The impact of familial, behavioural and psychosocial factors on the SES gradient for childhood overweight in Europe. A longitudinal study.

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Conflict of interest

The authors declare no conflict of interest.

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Abstract

BACKGROUND: In highly developed countries, childhood overweight as well as many overweight-related risk factors are negatively associated with socioeconomic status (SES).

OBJECTIVE: To investigate the longitudinal association between parental SES and childhood overweight, and to clarify whether familial, psychosocial or behavioural factors can explain any SES gradient.

METHODS: The IDEFICS baseline and follow-up surveys are used to investigate the longitudinal association between SES, familial, psychosocial and behavioural factors, and the prevalence of childhood overweight. 5,819 children (50.5 % boys, 49.5 % girls) were included.

RESULTS: The risk for being overweight after two years at follow-up in children who were non-overweight at baseline increases with a lower SES. For children who were initially overweight a lower parental SES carries a lower probability for a non-overweight weight status at follow-up. The effect of parental SES is only moderately attenuated by single familial, psychosocial or behavioural factors; however, it can be fully explained by their combined effect. Most influential of the investigated risk factors were feeding / eating practices, parental BMI, physical activity behaviour, and proportion of sedentary activity.

CONCLUSION: Prevention strategies for childhood overweight should focus on actual behaviours while acknowledging that these behaviours are more prevalent in lower SES families.

INTRODUCTION

Childhood overweight and obesity is associated with several somatic and psychosocial health-related factors later in life including higher prevalence of comorbidities [1-5], higher mortality rates [5], lower educational attainment [6], and developmental delays [7]. In highly developed countries, childhood overweight and obesity is negatively associated with parental socioeconomic status, i.e. overweight and obesity are more prevalent in children from families with low socioeconomic status [8, 9]. This negative SES gradient of childhood obesity indicates SES differences in energy-related behaviours and other psychosocial and familial risk factors, and it is often suggested that, where such a gradient is present, prevention measures should be specifically targeted at groups with low socioeconomic status[10]. Parental SES is not directly influencing a child's weight status. A multitude of behavioural factors within the family context has been explored. This is especially true for food-related behaviours[11-13], but also physical activity, sleep, media use[14, 15], and, albeit much rarer, psychosocial factors like e.g. lack of social networks have been shown to be associated with childhood obesity[16]. Although familial clustering of overweight and obesity is well established[17], the underlying causes are unknown. Familiality might be driven by genetics, a shared environment, social role modelling, or a combination thereof. Concise research on intermediate factors truly trying to explain the SES-obesity association of childhood obesity is scarce. One of the first attempts is the study of Goisis and colleagues who found that smoking during pregnancy, breastfeeding, early physical activity and dietary factors attenuates the income gradient of childhood overweight and obesity in a UK nationally representative cohort study.[18] However, more studies are needed to substantiate and further investigate these findings.

In a previous study, we analysed the cross-sectional association between socioeconomic status and overweight in the baseline survey of the IDEFICS study, a multi-centre European cohort study on diet- and lifestyle-related diseases in children [19]. We found a negative SES gradient in five of the eight IDEFICS survey centres (Belgium, Germany, Sweden, Estonia, Spain) and a zero association for the other three centres (Cyprus, Hungary, Italy), and we were able to link the presence and direction of the SES gradient to the degree of human development in the survey centres [19]. For the present paper, we will be investigating data from Belgium, Germany, Sweden, Estonia and Spain, since these five centres were shown to be homogenous with regard to their cross-sectional SES-overweight association, allowing pooling of the data.

The aim of the paper is two-fold: Firstly, we would like to investigate the impact of SES at baseline on childhood overweight / obesity at follow-up, and secondly, we would like to clarify whether familial, psychosocial and behavioural factors can explain any observed SES gradient.

METHODS

The IDEFICS study is a multi-centre population-based intervention study on childhood obesity that was carried out in selected regions of eight European countries comprising Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain and Sweden [20, 21]. The study was set up in pre- and primary school settings in control and intervention regions in each of these countries. Two major surveys (baseline (T0) and follow-up (T1)) were conducted in pre-schools and primary school classes (1st and 2nd grades at baseline). The baseline survey (September 2007 - May 2008) achieved an overall response rate of 51% (ranging from 41% to 66% in the single countries) and included 16,220 children aged 2 to 9 years. The follow-up survey (September 2009 - May 2010) was conducted two years later, and follow-up was organised such that the schools were visited during the same month as in the baseline survey. The follow-up survey at T1 reached an overall response rate of 68% (ranging from 49% to 84% in the single countries) and included 11,038 children aged 4 to 11 years. The general design of the IDEFICS study has been described elsewhere [20, 21].

The present study only includes 5,819 children (50.5 % boys, 49.5 % girls) from the centres in which a social gradient for overweight and obesity was established previously [19] i.e. from Belgium, Germany, Sweden, Estonia and Spain (N=6,497 children), for whom full information on the socioeconomic factors is available.

In both surveys, self-administered questionnaires have been filled in by the parents to gather information on the children's behaviours, parental attitudes and on the social environment of the children. The questionnaire was developed in English, translated to the respective languages and back translated to English to minimize any heterogeneity due to translation problems. Different language versions were available in the centres, and help was offered to those parents who felt they were not able to fill in the questionnaire by themselves. Moreover, anthropometric indicators were assessed. Weight was measured using a TANITA BC 420 SMA with the children being in a fasting status and wearing only underwear. Standing height was measured with the children's head in a Frankfort plane using a stadiometer SECA 225. As in the weight measurement, the children were wearing only underwear, all hair ornaments were removed.

In random subsamples of participating children, additional measurements have been carried out [20]. In the baseline survey, accelerometer measurements are available for 46% of the children, and 24-hour dietary recalls have been done in 67.5% of the children. The methodology of these measurements is described below.

Variables included in this study

Familial factors

For assessing the **socioeconomic status (SES)** of the children, we employed an additive SES indicator comprising a) equivalized household income (net income of the household equivalized to the number of household members using the OECD square root scale[22] and adjusted for median equivalized income of the respective country), b) parental educational level (maximum ISCED level of the parents[23]), and c) parental level of occupational position (maximum level of the parents using the European Socioeconomic Classification (ESeC), a modified Erikson-Goldthorpe-Portocarero Schema[24]). Cronbach's alpha for the three indicators was 0.67. We scaled the indicators to the interval [1,5] and summed them up. The SES score ranges from 3 (lowest SES) to 15 (highest SES). The construction of the indicator is described in detail in our previous work [19]. Baseline descriptive data of the SES indicator and its components in the five countries can be found in Supplementary Table A1.

Familial clustering of overweight and obesity was assessed using self-reported parental BMI. This was assessed in the questionnaire by the question "What is your height and weight? Please give information of parents with whom the child is living." Any numbers could be given as answers. The parental BMI was calculated as weight (kg) / squared height (m^2).

Parental feeding practices were assessed using an abridged version of the Pre-schooler Feeding Questionnaire (PFQ) developed by Baughcum and colleagues [25]. Items with highest factor loadings were selected relating to the five constructs that were hypothetically related to childhood overweight: *difficulty in child feeding* (it is a struggle to get child to eat, child has poor appetite; Cronbach's alpha 0.79), *concern about child overeating or being overweight* (have to stop child from eating too much, think about putting child on a diet to keep him/her from becoming overweight, worried child is eating too much; Cronbach's alpha 0.82), *pushing the child to eat more* (make child eat all the food on the plate, use food child likes as a way to get child to eat healthy; Cronbach's alpha 0.39), *structure during feeding interaction* (child watches TV at meals (reversed item), parent sits down with child during mealtime; Cronbach's alpha 0.43), and *age-inappropriate feeding* (parent feeds child her-/himself if child does not eat enough).

Psychological factors

Child's strengths and difficulties were assessed using the Strengths and Difficulties Questionnaire (SDQ) [26]. We assessed four of the five constructs of this questionnaire, namely *emotional difficulties* (Cronbach's alpha 0.63), *behavioural difficulties* (Cronbach's alpha 0.51), *difficulties with peers* (Cronbach's alpha 0.54) and *pro-social behaviour* (Cronbach's alpha 0.58).

Behavioural factors

The assessment of the child's **dietary behaviour** was based on parental report using one computer-assisted 24-hour dietary recall combined with assessment of all school meals of the particular day. Energy intake per day was calculated using country-specific information. We excluded under- and over-reporters from the data by using adapted Goldberg cut-offs. For the adaptation, Goldberg cutoff values[27] were recalculated using age- and sex-specific reference values [28]. For our analyses, we adjusted intake by dividing energy intake in calories by body mass in kg. Further details on the 24-hour dietary recall method employed in the IDEFICS study can be found elsewhere[29].

Child's **physical activity** behaviour was assessed by two different methods. In the parental questionnaire, the Outdoor Playtime Checklist (OPC) was employed [30]. From the OPC, we derived the typical outdoor playtime in hours per week of the child. This measure had high rank correlation with accelerometer measurements in a study in pre-school children in the U.S. [30]. Moreover, we asked for the time, the child typically spends in a sports club per week. This questionnaire information was complemented in a subsample of children by accelerometer measurements. The accelerometer device (ActiGraph, Pensacola, FL, USA) was placed on the right hip for three days (two weekdays, one weekend day) during waking hours. The sampling interval (epoch) was set at 15 seconds. Periods of 20 minutes or more consecutive zero counts were replaced by missing data before further analysis. Accelerometer measurements were considered to be valid if at least 3-day measurements with a minimum of 6 hours daily wearing time were available. Average wear time per day was 11.5 hours with a standard deviation of 1.18 hours in our sample. For the analyses, we used an averaged count per minute, and time spent in moderate or vigorous physical activity using the cut-offs of Evenson [31]. Additionally, the accelerometer data were used to calculate the percentage of time spent in sedentary activities of total accelerometer wear time. Child's **sedentary behaviour** was assessed via parental questionnaire. The hours per week the child typically spends using audio-visual media was assessed for weekdays and weekends separately and averaged over the week. As a second indicator, the number of different media devices in the child's bedroom was assessed using a closed question for the presence of five different types of media devices (TV, Computer, Internet connection, Video / DVD player and PlayStation / Game console).

Statistical methods

Body mass index (BMI) was calculated by dividing body mass in kilograms by squared body height in meters. BMI of children was categorized into International Obesity Task Force (IOTF) categories. For this purpose, we interpolated the given categories for continuous age as proposed by Cole et al. [32, 33] by using cubic splines, and categorized each child according to his / her continuous age (measurement day-birthday). For this paper, we built two categories for weight status: a) IOTF underweight and IOTF normal weight and b) IOTF overweight and IOTF obese.

To analyse the cross-sectional association of SES with the prevalence of overweight including obesity, age-, and study centre-adjusted prevalence odds ratios (OR) were calculated using logistic regression models.

For longitudinal effects, we analysed the impact of a putative risk factor at T0 on the change of weight status from T0 to T1. For this, hazard ratios (HR) were calculated employing Cox proportional hazard models with age at T1 as time-dependent covariate stratified by weight status at T0. We included the study centres as random effects. Thus, for each weight category we modelled the proportional effects of a factor on the risk of a change of this weight status at any given age independent of study centre. By this approach, we also eliminated country effects and possible intervention / control group effects. Using the same method, we estimated the HR for familial, psychosocial and behavioural factors on a change from IOTF underweight / IOTF normal weight at T0 to IOTF overweight / IOTF obesity at T1. We adjusted the proportional hazard models by SES to explore whether any SES gradients can be explained by the analysed risk factors. In a last step, we analysed the interplay of risk factors on change of weight status in a multivariate model (model I). To ensure that our results were not influenced by the choice of subsamples for accelerometer measurements and / or 24-hour dietary recall, we analysed a second multivariate model where these variable were excluded beforehand (model II). The model building for the two latter models was done using best subset selection to eliminate any possible bias introduced by automated model building procedures [34]. We reported the Wald statistics to judge the relative importance of the single factors[35]. Statistical significances are reported based on a significance level of $\alpha=0.05$.

All statistical analyses were done with SAS 9.2 (SAS Institute, Cary (NC), USA). The code is available from the authors upon request.

Ethical issues

All parents or legal guardians of the participating children gave written informed consent to data collection, examinations, collection of samples, subsequent analysis and storage of personal data and collected samples. Additionally, each child gave oral consent after being orally informed about the modules by a study nurse immediately before every examination using a simplified text. Study participants and their parents / legal guardians could consent to single components of the study while abstaining from others. All procedures were approved by the relevant local or national ethics committees by each of the five study centres, namely from the Ethics Committee of the University Hospital Ghent (Belgium), the Tallinn Medical Research Ethics Committee of the National Institutes for Health Development (Estonia), the Ethics Committee of the University Bremen (Germany), the Ethics Committee for Clinical Research of Aragon (Spain), and the Regional Ethical Review Board of Gothenburg (Sweden).

RESULTS

Basic characteristics of the 5,819 included children (2,931 boys, 2,888 girls) can be found in Table 1. The sample is well balanced regarding sex and country (ranging from 17.6% children from Germany to 24.2% children from Sweden). At T0, the prevalence of overweight and obesity was 12.3% (N=712). Two years later, at T1, this prevalence was 15.4% (N=896). The proportion of children with a change of weight status from T0 to T1 was 5.5% for underweight / normal weight at T0 to overweight / obesity at T1 (N=320; 6.3% of all underweight / normal weight children at T0) and 2.4% for a change from overweight / obesity at T0 to underweight / normal weight at T1 (N=140; 19.7% of all overweight / obese children at T0).

>>>> Include Table 1 about here

Table 2 shows the influence of SES on the weight status and on the change of weight status over time. SES is cross-sectionally associated with overweight / obesity at both time points. The higher the socioeconomic status, the lower the prevalence of overweight / obesity. The SES gradient is slightly steeper at T1 (POR: 0.903 95%CI: 0.882-0.925) than at T0 (POR: 0.919 95%CI: 0.896-0.944). SES is also protective against a change from underweight / normal weight at T0 to overweight / obesity at T1 (HR: 0.938; 95% CI: 0.905-0.974) and bears a higher chance for a change from overweight / obesity at T0 to underweight / normal weight at T1 (HR: 1.108; 95% CI 1.040-1.180).

>>>> Include Table 2 about here

The impact of single familial, psychosocial and behavioural factors on a change from IOTF underweight / IOTF normal weight at T0 to IOTF overweight / IOTF obesity at T1 and on the SES gradient of this change is displayed in Table 3. Statistically significant factors bearing a higher risk of changing to overweight / obesity are parental BMI (maternal BMI: HR: 1.104; 95% CI: 1.080-1.127; paternal BMI: HR: 1.108; 95% CI: 1.073-1.143), child's difficulties with peers (HR: 1.091; 95% CI: 1.015-1.173), parental concern for overweight or overeating (HR: 1.397; 95% CI: 1.281-1.523), age-inappropriate feeding (HR: 1.107; 95% CI: 1.041-1.178) and percentage of sedentary activity (HR: 1.065; 95% CI: 1.030-1.102). Statistically significant factors that protect against a change from normal weight to overweight / obesity are reported difficulties in feeding (HR: 0.899; 95% CI: 0.839-0.962), pushing the child to eat more (HR: 0.917; 95% CI: 0.847-0.994), physical activity as expressed in average accelerometer counts per minute (HR: 0.999; 95% CI: 0.998-1.000), daily MVPA in minutes (HR: 0.980; 95% CI: 0.972-0.987) or time spent in a sports club (HR: 0.805; 95% CI: 0.744-0.871). These results hold true also after adjustment by SES, which only explains a small part of the observed single effects (data not shown).

The SES gradient (raw HR for SES score: 0.938; 95% CI: 0.905-0.974) was most strongly attenuated (change towards the 1) by maternal BMI (adjusted HR for SES score: 0.960; 95% CI: 0.924-0.998), followed by the physical activity behaviour of the child and the child's strengths and difficulties.

>>>> Include Table 3 about here

The results of the multivariate models are displayed in Table 4. In model I, which was built using all investigated variables, three variables are protective of weight status change from T0 to T1. This concerns difficulties in feeding (HR: 0.772; 95% CI: 0.691-0.863) daily MVPA (HR: 0.968; 95% CI: 0.950-0.986) and time spent in a sports club (HR: 0.876; 95% CI: 0.787-0.976). A higher risk for weight status change from T0 to T1 carry parental BMI, age-inappropriate feeding (HR: 1.271; 95% CI: 1.151-1.404) and time spent in sedentary activities (HR: 1.119; 95% CI: 1.008-1.242). The hazard rate for accelerometer average count per minute, which was below 1 in the bivariate model (Table 3), takes a value of 1.006 (95% CI: 1.003-1.009) in the multivariate model.

Similar results were obtained in model II that does not include the variables that are only available in subsamples (accelerometer, 24-hour dietary recall). The HRs for SES were closer to unity and no longer statistically significant in both multivariate models (model I: HR for SES: 0.990; 95% CI: 0.934-1.050; model II: HR for SES: 0.986; 95% CI: 0.943-1.030).

>>>> Include Table 4 about here

DISCUSSION

This paper investigated the longitudinal association of familial, psychosocial and behavioural factors with childhood overweight and their interplay with socioeconomic status. In our study, a low parental SES in non-overweight children is a risk factor for the development of overweight or obesity two years later. This effect of parental SES is only moderately attenuated by single familial, psychosocial or behavioural factors; however, it can be fully explained by the concerted effect of such factors. Most influential factors for the development of overweight or obesity were feeding / eating practices, parental BMI, the child's physical activity behaviour, and time spent with audio-visual media, which was surprisingly protective in our study. For the child's strengths and difficulties single effects were found which were no longer significant in multivariate models. We also found that, vice versa, for children who were initially overweight a lower parental SES carried a lower probability to change back to a non-overweight weight status. For this case, the effect of most behavioural factors was simply reversed (see supplementary table A3).

The findings from our study confirm the results from the literature regarding the high and independent impact of parental BMI on the risk for overweight of the offspring [36]. Our results regarding the association of parental feeding practices with overweight in children differ from the result obtained in the original study by Baughcum and colleagues [25]. In their cross-sectional study, surprisingly only two of the five investigated factors were associated with childhood overweight. In our study, we found a longitudinal effect of four factors on the risk of a non-overweight child to develop overweight or obesity in one of the multivariate models. Two of the investigated factors, pushing the child to eat more as well as difficulties in child feeding, were not risk-elevating factors as hypothesized by Baughcum et al [25], but were protective. However, other longitudinal studies also found overeating to be positively and picky eating to be negatively associated with BMI [38]. Moreover, it is likely that the child's BMI is influencing parental feeding practice, thus confounding any cross-sectional associations [39]. Previous studies have linked children's strengths and difficulties with childhood overweight [40, 41]. However, effects have been found to be rather small. A longitudinal study showed that the effect of weight status on later Strengths and Difficulties Questionnaire (SDQ) score might be larger than the effect of SDQ score on weight change [42]. In our study, a higher score on the SDQ subscale peer problems in non-overweight children was statistically significant related to the risk of developing overweight at T1. Previous cross-sectional studies have repeatedly shown associations between objectively measured physical activity with weight status in children [43, 44]. However, the rare longitudinal studies show ambiguous results [45-47], and association might be bidirectional [48]. In our study, both average counts per minute (cpm) and daily MVPA in minutes contributed to the hazard of becoming overweight at T1 in children that were non-overweight at T0, and these variables were also able to explain part of the SES gradient of the overweight risk, albeit average cpm was a risk factor in the multivariate model. A possible explanation could be non-linearity in either the MVPA-obesity association or proportion of sedentary activities-obesity association, or even both. We also included questionnaire data on physical activity in our models Time spent in a sports club showed a protective effect in addition to the accelerometer-derived data. This variable was the one with the second highest influence in the model without accelerometer data indicating that this information might be valuable in studies where collection of objective physical activity data is not feasible. We found no effect of time spent outdoors on weight status. The proportion of sedentary activity derived from accelerometer data was a risk factor for obesity in the bivariate as well as the multivariate model. This is very similar to the results of Mitchell and colleagues [49] , however the raw effect (Table 3) does not disappear when adjusted for physical activity and other confounders (Table 4).

The current study has several limitations. First of all, the data of the study was collected in a multi-centre intervention study [50] which could have potentially influenced weight status at follow-up. For the sake of statistical power, we decided to include the intervention regions in our study, and we statistically controlled for a possible effect by including study centre as random effect. Secondly, we cannot rule out selection bias due to nonresponse. In the

IDEFICS study, we observed selection with regard to weight status at baseline [51]. This should not influence our results, since we restricted ourselves to underweight and normal weight children. A further selection bias might have been introduced within this paper due to the number of missing values, and measurements only performed in sub-samples. This holds especially for the multivariate models presented in Table 4. Although the subsamples were selected randomly, the parents or children could refuse any single procedure of the surveys. We found only little differences in SES scores, sex or age of the children included in Model I (mean SES score = 10.61, % girls: 47.5, mean age = 7.81 years) versus Model II (mean SES score = 10.69, % girls: 47.7, mean age = 7.71 years), compared to a mean SES score of 10.49 (% girls: 48.7, mean age = 7.75 years) in the total group of normal weights at T0. The largest difference we found stems from the heterogeneous proportion of accelerometer measurements in IDEFICS between countries (Belgium: 29.2%, Estonia: 65.3%, Germany: 53.4%, Spain: 84.7%, Sweden: 32.4%). Since we accounted for study centre in the models, and moreover the HR estimate for accelerometer counts was stable also after removing the random effect for study centre, we do not believe that this impacts our results.

With the exception of the accelerometer measurements all of the investigated familial, psychosocial and behavioural factors including the social indicators of the study were gathered by parental self-report, which might have influenced the results. Most of the derived variables stem from well-known validated instruments [25, 30, 52-54], however the reliability as measured by Cronbach's alpha for some of the sub-scales is very low. We only included multi-scales that had similar Cronbach's alpha values in our data as those published by the scale authors or by other previous papers. Nevertheless, especially two of the feeding / eating practices (pushing the child to eat more, structure during meals) have extremely low values and should be interpreted with caution. Both sub-scales did not enter the multivariate models. While SES is often used as a putative confounder in validation studies, the validity of self-reported social indicators themselves is largely understudied. The energy intake of the child assessed by 24-hour dietary recall is only derived from a single day of reporting. Although the validity of the instrument in general appears to be high [55], the restriction to a single day of reporting implies that the variable we used, energy intake, is only valid on group level, but not necessarily on individual level [56]. This very well might explain the lack of association between energy intake and risk of overweight in our study.

A particular strength of the study is the fact that the data was gathered in a standardized way in all participating centres. The BMI measurement followed a strictly standardized procedure and was taken with the children being in a fasting status. Children not in fasting status were generally excluded from the database, and we had only 70 (1.2%) documented cases were very small amounts (like e.g. a cookie) had been eaten in the last 8 hours prior to the examination. Quality control procedures, like e.g. central trainings and external site visits, ensured comparability of measurements across centres. Height and weight measurements in the IDEFICS survey centres have an intra- and inter-observer reliability of more than 99% in each of the study centres [57]. Moreover, the questionnaire data on physical activity behaviour is supplemented by objective data from accelerometer measurements in a subsample of children. In a separate validation study, the accelerometer measurements (counts per minutes) in small children show a high correlation with energy expenditure derived by doubly labelled water measurements [58].

Another advantage of our study is the strict longitudinal approach. We are able to disentangle cause and effect and rule out any reverse causation that might otherwise have biased the results.

In our study, the association of SES and childhood overweight was fully explained by familial, psychological and behavioural factors. This result suggests that prevention measures do not inevitably have to target specific social groups. Although, it is true that obesity-prone behaviour is more prevalent in low SES groups and that it takes tailored efforts in terms of communication and measures to be successful in these groups [59, 60], it has to be kept in mind that there is not a one-to-one association between the here investigated factors and SES group. Moreover, specific attention to one group might lead to stigmatization and thus may have unwanted side-effects [61]. An alternative intervention approach would be targeting specific behaviours, e.g. age-inappropriate feeding, in the total population working with a broad choice of culturally sensitive measures through different channels.

CONFLICT OF INTERESTS

We certify that there is no conflict of interest with any financial organisation regarding the material discussed in the manuscript.

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Table 1: Basic characteristics of included children

	Boys N=2,931	Girls N=2,888	All N=5,819
Age at T1: Mean (SD)	7.77 (1.87)	7.87 (1.86)	7.82 (1.87)
Country in %			
Belgium	18.1	18.5	18.3
Estonia	20.2	21.8	21.0
Germany	18.0	17.1	17.6
Spain	19.1	18.7	18.9
Sweden	24.6	23.8	24.2
BMI category at T1 (IOTF) in %			
Underweight	10.5	10.4	10.5
Normal weight	75.2	73.0	74.1
Overweight	11.2	13.4	12.3
Obesity	3.1	3.2	3.1
BMI category at T0 (IOTF) in %			
Underweight	11.3	10.3	10.8
Normal weight	78.1	75.8	77.0
Overweight	7.6	10.7	9.2
Obesity	3.0	3.2	3.1
Change of BMI category (IOTF) T0 -> T1 in %			
Underweight / Normal weight -> Overweight / Obesity	5.7	5.4	5.5
Overweight / Obesity -> Underweight / Normal weight	2.0	2.7	2.4
SES score at T0: Mean (SD)	10.4 (2.9)	10.4 (3.0)	10.4 (2.9)

Table 2: Influence of socio-economic status (SES) at T0 on IOTF weight status and on change of IOTF weight status over time

	Age-, and study centre- adjusted prevalence odds ratios		
	POR	**95% CI**	**N**
Overweight / obesity at T0	0.919	0.896-0.944	5,819
Overweight / obesity at T1	0.903	0.882-0.925	5,819
	Hazard rates with age as time-dependent variable and study centre as random effect		
	HR	**95% CI**	**N**
Change from underweight / normal weight at T0 to overweight / obesity at T1	0.938	0.905-0.974	4,908
Change from overweight / obesity at T0 to underweight / normal weight at T1	1.108	1.040-1.180	708

Table 3: Influence of single factors in normal weight children at T0 on the risk of overweight / obesity at T1 and on SES score gradient

Raw and SES-adjusted hazard rates (HR) and 95% confidence limits (95% CL)

	HR for investigated factors		HR for SES score	
	Unadjusted models		Risk factor-adjusted models	
	HR	**95% CL**	**HR**	**95% CL**
Unadjusted SES score			**0.938**	**0.905-0.974**
Familial clustering at T0				
BMI Mother in kg/m^2	**1.104**	**1.080-1.127**	**0.960**	**0.924-0.998**
BMI Father in kg/m^2	**1.108**	**1.073-1.143**	**0.927**	**0.891-0.965**
Child's strengths and difficulties at T0				
Emotional difficulties	0.967	0.907-1.031	**0.933**	**0.899-0.968**
Behavioural difficulties	1.067	0.977-1.166	**0.940**	**0.906-0.976**
Difficulties with peers	**1.091**	**1.015-1.173**	**0.948**	**0.911-0.987**
Pro-social behaviour	0.923	0.852-1.000	**0.942**	**0.908-0.978**
Feeding / Eating practices at T0				
Difficulties in feeding	**0.899**	**0.839-0.962**	**0.938**	**0.903-0.973**
Concern for overweight or overeating	**1.397**	**1.281-1.523**	**0.936**	**0.902-0.971**
Pushing the child to eat more	**0.917**	**0.847-0.994**	**0.932**	**0.897-0.967**
Structure during meals	0.949	0.876-1.029	**0.937**	**0.903-0.973**
Age-inappropriate feeding	**1.107**	**1.041-1.178**	**0.942**	**0.907-0.977**
Child's dietary behaviour at T0				
24 HDR: Intake in kcal per kg body mass	0.997	0.988-1.007	**0.935**	**0.885-0.989**
Child's physical activity behaviour at T0				
Accelerometer: average counts per minute	**0.999**	**0.998-1.000**	0.954	0.910-1.001
Accelerometer: daily MVPA in minutes	**0.980**	**0.972-0.987**	0.955	0.911-1.001
Outdoor playtime (h/week)	1.020	0.940-1.107	**0.948**	**0.910-0.986**
Time in sports club (h/week)	**0.805**	**0.744-0.871**	**0.957**	**0.922-0.984**
Child's sedentary behaviour at T0				

	HR for investigated factors		HR for SES score	
	Unadjusted models		Risk factor-adjusted models	
	HR	95% CL	HR	95% CL
Accelerometer: % spent in sedentary activity	**1.065**	**1.030-1.102**	0.954	0.910-1.000
Audio-visual media time (h/week)	0.993	0.976-1.010	**0.937**	**0.902-0.974**
Number of media devices in bedroom	0.997	0.851-1.106	**0.936**	**0.902-0.972**

Bold numbers indicate statistical significance at α=0.05.

All hazard rates are modelled with age as time-dependent variable and study centre as random effect.

Table 4: Influence of combined factors in normal weight children at T0 on the risk of overweight / obesity at T1 and on SES score gradient

Multivariate models with (Model I) and without (Model II) accelerometer data: Hazard rates (HR) and 95% confidence limits (95% CL)

	Model I			**Model II**		
	HR	**95% CL**	**Wald statistics**	**HR**	**95% CL**	**Wald statistics**
Familial clustering at T0						
BMI Mother	**1.066**	**1.030-1.104**	13.377	**1.086**	**1.059-1.114**	41.302
BMI Father	**1.078**	**1.030-1.129**	10.303	**1.079**	**1.043-1.116**	7.298
Feeding / Eating practices at T0						
Difficulties in feeding	**0.772**	**0.691-0.863**	20.834	**0.804**	**0.738-0.876**	24.714
Age-inappropriate feeding	**1.271**	**1.151-1.404**	22.462	**1.202**	**1.113-1.299**	26.127
Child's physical activity behaviour at T0						
Accelerometer: Average count per minute	**1.006**	**1.003-1.009**	18.813	-	-	-
Accelerometer: Daily MVPA in minutes	**0.968**	**0.950-0.986**	11.881	-	-	-
Time in sports club (h/week)	**0.876**	**0.787-0.976**	5.726	**0.812**	**0.743-0.887**	21.290
Child's sedentary behaviour at T0						
Accelerometer: % spent in sedentary activity	**1.119**	**1.008-1.242**	4.438	-	-	-
SES	0.990	0.934-1.050	0.113	0.986	0.943-1.030	0.396
% Missing		**57.6**			**16.9**	
n included in the model		**2,179**			**4,490**	

Variables not entering any of the models: Emotional difficulties at T0, Behavioural difficulties at T0, Difficulties with peers at T0, Prosocial behaviour at T0, Concern for overweight or overeating at T0, Pushing the child to eat more at T0, Structure during meals at T0, Intake in kcal per kg body mass at T0, Outdoor playtime at T0, Audio-visual media time at T0, Number of media devices in bedroom at T0. The variable SES was forced into the model.

Bold numbers indicate statistical significance at $\alpha=0.05$.

All hazard rates are modelled with age as time-dependent variable and study centre as random effect.

Table A1: Basic characteristics of included children: SES indicators

Country	**Belgium**	**Estonia**	**Germany**	**Spain**	**Sweden**
Sample size	**N=1,520**	**N=1,415**	**N=1,669**	**N=1,507**	**N=1,619**
Age in yrs: mean (std)	5.6 (1.6)	5.9 (2.1)	6.1 (1.8)	5.7 (1.8)	5.7 (2.0)
Parental education§					
ISCED 0-2 in %	3.2	1.8	35.4	7.8	1.2
ISCED 3-4 in %	49.1	83.3	48.8	38.1	27.7
ISCED 5-6 in %	47.7	14.9	15.8	54.1	71.0
Parental occupation§					
Lower technical & routine occ. in %	11.4	18.2	23.9	11.0	11.0
Lower services & sales occ. in %	16.6	6.6	12.0	15.2	8.5
Small employers & self-employed in %	13.4	10.0	6.2	15.7	8.4
Intermediate employee in %	26.8	23.8	34.8	25.0	25.3
Salariat in %	31.0	41.3	20.9	31.7	45.5
Equivalized yearly household income					
In Euros: mean (std)	19,147 (6,898)	8,218 (4,819)	14,049 (6,789)	15,689 (6,159)	23,145 (7,301)
In PPS: mean (std)	18,685 (6,732)	11,206 (6,571)	13,817 (6,677)	16,900 (6,634)	20,024 (6,316)
SES					
Indicator: mean (std)	10.54 (2.83)	10.16 (2.84)	9.10 (3.38)	10.28 (2.88)	11.04 (2.79)

§Maximum of both parents

PPS: Purchasing power standards (PPS) were obtained by dividing the original value by the respective country-specific purchasing power parity of 2008.

Table A2: Correlation of obesity-prone behaviours with SES score at T0

Results from non-parametric correlation analysis: Spearman's rho (rho) and p-values

	rho	p-Value	Missing value for risk factor
Familial clustering at T0			
BMI Mother	**-0.154**	<0.001	2.4%
BMI Father	**-0.091**	<0.001	10.8%
Child's strengths and difficulties at T0			
Emotional difficulties	**-0.118**	<0.001	2.1%
Behavioural difficulties	**-0.095**	<0.001	1.7%
Difficulties with peers	**-0.164**	<0.001	2.1%
Pro-social behaviour	**0.054**	<0.001	2.2%
Feeding / Eating practices at T0			
Difficulties in feeding	-0.008	0.522	2.0%
Concern for overweight or overeating	**-0.036**	<0.001	2.1%
Pushing the child to eat more	**-0.042**	<0.001	2.7%
Structure during meals	**-0.146**	<0.001	2.0%
Age-inappropriate feeding	**-0.027**	0.040	1.6%
Child's dietary behaviour at T0			
24 HDR: Intake in kcal per kg body mass	0.033	0.075	51.1%
Child's physical activity behaviour at T0			
Accelerometer: average counts per second	-0.003	0.854	48.6%
Accelerometer: Daily MVPA in minutes	0.014	0.442	48.6%
Outdoor playtime (h/week)	**-0.122**	<0.001	5.0%
Time in sports club (h/week)	**0.122**	<0.001	3.0%
Child's sedentary behaviour at T0			
Accelerometer: % spent in sedentary activity	-0.004	0.816	48.7%
Audio-visual media time (h/week)	**-0.183**	<0.001	2.3%
Number of media devices in bedroom	**-0.168**	<0.001	1.0%

Bold numbers indicate statistical significance at α=0.05.

Table A3: Influence of single factors in overweight / obese children at T0 on the risk of normal weight at T1

Raw and SES-adjusted hazard rates (HR) and 95% confidence limits (95% CL)

	HR for investigated factors		HR for SES score	
	Unadjusted models		Risk-factor adjusted models	
	HR	95% CL	HR	95% CL
Unadjusted SES score				
			1.108	**1.040-1.180**
Familial clustering at T0				
BMI Mother in kg/m²	**0.929**	**0.889-0.972**	**1.079**	**1.009-1.152**
BMI Father in kg/m²	**0.915**	**0.867-0.966**	**1.134**	**1.061-1.213**
Child's strengths and difficulties at T0				
Emotional difficulties	0.937	0.846-1.038	**1.099**	**1.031-1.172**
Behavioural difficulties	1.118	0.962-1.299	**1.112**	**1.044-1.185**
Difficulties with peers	0.937	0.823-1.067	1.069	0.996-1.147
Pro-social behaviour	**0.857**	**0.754-0.966**	**1.105**	**1.036-1.178**
Feeding / Eating practices at T0				
Difficulties in feeding	**1.241**	**1.125-1.370**	**1.112**	**1.043-1.185**
Concern for overweight or overeating	**0.707**	**0.630-0.793**	**1.100**	**1.032-1.173**
Pushing the child to eat more	**1.281**	**1.116-1.470**	**1.100**	**1.032-1.173**
Structure during meals	**1.160**	**1.022-1.317**	**1.102**	**1.034-1.174**
Age-inappropriate feeding	**1.497**	**1.359-1.649**	**1.118**	**1.048-1.194**
Child's dietary behaviour at T0				
24 HDR: Intake in kcal per kg body mass	**1.034**	**1.019-1.049**	**1.158**	**1.043-1.285**
Child's physical activity behaviour at T0				
Accelerometer: average counts per minute	**1.002**	**1.000-1.003**	**1.124**	**1.025-1.232**
Accelerometer: daily MVPA in minutes	0.999	0.987-1.012	**1.123**	**1.025-1.230**
Outdoor playtime (h/week)	1.013	0.875-1.174	**1.129**	**1.051-1.213**
Time in sports club (h/week)	**0.757**	**0.659-0.868**	**1.162**	**1.085-1.243**

	HR for investigated factors		HR for SES score	
	Unadjusted models		Risk-factor adjusted models	
	HR	**95% CL**	**HR**	**95% CL**
Child's sedentary behaviour at T0				
Accelerometer: % spent in sedentary activity	0.975	0.927-1.026	**1.123**	**1.025-1.231**
Audio-visual media time (h/week)	**0.927**	**0.899-0.957**	**1.076**	**1.008-1.148**
Number of media devices in bedroom	**0.760**	**0.635-0.909**	**1.095**	**1.028-1.168**

Bold numbers indicate statistical significance at α=0.05.

All hazard rates are modelled with age as time-dependent variable and study centre as random effect.