < high school diploma *vs.* 19%, $P < 10^{-4}$), and to live in a low-income
179 household (22.2% *vs.* 10.8% with household monthly income ≤ 1500 €, $P < 10^{-4}$). However, there
180 was no significant difference in birth weight between the two samples.

181

182 **Interrelations between energy balance-related behaviors at age 2**

183 Associations between EBRBs at age 2 are presented by gender in **Table 2**. Among boys, higher
184 scores for the “Processed, fast-foods” dietary pattern were positively associated with screen time.
185 Among girls, “Guidelines” dietary pattern scores and, to a lesser extent, “Processed, fast-food”
186 dietary pattern scores were positively associated with outdoor play time (upper tertile). There was
187 no significant association in either gender between time spent at outdoor play and in front of a
188 screen (results not shown).

189

190 **Independent associations between screen time, outdoor play time, and dietary patterns at age** 191 **2 and child adiposity at age 5**

192 In boys, screen time at age 2 was the only EBRB that was significantly and positively associated
193 with %BF at age 5 in the separate models (**Table 3**). This association remained significant and the
194 coefficient estimates barely changed after adjustment for the other two EBRBs and for SEP. The
195 regression coefficient estimates suggest a graded dose-response relation (adjusted linear trend β
196 0.42, $P = 0.045$). In girls, both the time spent playing outdoors and the score on the “guideline”
197 dietary pattern at age 2 were significantly and negatively associated with %BF at age 5 in the
198 separate models. The association with outdoor play remained significant and the coefficient

199 estimates barely changed in the fully adjusted model, while the association with the “Guideline”
200 dietary pattern was no longer significant. The regression coefficient estimates for outdoor play
201 suggested that the effect was driven by the upper tertile of the variable. Similar results were found
202 with the other two estimates of %BF (i.e., based on Houtkooper’s and Slaughter’s equations)
203 (**Supplementary Table 1**). No EBRB was significantly and independently associated with BMI at
204 age 5 in either gender. Sensitivity analyses for the sample excluding children with imputed data
205 (complete case sample) produced consistent results (**Supplemental Table 2**).

206

207 **DISCUSSION**

208 This study, which highlights the precocity of the onset of behavioral risk factors for obesity, is to
209 our knowledge the first to find that the amounts of time spent on screen and in outdoor play during
210 toddlerhood are each prospectively and independently associated with later adiposity, regardless of
211 diet, SEP, and baseline BMI.

212

213 Our results confirm previous findings in preschoolers suggesting that early exposure to screens -
214 mainly measured as television viewing - is obesogenic.^{14 30} They further show that this effect is
215 apparent at an age as early as 2 in boys. The literature suggests several underlying mechanisms that
216 may explain this association, including reduced resting metabolic rate,³¹ displacement of more
217 active pursuits,³² exposure to advertising of junk food and fast food leading to increased children’s
218 requests for those particular foods and products, and increased snacking while watching television
219 or movies.^{33 34} Consistent with observations in older children,^{35 36} we found a positive association
220 between screen time and “Processed and fast-foods” dietary pattern scores at age 2, but only in
221 boys. This may help to explain why the positive association between screen time and later adiposity
222 was significant only in boys, even though it was unaltered by adjustment for dietary patterns.
223 Finally, screen time has been inversely associated with sleep time,³⁷ and short sleep duration has

224 been longitudinally associated with excess weight gain in early childhood.^{38,39} Screen time was not
225 associated with parent-reported sleep time at 2 years in our population (not shown). A previous
226 cross-sectional analysis of EDEN data at 3 years did however suggest that - again for boys only -
227 short sleep duration was positively associated with both screen time and BMI.⁴⁰ Current guidelines
228 recommend to avoid exposure to screens before age 2 and to limit screen time to less than 1 h or 2 h
229 daily between age 2 and 5.⁴¹⁻⁴⁴ In our sample of 2-year olds, only 12.2% had no screen activities at
230 all, while about a third had an hour or more daily. The graded dose-response shape of the
231 association with adiposity in our results, added to the growing evidence that increased screen time
232 in early years is associated with unfavorable scores on measures of psychological health and
233 cognitive development,^{30,45} is a further reason that parents should be informed about the deleterious
234 health effects of early screen exposure.

235

236 Our findings also provide unique insights into the protective role of outdoor play in toddlerhood for
237 later adiposity. This is consistent with the review by te Velde et al.¹⁴ that showed strong evidence
238 for an inverse longitudinal association between objectively-measured total physical activity at
239 preschool age and later overweight. As these authors noted, however, these findings did not allow
240 them to identify the specific components of physical activity that drove the association. Play time
241 spent outdoors has been positively related to total physical activity in preschoolers,²¹ and we can
242 reasonably hypothesize that this is also true at age 2, since the physical activity of children younger
243 than 5 is essentially unstructured, and might be described more appropriately as “active free play”.²⁰
244 Furthermore, preschoolers are generally more physically active outdoors than indoors.⁴⁶ Hence, it
245 has been suggested that outdoor play is a major contributor of physical activity in young children.⁴⁷
246 Toddlers who engage in more outdoor play are thus likely to expend more energy, which leads to
247 both a healthier energy balance and stimulated motor skills.⁵ Of note, the negative association
248 between outdoor play and adiposity was present only in girls. Outdoor play time may be an even

249 better indicator of total physical activity for girls than for boys, since girls are overall less active
250 than boys and may spend more of their indoor play time in quiet play (e.g., drawing, tinkering,
251 looking into books, which are considered as productive sedentary behaviors²⁶) than boys do.
252 Noteworthy, outdoor play in young children is under parental control, and there is some evidence to
253 suggest that children's physical activity is strongly associated with parental activity and
254 encouragement, especially in girls.⁴⁸ Moreover, only the upper tertile of outdoor play was
255 negatively associated with later adiposity, and girls in that highest tertile also had higher scores on
256 the "Guidelines" dietary pattern. Hence, taking toddlers outdoors to stimulate their motor skills and
257 provide them with an opportunity for active play may also reflect healthier family lifestyles and
258 attitudes, especially for girls.⁴⁸ Current physical activity guidelines⁴⁹⁻⁵¹ recommend that children
259 aged 1-5 years should be physically active every day for at least a total of 3 hours, at any intensity,
260 spread throughout the day. In our sample of 2-year old French children, the upper tertile of outdoor
261 play corresponds to a median play time around 2 to 4 hours, depending on the season. Although
262 parents have traditionally assumed that young children were spontaneously and sufficiently
263 physically active, growing evidence suggests that this is not necessarily the case and that large inter-
264 individual variability exists.^{20 52} Young girls are even less active than young boys,^{20 21} and our
265 results suggest that encouraging outdoor play may be a particularly effective way to promote
266 physical activity in young girls.

267

268 We found no strong evidence that dietary patterns at toddler ages are independent predictors of
269 subsequent body fat at 5 years, consistent with previous studies in children 0-5 years,^{14 15 18 38} but
270 not all.¹³ The current lack of consensus on the influence of diet on overweight is due in part to
271 methodological issues. Various measures have been used to define dietary intake; some studies have
272 focused on specific nutrients or foods, while others have addressed the diet as a whole, through
273 dietary patterns or eating behaviors. Residual confounding may also be important where analyses

274 have not taken major covariates such as physical activity and sedentary behavior into account.
275 Finally, most existing studies linking dietary intakes and child obesity are limited by their cross-
276 sectional designs. Nevertheless, given that dietary patterns emerge early in life, tend to track into
277 the preschool years and beyond,^{9 10 12 13} and that we found they co-varied with other EBRBs, it is
278 possible that the cumulative effect of dietary patterns on adiposity will become more visible at older
279 ages, when most children enter formal schooling and levels of physical activity tend to decrease,⁵³
280 as suggested by results from both the Avon Longitudinal Study of Parents and Children^{38 54} and the
281 Southampton Women's Survey.¹³

282

283 A novel aspect and main strength of our study was the assessment of these associations from
284 toddlerhood, prospectively and considering both sides of the energy equation (i.e., intake and
285 expenditure) as well as the effect modification by gender. The comprehensive and objective
286 measurements of adiposity, together with the consistency of these associations across different
287 measurements of fat mass and different samples (study sample with imputed data *vs.* complete-case
288 sample), are additional strengths of this work. Overall, our findings also show the relevance of
289 using specific measures of body fat, because none of the associations observed was significant with
290 BMI, which cannot distinguish between fat and fat-free mass. The sole reliance on parental report
291 of behaviors is however a limitation in our analyses. These measurements are subject to social
292 desirability bias and are relatively imprecise compared to objective measurements (e.g., by
293 accelerometry), which may have attenuated the associations under study. We acknowledge that the
294 estimation of food intake would have been more precise with a quantitative FFQ. Nevertheless,
295 research shows that frequency of consumption is actually the major determinant of intake, while the
296 inclusion of portion or serving size in FFQs adds limited information about variance in food
297 intake.⁵⁵ Therefore, frequencies of consumption have commonly been used to identify dietary
298 patterns,⁵⁶ which are recognized to be relevant not only for assessing the association between total

299 diet and obesity but also because they can be translated into guidelines for the public.⁵⁷ Finally,
300 although all levels of SEP were represented in this study, the sample is generally well educated (as
301 is most often the case in cohorts), with 81% of the mothers reporting \geq high school education.
302 Prevalence of overweight and obesity at 5 years was also lower than in the general population, i.e.,
303 7.6% vs. 11.9-13.5%.^{58 59} The presence of a selection bias is therefore possible and may have
304 implications for generalization of the findings. We can hypothesize that better representation of
305 disadvantaged families, in particular of those with clusters of unhealthy behaviors, would have
306 provided more contrast and better power to show higher effect sizes for the supposed longitudinal
307 effects of EBRBs on later adiposity. This may be especially true for dietary patterns, which are
308 known to be strongly socially patterned from early childhood.^{18 29} Remarkably, the current findings
309 suggest both adverse and protective effects even in this rather low-risk sample and thus make the
310 public health arguments even stronger.

311

312 In conclusion, this study shows longitudinal and gender-differentiated relations between screen time
313 and outdoor play in toddlerhood and later adiposity, while less conclusive findings were found for
314 the relation between dietary patterns and subsequent fat development. These results provide
315 additional evidence that early childhood - by age 2 - should be targeted as a critical time for
316 promoting healthy energy balance-related behaviors.

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337 the data and the accuracy of the data analysis. All researchers are independent of the funding
338 bodies. All members in the EDEN mother-child cohort study group designed the study and revised
339 the draft manuscript.

340

341 Supplementary information is available at the International Journal Obesity's website

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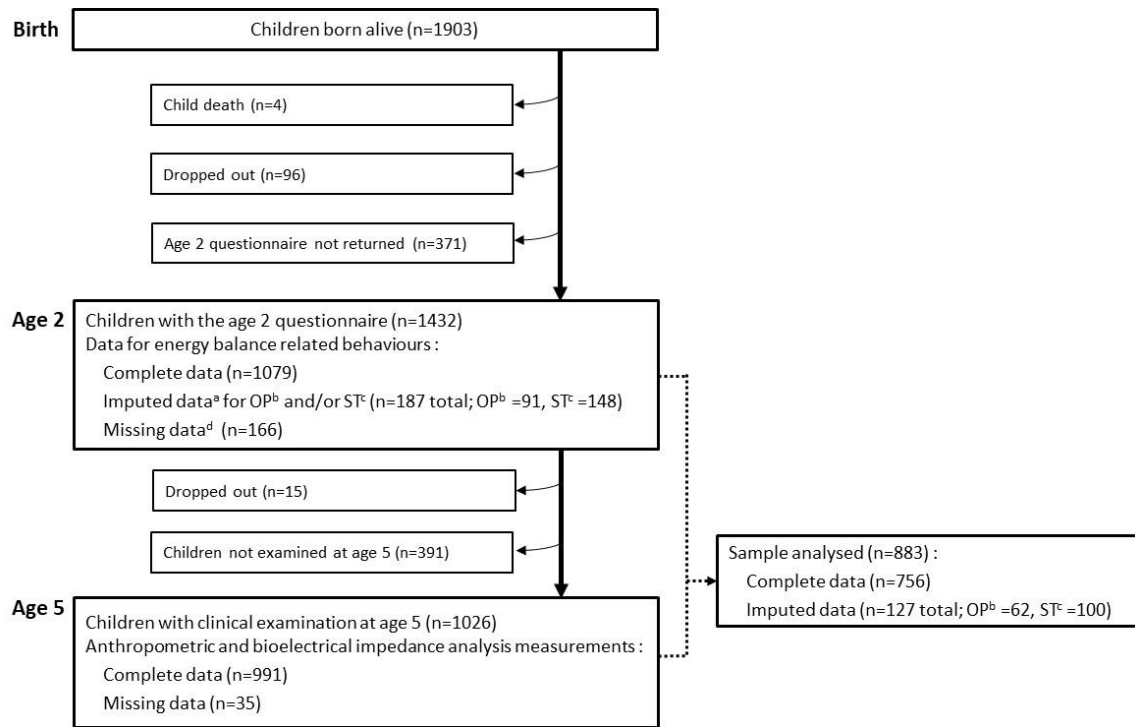


Figure 1: Flow diagram for selection of children

^a Non-responses to 1 or 2 questions regarding outdoor play and/or screen time were imputed (see methods);

^b Outdoor play time; ^c Screen time; ^d Completely missing for one or more energy balance-related behaviors.

Table 1. Children's characteristics, by gender (values are percentages (numbers) unless stated otherwise). The EDEN mother-child cohort.

	Boys (n=473)	Girls (n=410)	P
Variables at inclusion or birth			
Maternal education			
Did not complete high school	20.1 (95)	18.5 (76)	0.84
High school diploma	17.8 (84)	17.1 (70)	
2-year university degree	26.0 (123)	25.4 (104)	
≥ 3-year university degree	36.1 (171)	39.0 (160)	
Household income, €/month			
≤ 1500	11.6 (55)	9.7 (40)	0.51
1501 to 2300	28.8 (136)	27.1 (111)	
2301 to 3000	32.4 (153)	31.0 (127)	
3001 to 3800	15.4 (73)	19.5 (80)	
> 3800	11.8 (56)	12.7 (52)	
Centre			
Nancy	56.0 (265)	49.8 (204)	0.06
Poitiers	44.0 (208)	50.2 (206)	
Maternal age at delivery (y), mean(SD)	30.2 (4.7)	30.1 (4.8)	0.77
Birth weight (g), mean (SD)	3357 (526)	3218 (482)	<0.001
Children's characteristics at age 2 years			
Screen time, min/day			
≤15	33.8 (160)	34.6 (142)	0.43
>15 to <60	31.3 (148)	34.4 (141)	
≥60	34.9 (165)	31.0 (127)	
Outdoor play time ^a			
Low (Tertile 1)	28.5 (135)	38.3 (157)	0.003
Medium (Tertile 2)	34.0 (161)	33.2 (136)	
High (Tertile 3)	37.4 (177)	28.5 (117)	
"Processed, fast food" dietary pattern scores, mean (SD)	-0.03 (0.96)	-0.04 (0.96)	0.80
"Guidelines" dietary pattern scores, mean (SD)	-0.02 (0.93)	0.10 (0.97)	0.080
BMI (kg/m ²) ^b , mean (SD)	17.3 (1.9)	17.5 (2)	0.048
Children's characteristics at age 5 years			
BMI (kg/m ²) mean (SD)	15.4 (1.3)	15.4 (1.4)	0.74
Prevalence of overweight (including obesity) ^c	5.7 (27)	9.8 (40)	0.024
Percentage of body fat ^d , mean (SD)	12.6 (2.9)	16.7 (3.2)	<0.001

^aRanges for outdoor play time categories. Low (Tertile 1): spring (9 min to 1 h 23 min), summer (23 min to 1 h 58 min), autumn (4 min to 1 h 12 min), winter (0 min to 50 min). Intermediate (Tertile 2): spring (1 h 24 min to 2 h 15 min), summer (1 h 59 min to 2 h 55 min), autumn (1 h 13 min to 1 h 58 min), winter (51 min to 1 h 18 min). High (Tertile 3): spring (2 h 16 min to 6 h), summer (2 h 56 min to 6 h 34 min), autumn (1 h 59 min to 6 h), winter (1 h 19 min to 4 h 09 min).

^bPredicted BMI based on Jense's nonlinear model²⁸ (see methods).

^cInternational Obesity Task Force cut-off.⁶⁰

^dBased on Goran et al.²⁵ equation.

Table 2. Associations between dietary patterns scores^a and both outdoor play and screen times (values are linear regression coefficients (95% CI))^b. The EDEN mother-child cohort

	Boys (n=473)		Girls (n=410)	
	"Processed, fast food" dietary pattern scores	"Guidelines" dietary pattern scores	"Processed, fast food" dietary pattern scores	"Guidelines" dietary pattern scores
Outdoor play time^c				
Low (Tertile 1)	ref	ref	ref	ref
Intermediate (Tertile 2)	0.10 (-0.11, 0.31)	0.08 (-0.13, 0.29)	-0.04 (-0.25, 0.18)	-0.08 (-0.30, 0.14)
High (Tertile 3)	0.22 (0.01, 0.43)	-0.04 (-0.24, 0.17)	0.24 (0.00, 0.47)	0.41 (0.17, 0.64)
<i>P</i>	0.12	0.52	0.052	0.0002
Screen time (min/day)				
≤15	ref	ref	ref	ref
>15 to <60	0.03 (-0.18, 0.23)	0.05 (-0.16, 0.26)	0.23 (0.01, 0.44)	0.07 (-0.16, 0.30)
≥60	0.38 (0.18, 0.58)	0.06 (-0.15, 0.26)	0.17 (-0.07, 0.40)	-0.05 (-0.29, 0.19)
<i>P</i>	0.0002	0.83	0.12	0.60

^aScores for each pattern were calculated at the individual level by summing the observed standardized frequencies of consumption per food group, weighted according to the PCA loadings.

^bLinear regression analyses were undertaken including outdoor play and screen time in separate models. All models adjusted for centre (Poitiers or Nancy) and SEP variables (maternal education and household income).

^cRanges for outdoor play time categories. Low (Tertile 1): spring (9 min to 1 h 23 min), summer (23 min to 1 h 58 min), autumn (4 min to 1 h 12 min), winter (0 min to 50 min). Intermediate (Tertile 2): spring (1 h 24 min to 2 h 15 min), summer (1 h 59 min to 2 h 55 min), autumn (1 h 13 min to 1 h 58 min), winter (51 min to 1 r 18 min). High (Tertile 3): spring (2 h 16 min to 6 h), summer (2 h 56 min to 6 h 34 min), autumn (1 h 59 min to 6 h), winter (1 h 19 min to 4 h 09 min).

Table 3. Associations between EBRBs^a at age 2 and adiposity at age 5 (values are linear regression coefficients (95% CI)). The EDEN mother-child cohort.

	Boys (n=473)				Girls (n=410)			
	%BF ^b		BMI		%BF ^b		BMI	
	Separate models ^c	Fully-adjusted model ^d	Separate models ^c	Fully-adjusted model ^d	Separate models ^c	Fully-adjusted model ^d	Separate models ^c	Fully-adjusted model ^d
Outdoor play time (min/d)^e								
Low (Tertile 1)	ref	ref	ref	ref	ref	ref	ref	ref
Intermediate (Tertile 2)	-0.31 (-0.82, 0.19)	-0.33 (-0.84, 0.18)	0.02 (-0.04, 0.31)	0.02 (-0.16, 0.20)	0.27 (-0.31, 0.85)	0.26 (-0.34, 0.85)	0.05 (-0.15, 0.24)	0.06 (-0.14, 0.27)
High (Tertile 3)	-0.11 (-0.61, 0.39)	-0.14 (-0.64, 0.37)	0.13 (-0.16, 0.19)	0.14 (-0.03, 0.32)	-0.89 (-1.50, -0.28)	-0.93 (-1.58, -0.28)	-0.09 (-0.30, 0.11)	-0.06 (-0.28, 0.16)
<i>P</i>	0.46	0.43	0.25	0.21	0.001	0.002	0.43	0.55
Screen time (min/d)								
≤15	ref	ref	ref	ref	ref	ref	ref	ref
>15 to <60	0.25 (-0.25, 0.74)	0.25 (-0.25, 0.74)	0.08 (-0.10, 0.25)	0.08 (-0.09, 0.26)	0.33 (-0.27, 0.93)	0.26 (-0.34, 0.86)	0.11 (-0.09, 0.31)	0.08 (-0.12, 0.29)
≥60	0.48 (0.00, 0.96)	0.51 (0.02, 1.01)	0.002 (-0.17, 0.17)	0.04 (-0.14, 0.21)	0.14 (-0.48, 0.76)	0.06 (-0.58, 0.70)	0.07 (-0.14, 0.28)	0.04 (-0.18, 0.26)
<i>P</i>	0.053 ^f	0.045 ^f	0.62	0.65	0.55	0.68	0.56	0.72
Dietary patterns (scores)								
"Processed, fast-food"	0.04 (-0.17, 0.25)	0.02 (-0.20, 0.25)	-0.04 (-0.11, 0.04)	-0.04 (-0.11, 0.04)	0.15 (-0.10, 0.41)	0.19 (-0.08, 0.46)	0.07 (-0.02, 0.16)	0.08 (-0.01, 0.17)
<i>P</i>	0.690	0.829	0.324	0.364	0.244	0.176	0.106	0.099
"Guidelines"	-0.02 (-0.23, 0.20)	0.00 (-0.22, 0.22)	0.01 (-0.08, 0.07)	-0.01 (-0.09, 0.07)	-0.31 (-0.57, -0.06)	-0.21 (-0.47, 0.06)	-0.08 (-0.17, 0.01)	-0.07 (-0.16, 0.02)
<i>P</i>	0.87	0.97	0.90	0.81	0.017	0.12	0.067	0.12

^aEnergy balance-related behaviors.

^bBody fat percentage measured and calculated based on Goran's equation.²⁵

^cScreen time, outdoor play and dietary patterns were included in three separate models, which adjusted for center (Poitiers or Nancy), baseline BMI and exact age at the age 5 clinical examination.

^dThe three EBRBs were included simultaneously along with the SEP variables (maternal education and household income). All models adjusted for center (Poitiers or Nancy), baseline BMI and exact age at the age 5 clinical examination.

^eRanges for outdoor play time categories. Low (Tertile 1): spring (9 min to 1 h 23 min), summer (23 min to 1 h 58 min), autumn (4 min to 1 h 12 min), winter (0 min to 50 min). Intermediate (Tertile 2): spring (1 h 24 min to 2 h 15 min), summer (1 h 59 min to 2 h 55 min), autumn (1 h 13 min to 1 h 58 min), winter (51 min to 1 r 18 min). High (Tertile 3): spring (2 h 16 min to 6 h), summer (2 h 56 min to 6 h 34 min), autumn (1 h 59 min to 6 h), winter (1 h 19 min to 4 h 09 min).

^f*P* trend assessed using the median value of each category of the variable (after testing the linearity of the association using a F-test, *P*-values > 0.95).

Supplementary Table 1. Associations between EBRBs^a at age 2 and adiposity at age 5 (values are linear regression coefficients (95% CI)). The EDEN mother-child cohort.

	Boys (n=473)				Girls (n=410)			
	%BF ^b from Slaughter		%BF ^b from Houtkooper		%BF ^b from Slaughter		%BF ^b from Houtkooper	
	Separate models ^c	Fully-adjusted model ^d	Separate models ^c	Fully-adjusted model ^d	Separate models ^c	Fully-adjusted model ^d	Separate models ^c	Fully-adjusted model ^d
Outdoor play time (min/d)^e								
Low (Tertile 1)	ref	ref	ref	ref	ref	ref	ref	ref
Intermediate (Tertile 2)	-0.28 (-0.81, 0.24)	-0.34 (-0.61, 0.44)	-0.48 (-1.37, 0.42)	-0.47 (-1.38, 0.43)	0.35 (-0.23, 0.94)	0.34 (-0.26, 0.93)	0.04 (-0.89, 0.97)	0.003 (-0.94, 0.95)
High (Tertile 3)	-0.03 (-0.55, 0.49)	-0.08 (-0.87, 0.20)	-0.45 (-1.32, 0.43)	-0.46 (-1.35, 0.43)	-0.61 (-1.22, -0.01)	-0.72 (-1.37, -0.06)	-1.68 (-2.66, -0.71)	-1.63 (-2.66, -0.59)
<i>P</i>	0.49	0.42	0.51	0.51	0.010	0.007	0.001	0.003
Screen time (min/d)								
≤15	ref	ref	ref	ref	ref	ref	ref	ref
>15 to <60	0.24 (-0.27, 0.76)	0.25 (-0.27, 0.77)	0.33 (-0.55, 1.20)	0.32 (-0.56, 1.19)	-0.03 (-0.62, 0.56)	-0.13 (-0.73, 0.47)	1.14 (0.19, 2.09)	1.15 (0.19, 2.10)
≥60	0.50 (0.00, 1.00)	0.51 (-0.01, 1.02)	0.74 (-0.11, 1.58)	0.77 (-0.10, 1.65)	-0.09 (-0.70, 0.52)	-0.21 (-0.84, 0.43)	0.74 (-0.24, 1.72)	0.80 (-0.21, 1.81)
<i>P</i>	0.052 ^f	0.045 ^f	0.089 ^f	0.083 ^f	0.96	0.81	0.058	0.057
Dietary patterns (scores)								
"Processed, fast-food"	0.06 (-0.15, 0.28)	0.02 (-0.21, 0.25)	0.06 (-0.31, 0.43)	0.06 (-0.33, 0.45)	0.15 (-0.11, 0.41)	0.18 (-0.09, 0.45)	0.12 (-0.29, 0.53)	0.17 (-0.26, 0.60)
<i>P</i>	0.570	0.873	0.766	0.764	0.250	0.188	0.575	0.428
"Guidelines"	-0.02 (-0.25, 0.20)	0.01 (-0.22, 0.24)	-0.12 (-0.50, 0.26)	-0.11 (-0.50, 0.27)	-0.23 (-0.48, 0.03)	-0.14 (-0.40, 0.13)	-0.50 (-0.91, -0.10)	-0.36 (-0.78, 0.06)
<i>P</i>	0.83	0.93	0.55	0.56	0.080	0.31	0.016	0.092

^aEnergy balance-related behaviors.

^bBody fat percentage.

^cScreen time, outdoor play and dietary patterns were included in three separate models, which adjusted for center (Poitiers or Nancy), baseline BMI and exact age at the age 5 clinical examination.

^dThe three EBRBs were included simultaneously along with the SEP variables (maternal education and household income). All models adjusted for center (Poitiers or Nancy), baseline BMI and exact age at the age 5 clinical examination.

^eRanges for outdoor play time categories. Low (Tertile 1): spring (9 min to 1 h 23 min), summer (23 min to 1 h 58 min), autumn (4 min to 1 h 12 min), winter (0 min to 50 min). Intermediate (Tertile 2): spring (1 h 24 min to 2 h 15 min), summer (1 h 59 min to 2 h 55 min), autumn (1 h 13 min to 1 h 58 min), winter (51 min to 1 r 18 min). High (Tertile 3): spring (2 h 16 min to 6 h), summer (2 h 56 min to 6 h 34 min), autumn (1 h 59 min to 6 h), winter (1 h 19 min to 4 h 09 min).

^f*P* trend assessed using the median value of each category of the variable.

Supplementary Table 2. Associations between EBRBs^a at age 2 and adiposity at age 5 in the sample with complete case data (values are linear regression coefficients (95% CI)). The EDEN mother-child cohort.

	Boys (n=411)		Girls (n=345)	
	%BF ^b		%BF ^b	
	Separate models ^c	Fully-adjusted model ^d	Separate models ^c	Fully-adjusted model ^d
Outdoor play time (min/d)^e				
Low (Tertile 1)	ref	ref	ref	ref
Intermediate (Tertile 2)	-0.25 (-0.79, 0.30)	-0.24 (-0.79, 0.31)	0.29 (-0.36, 0.94)	0.32 (-0.34, 0.98)
High (Tertile 3)	-0.14 (-0.68, 0.40)	-0.13 (-0.68, 0.42)	-1.00 (-1.67, -0.33)	-1.05 (-1.77, -0.34)
<i>P</i>	0.671	0.69	0.001	0.001
Screen time (min/d)				
≤15	ref	ref	ref	ref
>15 to <60	0.29 (-0.25, 0.83)	0.29 (-0.25, 0.84)	0.33 (-0.34, 1.01)	0.20 (-0.48, 0.88)
≥60	0.54 (0.03, 1.06)	0.60 (0.07, 1.13)	-0.04 (-0.73, 0.66)	-0.20 (-0.92, 0.52)
<i>P</i>	0.042 ^f	0.028 ^f	0.49	0.52
Dietary patterns (scores)				
"Processed, fast-food"	-0.0002 (-0.22, 0.22)	-0.01 (-0.24, 0.23)	0.11 (-0.18, 0.40)	0.15 (-0.51, 0.08)
<i>P</i>	0.999	0.951	0.444	0.317
"Guidelines"	-0.04 (-0.28, 0.19)	-0.03 (-0.27, 0.20)	-0.33 (-0.62, -0.05)	-0.21 (-1.36, -0.18)
<i>P</i>	0.72	0.79	0.023	0.16

^aEnergy balance-related behaviors.

^bBody fat percentage measured and calculated based on Goran's equation.²⁵

^cScreen time, outdoor play and dietary patterns were included in three separate models, which adjusted for center (Poitiers or Nancy), baseline BMI and exact age at the age 5 clinical examination.

^dThe three EBRBs were included simultaneously along with the SEP variables (maternal education and household income). All models adjusted for center (Poitiers or Nancy), baseline BMI and exact age at the age 5 clinical examination.

^eRanges for outdoor play time categories. Low (Tertile 1): spring (9 min to 1 h 23 min), summer (23 min to 1 h 58 min), autumn (4 min to 1 h 12 min), winter (0 min to 50 min). Intermediate (Tertile 2): spring (1 h 24 min to 2 h 15 min), summer (1 h 59 min to 2 h 55 min), autumn (1 h 13 min to 1 h 58 min), winter (51 min to 1 r 18 min). High (Tertile 3): spring (2 h 16 min to 6 h), summer (2 h 56 min to 6 h 34 min), autumn (1 h 59 min to 6 h), winter (1 h 19 min to 4 h 09 min).

^f*P* trend assessed using the median value of each category of the variable.

