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Science & Technology in childhood Obesity Policy

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Start date of project: 1st June 2018 Duration: 48 months

D2.5: Obesity in children and adolescents by socioeconomic status

Finnish Institute for Health and Welfare, University of Turin

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Dissemination Level

PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Abbreviation	Definition
Avohilmo	Finnish Register of Primary Health Care Visits
BMI	Body Mass Index
COSI	Childhood Overweight Surveillance Initiative
EHII	Equivalized Household Income Indicator
EUSILC	European Union statistics on income and living conditions
IOTF	International Obesity Task Force
NCD	Non-Communicable Disease
NCD-RisC	NCD Risk Factor Collaboration
OECD	Organisation for Economic Co-operation and Development
SEP	Socioeconomic position
THL	Finnish Institute for Health and Welfare
WHO	World Health Organization

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Science and Technology in childhood Obesity Policy

1. Executive summary

The main aim of the WP2 in the STOP project was to measure childhood obesity, its trends, socioeconomic patterns (SEP) and geographical variations. The task 2.5 concentrated on socioeconomic patterns. The main aim was to identify European data sources including information on both childhood obesity measures as well as socioeconomic indicators, collect feasible data sets and perform analyses on childhood obesity stratified by SEP.

In the action plan of the STOP project, the task 2.5 of WP2 is described as follows: "NCD-RisC European collaborators will re-analyse the data available to them to generate mean body mass index (BMI) and prevalence of a comprehensive set of BMI categories ranging from underweight to obesity, stratified by age and sex, as well as by SEP. SEP strata will be generated based on all the available measures, including education, occupation, and income."

Information on the weight and height of children, especially under 5, is not routinely available from population-based surveys in Europe. The World Health Organization (WHO) European region's Childhood Overweight Surveillance Initiative (COSI) has collected data on children's height and weight, and also on socioeconomic factors of children aged 6-9 years. COSI network is continuously analysing and reporting the prevalence data by countries and recently has also carried out analyses stratified by socioeconomic status of the family. In STOP WP2 task 2.5 we concentrated on examining the other possible data sources in Europe and especially those including data of children below school age.

As it was observed that the availability of European data sources including information on children's weight and height together with SEP indicators was extremely scarce and the use of SEP indicators was highly heterogeneous, we carried out a scoping review on recent research on childhood obesity and SEP in Europe. There were two main aims: 1) to figure out the used approaches and SEP indicators to get better understanding on the availability of information on obesity by SEP and the similarities and differences in how SEP of children has been measured and 2) what associations between SEP and obesity has been observed.

In addition, the task leader, Finnish Institute for Health and Welfare, had a possibility to collect an extensive register-based dataset on children's weight and height and to link that on an individual level to a large set of different family's socioeconomic indicators available from national administrative registers. This data was used to explore more thoroughly the contribution of different SEP indicators on differences in childhood obesity among children aged 2 to 17 years of age.

In collaboration with Univesrity of Turin (Universita degli Studi di Torino), Italy, the large Finnish register-based data set was used to validate the household income prediction model developed by Pizzi et al. within the EU project LifeCycle in collaboration with STOP based on EUSILC data. Using the SEP indicators from the Finnish register data, we analysed how well the developed household income prediction model predicted the household income in the Finnish settings compared with the actual income indicator available from the Finnish registers.

All these components of the WP2 task 2.5 are described in more detail below and publications, data descriptions and presentations on analysis results are attached to the report.

The leader for the WP2 task 2.5 is professor Tiina Laatikainen (Finnish Institute for Health and Welfare, THL).

Science and Technology in childhood Obesity Policy

2. Socioeconomic position and the anthropometric data of children in four European countries

One of the tasks in WP2 was to figure out the availability of information on socioeconomic status (SEP) and the anthropometric data of children in Europe, analyse the association of different SEP indicators and overweight and obesity in children as well as to model and create mean BMI and BMI category trends in European countries also by SEP.

The World Health Organization (WHO) European region's Childhood Overweight Surveillance Initiative (COSI) has an extensive cross-sectional data on childhood overweight and obesity including SEP indicators of children reported by parents, including more than 120 000 children aged 6-9 in 24 countries. The COSI results on associations between overweight/obesity and SEP indicators (parental education, parental employment status, and family-perceived wealth) have already been reported (Buoncristiano M et al. 2021) and thus it was agreed in the STOP project that other potential data sets that could be used in analyses on childhood overweight/obesity and socioeconomic status of family would be identified.

Methods and material

The NCD-RisC database which is administered by a network of health scientists around the world and provides rigorous and timely data on major risk factors for NCDs contains very little SEP data on children, so THL asked the STOP partners to complete a questionnaire (Attachment 1) on the availability of data combining anthropometric and SES in children in their country and to express their willingness to be part of the pooled analyses. The request was also distributed by the STOP coordination team to the OECD networks on childhood obesity.

The questionnaire included the following questions: data source, age groups represented in the data, year(s) of data collection, area/areas of the data collection (eg. national, regional), availability of anthropometric data (weight, height, BMI, waist circumference), cut off points/criteria for overweight and obesity (WHO, IOTF, other), specific permits and requirements for data use in SES analyses and requirements (eg. anonymization of the data) and the possibility to disclose data for pooled analyses.

Based on the questionnaire and assessment of the data availability, THL received answers from Estonia, Romania, Slovenia, Switzerland, Belgium, and Croatia (Attachment 2). In addition, through other contacts possible data sources were identified from France and UK and the responsible researchers or institutions were contacted by the STOP project. The data from France did not fulfil the data requirements as weight and height were partly self-reported.

According to the received information the data available was very scarce. Based on the information received through the questionnaire data from Estonia and Belgium were chosen for analyses, because age groups, SEP variables and their categories were more comparable than the data from Croatia, Romania, Switzerland and Slovenia. In Finland, the data on children's height and weight and SEP indicators was available from administrative registers after a separate permission process. From UK, the Health Survey for England 2018 data was retrieved through the data portal.

SEP variables which were used for analyses were: highest family education and income. Children were divided into four age groups by gender: 2-4- (Belgium 3-4), 5-10- (Belgium 5-9), 11-15- and 16–17-year-olds boys and girls. Based on low number of cases in older age groups, in some analyses also combined age group 11-17 was used.

The highest family education was defined based on the education level of mother and father. It was categorized into two categories: low and medium/high. Family income was classified into three categories: low, middle, and high. There were no data on income of family from Belgium. Income and education were analysed using age grouping.

Obesity comparisons between Estonia, Belgium, UK and Finland on gender, age, highest family education and family income groups were done using logistic regression analysis. Data from Estonia, Belgium, UK and Finland for boys and girls in two to four age groups were analysed. Age groups were 3-4 years and 5-9 years for Belgium. These two youngest age groups were 2-4 years and 5-10 years for other countries. For Estonia, UK, and Finland two oldest age groups were 11-15 years and 16-17 years. Differences of family income were analysed in three (low, middle and high) tertile groups and differences of highest family education were analysed in two groups (combined low and medium education and high education). There was no family income data available for Belgium. Analysis of differences for family income and highest family education were done taking into account age in three groups (2-10 years, 11-15 years and 16-17 years) or in two groups (2-10 years and 11-17 years) and in Belgium only in one age group (3-9 years).

Analyses by country were done by fitting five alternative models:

(1) Full model with age-gender -interaction
(2) No interaction, just main effects of age group and gender
(3) Only main effect of age
(4) Only main effect of sex
(5) Only constant effect

Results

Based on likelihood ratio test comparing nested models best fitting logistic model for Belgium was model 1, for Estonia model 2, for UK model 3 and for Finland model 1. So, country data had very different obesity prevalence structure based on age and gender groups. Based on this, final comparisons were done analysing the age and gender -adjusted prevalences.

Based on results of age and gender -adjusted prevalences (average marginal prevalences based on full logistic regression model) and differences between them, UK had highest obesity prevalence (15.3%) (Figure 1, Table 1). For other countries these prevalences were significantly (p-value <0.001) lower (8.5%-8.8%). No significant differences in age and gender -adjusted prevalences were found in Belgium, Estonia and Finland (p-value= 0.763 or higher) (Table 2).

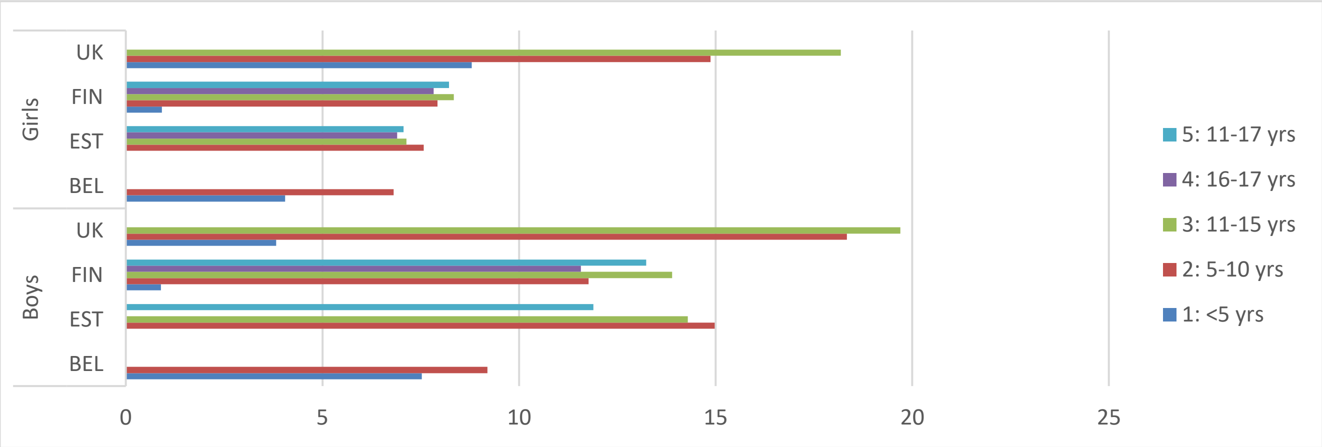

Figure 1. *Obesity prevalence in children in four European countries by gender and age group, %*

Table 1. *Available data and prevalence of obesity*

		Boys			Girls		
	Age group	N	Number of children with obesity	Percent	N	Number of children with obesity	Percent
UK	2-4	131	5	3,82	125	11	8,80
	5-10	289	53	18,34	343	51	14,87
	11-15	269	53	19,70	242	44	18,18
Estonia	2-4	0			0		
	5-10	227	34	14,98	264	20	7,58
	11-15	105	15	14,29	112	8	7,14
	16-17	38	<4		58	4	6,90
	11-17	143	17	11,89	170	12	7,06
Belgium	3-4	146	11	7,53	148	6	4,05
	5-9	402	37	9,20	367	25	6,81
	11-15	0			0		
	16-17	0			0		
Finland	2-4	19030	170	0,89	18078	166	0,92
	5-10	41279	4860	11,77	39776	3154	7,93
	11-15	28507	3961	13,89	27722	2312	8,34
	16-17	11360	1314	11,57	8616	675	7,83
	11-17	39867	5275	13,23	36338	2987	8,22

Table 2. Country differences in obesity prevalence

		Obesity prevalence difference	s.e.	p-value
Boys, <5yrs	BEL-UK	3,72	2,75	0.177
	FIN-UK	-2,92	1,68	0.081
	FIN-BEL	-6,64	2,19	0.002
Boys, 5-10/5-9yrs	EST-UK	-3,36	3,29	0.306
	BEL-UK	-9,14	2,69	0.001
	FIN-UK	-6,57	2,28	0.004
	BEL-EST	-5,77	2,77	0.037
	FIN-EST	-3,20	2,37	0.177
	FIN-BEL	2,57	1,45	0.076
Boys, 11-15yrs	EST-UK	-5,42	4,19	0.196
	FIN-UK	-5,81	2,43	0.017
	FIN-EST	-0,39	3,42	0.909
Boys, 16-17yrs	FIN-EST			
Boys, 11-17yrs	FIN-EST	1,34	2,71	0.620
Girls, <5yrs	BEL-UK	-4,75	3,01	0.115
	FIN-UK	-7,88	2,53	0.002
	FIN-BEL	-3,14	1,62	0.053
Girls, 5-10/5-9yrs	EST-UK	-7,29	2,52	0.004
	BEL-UK	-8,06	2,33	<0.001
	FIN-UK	-6,94	1,93	<0.001
	BEL-EST	-0,76	2,09	0.715
	FIN-EST	0,35	1,63	0.829
	FIN-BEL	1,12	1,32	0.398
Girls, 11-15yrs	EST-UK	-11,04	3,47	<0.001
	FIN-UK	-9,84	2,48	<0.001
	FIN-EST	1,20	2,44	0.624
Girls, 16-17yrs	FIN-EST	0,94	3,34	0.779
Girls, 11-17yrs	FIN-EST	1,16	1,97	0.556

Highest family education, gender, and age group analysis of obesity

Based on results of age – gender -adjusted differences between combined low and medium and high education group between countries, combined low and medium education group had 5.1% - 7.5% higher obesity prevalence (p-value=0.041 or lower). There were no significant differences between countries (Table 3).

Table 3. *Obesity by the highest level of parents' education*

			Boys			Girls		
	Age group	Highest education	N	Number of children with obesity	%	N	Number of children with obesity	%
United Kingdom	2-10	High	199	28	14,07	222	19	8,56
	2-10	Low/medium	220	30	13,64	244	43	17,62
	11-15	High	100	17	17,00	108	14	12,96
	11-15	Low/medium	165	36	21,82	132	29	21,97
	16-17	High	0			0		
	16-17	Low/medium	0			0		
Estonia	5-10	High	120	13	10,83	138	11	7,97
	5-10	Low/medium	107	21	19,63	124	8	6,45
	11-15	High	49	5	10,20	44	<4	
	11-15	Low/medium	56	10	17,86	66	7	10,61
	16-17	High	16	<4		23	<4	
	16-17	Low/medium	21	<4		32	<4	
	11-17	High	65	5	7,69	67	<4	
	11-17	Low/medium	77	12	15,58	98	10	10,20
Belgium	3-9	High	346	22	6,36	325	11	3,38
	3-9	Low/medium	189	23	12,17	185	19	10,27
Finland	2-10	High	35501	2274	6,41	34314	1443	4,21
	2-10	Low/medium	24808	2756	11,11	23540	1877	7,97
	11-15	High	16787	1765	10,51	16322	988	6,05
	11-15	Low/medium	11720	2196	18,74	11400	1324	11,61
	16-17	High	6799	585	8,60	5090	298	5,85
	16-17	Low/medium	4561	729	15,98	3526	377	10,69
	11-17	High	23586	2350	9,96	21412	1286	6,01
	11-17	Low/medium	16281	2925	17,97	14926	1791	11,40

Family income, gender, and age group analysis of obesity

Based on results of age – gender -adjusted linear effects of family income group between countries, higher income group (middle compared to low group or high compared to middle group) had 2.1%-2.8% lower obesity prevalence. This effect was significant (p-value=0.020 or lower) for UK (-2.8%) and for Finland (-2.1%). For Estonia effect was -2.5 and not statistically significant (p-value= 0.070), which however is most likely due to small sample size (Table 4).

Additional analyses: country comparisons by age – gender -groups were done, but no clear conclusions could be drawn based on these results.

Discussion

The availability of other than COSI data on children's height, weight and socioeconomic indicators in Europe was very scarce. Only few studies that have recently measured these indicators were available. However, none of those had repeated data collections. Any trend analyses were thus not possible. The amount of SEP indicators was also limited. Only a few studies had more than one SEP indicator measured.

The analyses carried out in a few countries where data was available (UK, Finland, Estonia and Belgium) showed that the highest obesity prevalence in children was found in UK. Prevalences did not significantly differ in other studied countries. Children with parents having low or medium level education were more likely obese compared with children having highly educated parents in all studied countries. There was no significant difference between countries. Also, family income was associated with obesity in childhood. In UK and Finland there were statistically significant differences according to family income. In Estonia, the association was not statistically significant, but was most likely affected by the small sample size. Income information was not available in Belgium.

Table 4. *Income effects on child obesity*

			Boys			Girls		
	Age group	Income	N	Obesity cases	%	N	Obesity cases	%
UK	2-10	low	131	21	16.03	159	27	16.98
	2-10	middle	119	11	9.24	122	16	13.11
	2-10	high	116	14	12.07	130	11	8.46
	11-15	low	131	28	21.37	89	17	19.10
	11-15	middle	52	12	23.08	61	12	19.67
	11-15	high	57	10	17.54	61	7	11.48
	16-17	low			NA			NA
	16-17	middle			NA			NA
	16-17	high			NA			NA
EST	5-10	low	69	11	15.94	87	6	6.90
	5-10	middle	57	13	22.81	65	7	10.77
	5-10	high	92	8	8.70	99	7	7.07
	11-15	low	37	8	21.62	50	5	10.00
	11-15	middle	29	<4		24	<4	
	11-15	high	31	<4		29	<4	
	16-17	low	11	<4		20	<4	
	16-17	middle	12	<4		14	<4	
	16-17	high	10	<4		12	<4	
	11-17	low	48	9	18.75	70	7	10.00
	11-17	middle	41	4	9.76	38	<4	
	11-17	high	41	<4		41	<4	
FIN	2-10	low	21747	2146	9.87	20928	1434	6.85
	2-10	middle	20921	1726	8.25	19839	1149	5.79
	2-10	high	17641	1158	6.56	17087	737	4.31
	11-15	low	9088	1567	17.24	8837	939	10.63
	11-15	middle	8604	1290	14.99	8353	763	9.13
	11-15	high	10815	1104	10.21	10532	610	5.79
	16-17	low	3551	510	14.36	2767	265	9.58
	16-17	middle	3319	444	13.38	2360	205	8.69
	16-17	high	4490	360	8.02	3489	205	5.88
	11-17	low	12639	2077	16.43	11604	1204	10.38
	11-17	middle	11923	1734	14.54	10713	968	9.04
	11-17	high	15305	1464	9.57	14021	815	5.81

4. Overweight and obesity by socioeconomic position in a large Finnish register data

As the data on childhood anthropometric measures and indicators of socioeconomic position (SEP) was very scarce outside the COSI data, more thorough analyses on associations of different socioeconomic indicators of the family on childhood overweight and obesity were carried out using a large data set achieved from the Finnish administrative registers.

Data on measured height and weight of children were extracted from the Finnish Register of Primary Health Care Visits (Avohilmo) for years 2016-2018. Overweight and obesity were defined according to the WHO growth reference criteria. Avohilmo data were linked on individual level to Statistic Finland's data on SEP of adults living at the same address as a child. Register-based data on height and weight and SEP of parents were available on 194 423 children and adolescents (100 216 boys and 94 207 girls) aged 2 to 17 years.

The following SEP indicators were selected for analysis; mother's and father's educational level of highest degree, household's disposable money income, father's/mother's age and municipality group of municipalities of domicile according to the 2016 regional division. The selection was based on the highest relative influence on obesity risk observed in our other STOP study (attachment 4).

Analyses showed that overweight and obesity were more common in children with parents having low education and low household's disposable money income compared with children with parents having high education and high household's disposable money income. The difference between the lowest and the highest levels of parental education or household's disposable money income and the obesity prevalence in children was larger than the differences between levels of parental education or household's disposable money income and the overweight prevalence. Overweight and obesity were more common in all age groups of children living in rural areas compared with children living in urban areas.

The manuscript prepared on the results is as an Attachment 3.

Manuscript

Mäki P, Levälahti E, Lehtinen-Jacks S, Laatikainen T. Overweight and obesity in children and adolescents by socioeconomic position of parents – a register-based study. Manuscript.

5. Literature review on SEP indicators and obesity

As part of WP 2, THL made a scoping literature review on SEP indicators and obesity in children to identify which SEP indicators are the most used and the most relevant factors in childhood obesity (Sares-Jäske et al. 2022).

The review including 53 studies focused on studies about European general populations from the 21st century considering children and adolescents aged 0-17 years. According to the review the most used indicator was mother's education and the most used indicator group parental education. Composite SEP, parental education and parental occupation indicators showed most frequently inverse associations with obesity measures (i.e. lower parental SEP associating with higher adiposity), while household income and affluence and property indicators showed approximately even number of inverse and non-significant associations. Instead, majority of parental employment indicators, showed non-significant associations and a third showed positive associations (i.e. higher parental SEP associating with higher adiposity). Of all association analyses, 55% were inverse, 36% were non-significant, and 8% were positive.

It seems that children with parents of higher SEP have lower likelihood of obesity in Europe. Parents' employment appears to differ from other SEP indicators, so that having an employed parent(s) does not associate with lower likelihood of obesity. Positive associations seem to occur more frequently in poorer countries.

The published paper is as an Attachment 4.

Published paper

Sares-Jäske L, Grönqvist A, Mäki P, Tolonen H, Laatikainen T. Family socioeconomic status and childhood adiposity in Europe - A scoping review. Prev Med. 2022 May 17:107095. doi: 10.1016/j.ypmed.2022.107095. Epub ahead of print. PMID: 35594926.

6. Predictive value of different socioeconomic position indicators of the family on SEP differences in childhood obesity

In Finland, children's weight and height are regularly measured in the health check-ups in child health care and school health care. This data is gathered to the national health care register. Socio-economic data is available from national administrative registers and can be linked on individual level to health care data.

THL conducted a pilot study to analyse the impact of a large set of objective register-based indicators of socioeconomic position on objectively measured childhood obesity among the whole child population aged 2 to 17 years in Finland.

Socioeconomic indicators were received from Statistic Finland for adults (both parents) who live in the same household with a child.

Data on overweight and obesity in children were picked from the National Outpatient Register on Primary Health Care Services (Avohilmo). Data included 0-17-years old children (N=647921) who have visited child or school health clinics from 1st of January 2016 to 31st of December 2018. Obesity was defined according to the WHO growth reference curves.

Avohilmo data were linked to the data of the Statistic Finland on socioeconomic status of children/family (describing the socioeconomic situation of adult/adults living in the same household). Sociodemographic and socioeconomic indicators obtained from Statistics Finland were linked on individual level for adults (both parents) who lived in the same household (42 predictors).

Boosted regression model was used to analyse the contribution of SEP to obesity. The parents' SEP was inversely associated with obesity among the offspring. A remarkable number of objective SEP indicators was analysed with parents' education and household income finally being the indicators most strongly associated with obesity among children.

The submitted manuscript prepared on the results is as an Attachment 5.

Submitted manuscript

Paalanen L, Levälahti E, Mäki P, Tolonen H, Laatikainen T. The association of socioeconomic position and childhood obesity: a register-based study. 2022 (submitted to BMJ)

7. Household income prediction model

Within the framework of the H2020 LifeCycle and in collaboration with STOP project an Equivalized Household Income Indicator was developed. The work was coordinated by the Department of Medical Sciences in the University of Turin (Universita degli Studi di Torino), Italy. It is now available in approximately 20 European studies. EHII – Equivalized Household Income Indicator is a standardized and comparable household income indicator for use across European studies, based on external data from the pan-European surveys - European Union Statistics on Income and Living Conditions (EUSILC), and internal data from the studies.

EUSILC data collection began in 2003 in few countries with subsequent expansion across Europe in 2005 and 2011. Samples of persons aged 16 years or older in 28 European Union States as well as Iceland, Norway and Switzerland (~500,000 European residents annually).

EUSILC collects comparable annual microdata at both individual and household level. Household level includes housing conditions, material deprivation and aggregated income data. Individual level includes basic demographic data, education information, limited health data, labour force data.

Construction of the EHII began with identification of “common variables”, i.e. those variables available both in the study and in EUSILC (marital status, parental age, citizenship and education, self-defined occupation/type of employment contract, ISCO codes, house type/property/size). The next step was to choose the aggregated income measure of interest: total disposable household income (employee/self-employment income, pensions, benefits, allowances, company car, income from rental, interests/dividends/profit minus taxes on wealth, income and social insurance contributions), equivalized in terms of household size and composition.

In the last step of construction of the EHII

1. The available “common variables” in the EUSILC database (2011) were categorized to match the structure of the variables in the study.
2. The chosen income was regressed on these “common variables”.
3. The prediction capability of the model was assessed using the R^2 statistics and the model was validated using EUSILC independent data (2015).
4. When appropriate (see point 3) the regression coefficients derived from point 2 were applied to the study data to derive the EHII.

The published paper is as an Attachment 6.

Published paper

Pizzi C, Richiardi M, Charles MA, Heude B, Lanoe JL, Lioret S, Brescianini S, Toccaceli V, Vrijheid M, Merletti F, Zugna D, Richiardi L. Measuring Child Socio-Economic Position in Birth Cohort Research: The Development of a Novel Standardized Household Income Indicator, Int J Environ Res Public Health, 2020. doi:10.3390/ijerph17051700.

8. Validation of the household income prediction model with Finnish register data

As an additional task in WP2 task 2.5 in collaboration with University of Turin, Italy a validation study on household income indicator was carried out.

EHII model coefficients were merged to Finnish administrative register data including information on children's height and weight from the Finnish Health Care Register and SEP data from Statistics Finland registers. Based on merged coefficients, income prediction was calculated.

Derived EHII regression coefficients based on eight models were applied to Finnish data i.e. EHII predicted in Finnish data. Model 1 has all available predictors included. Models 2-8 have some of the predictors excluded. Consistency of the disposable household income equivalized in terms of household size with EHII predictions was evaluated using regression model and comparing deciles of household income variable with EHII predictions. Prediction based on model 1 had R-square= 42.4. R-square was lower for model 2 - model 8 EHII predictions. Model 1 predicted deciles compared to estimated equalized household income deciles had lower level in euros especially for higher deciles.

Logistic regression models were used to analyse the association of household income deciles and EHII prediction deciles to obesity (based on WHO-criterion). Logistic regression model for obesity on household income deciles had preudo-R2=0.4. Model for obesity on Model 1 EHII prediction deciles had preudo-R2=1.3. Model for obesity on Model 7 EHII prediction (household size predictor excluded) deciles had the highest preudo-R2=1.7.

The results of the analyses are presented in more detail in the Attachment 7.

Discussion

The consistency of disposable household income indicator of families achieved from the Finnish registers compared with the EHII predictions was reasonably good. The predictions were at somewhat lower level than the registered information. This was especially seen when the disposable household income level exceeded 2500 euros. The model 1 including all available predictors (slide 7 in attachment 7) had the best predictive value.

9. Conclusions

The original aims of WP2 task 2.5. were not fully met as it appeared that the availability of data in Europe including information on measured height and weight and indicators of SEP of children is very limited. There was no possibility to analyse trends of obesity by socioeconomic position. The aims were modified during the project to 1) assess the situation of availability of high quality data sources on childhood obesity and SEP indicators in Europe, 2) illustrate through some surveys the existing differences in patterns of SEP differences in childhood obesity in four European countries, 3) compile an overview of studies measuring obesity differences by SEP in children in Europe, 4) examine the usefulness of administrative data sources in assessment of SEP differences, 5) assess the predictive value of different SEP indicators on differences in childhood obesity using a large Finnish data retrieved from administrative registers, 6) finalize the Equivalized Household Income Indicator and to assess its predictive value using Finnish register data.

It was observed that the current availability of high-quality data on childhood obesity including SEP indicators is very limited. Only a few studies include measured data and more than one SEP indicator. The administrative register data from Finland appeared useful and valuable as it included a large amount of different SEP indicators and the quality of height and weight measures was also reasonably good. However, the use of such data requires special permissions and can be analysed only in secured data platforms making the use of data complicated for research purposes. Anyhow as carrying out health examination surveys among children are challenging and expensive resulting in that they are very seldom repeated to provide data on trends, in future attention should be paid in developing data collection directly from health service system and in improving the possibilities to link the data with other administrative registers including information for example on SEP.

The scoping review of European studies on association between childhood obesity and SEP showed that the most common indicators used in surveys were parents' education and household income. However, the way of measuring those differed considerably. There were also differences how the obesity or overweight of children was defined. Thus, there would be a need for a standardized indicators to measure the SEP in childhood to achieve more comparable information.

The analyses on predictive value of various different SEP indicators available from the Finnish register data showed that the parents' education and household income were most strongly associated with childhood obesity. These were also the indicators mostly used in earlier surveys in Europe based on the scoping review.

The developed Equivalized Household Income Indicator (EHII) is one good solution in creating comparability to measurement of SEP in different countries. The validation analyses carried out in this project also showed that the predictive value of EHII compared with actual income information from register data in Finland is reasonably good. Similar validations could be carried out with other available data sources.

10. List of Attachments

1. Data description form, STOP/WP2/Task 2.5
2. Summary of the available surveys with obesity and SEP data of children
3. Mäki P, Levälahti E, Lehtinen-Jacks S, Laatikainen T. Overweight and obesity in children and adolescents by socioeconomic position of parents – a register-based study. (Manuscript, PDF)
4. Sares-Jäske L, Grönqvist A, Mäki P, Tolonen H, Laatikainen T. Family socioeconomic status and childhood adiposity in Europe - A scoping review. Prev Med, 2022 May 17:107095. doi: 10.1016/j.ypmed.2022.107095.
5. Paalanen L, Levälahti E, Mäki P, Tolonen H, Sassi F, Ezzati M, Laatikainen T. The association of socioeconomic position and childhood obesity: a register-based study. (submitted to BMJ, PDF)
6. Pizzi C, Richiardi M, Charles MA, Heude B, Lanoe JL, Lioret S, Brescianini S, Toccaceli V, Vrijheid M, Merletti F, Zugna D, Richiardi L. Measuring Child Socio-Economic Position in Birth Cohort Research: The Development of a Novel Standardized Household Income Indicator, Int J Environ Res Public Health, 2020. doi:10.3390/ijerph17051700.
7. Pizzi C, Laatikainen T: Validation of a standardised income indicator (EHII) to predict childhood obesity: evidence from Finnish register data (Power point presentation, PDF)

Attachment 1. Data description form - STOP/WP2/Task 2.5

Anthropometrics and socioeconomic information of children

Country: **Contact person in data related issues and contact information (name, e-mail, phone):**

Do datasets exist combining anthropometrics and SES indicators: yes/no

List these datasets:

Age groups represented in the data:

Data collection year/years:

Area/areas of the data collection (eg. national, regional):

Is the data part of COSI data: yes/no

What anthropometric information is available (weight, height, BMI, waist circumference):

If only BMI categories are available, which criteria are used (WHO, IOTF, other):

Special permissions required for data use in SES analyses if the STOP project (Is there possibility to release data for joined analyses and what are the requirements for that eg. anonymization of the data):

*Please, indicate in the table below, which SES indicators are available in your data and describe the variable as accurately as possible (question used in collecting the data**, coding of the variable). In the comments field you can add any additional information.***

SES indicator/indicators	Description of the variable/variables	Comments
mother's/father's highest degree/educational level (eg. high school, vocational training etc.)		
mother's/father's years of education		
mother's/father's occupational status (eg. employed, unemployed etc.)		
mother's/father's type of occupation (e.g. managerial, professional, clerical, etc.)		
mother's / father's sector of occupation (e.g. Industry classification)		
parents'/household income, disposable income etc.		

type of family (eg. nuclear family, reconstituted family, single parent etc.)		
size of family		
size of household-dwelling unit		
number of children in family (describe if children under school age, under 18 years etc. can be separated)		
form of housing		
home ownership		
room density/living space		
Family Affluence Scale (FAS)		
migrant status		
ethnic minority status		
any other SES related indicator, what?		

Attachment 2. Summary of the available surveys with obesity and SEP data of children

SES indicators	Indicator availability/Description of the variable/variables						
	Estonia	Romania		Slovenia	Switzerland	Belgium	Croatia
Name of the study	Childhood Obesity Surveillance Initiative (COSI) 2019 Estonian National Dietary Survey (ENDS) 2014 Age groups represented in the data: COSI 2019: 7-8 years and 10-11 years ENDS 2014: 4 months – 17 years Data collection year/years: COSI: 2019 ENDS: 2014 Area/areas of the data collection (eg. national,regional): Both national Anthropometric information available: Weight, height, BMI, waist, and hip circumferences for both datasets	Timis STUDY - approx. 530 individuals measured in schools and kindergartens Age groups represented in the data: 3-18 Data collection year/years:2014 Area/areas of the data collection (eg. national, regional): regional Is the data part of COSI data: no Anthropometric information available: weight, height, BMI, waist circumference, hip circumference Romanian is also participating in the COSI study and	Dolj STUDY - aprox 1500 individuals measured in schools and kindergartens Age groups represented in the data: 2-18 Data collection year/years:2010-2011 Area/areas of the data collection (eg. national, regional): regional Is the data part of COSI data: no Anthropometric information available: weight, height, BMI Romanian has also participated in the Epode for the Promotion of Health Equity (EPHE) study Children aged 6-8 years participated, resulting in a total sample of 1266 children and their families. Prof	ACDSi dataset Age groups represented in the data: 6-19 Data collection year/years: 2013 and 2014 Area/areas of the data collection (eg. national, regional): national Is the data part of COSI data: no Anthropometric information available: weight, height, BMI, waist circumference, a number of skinfolds, circumferences, widths, lengths, sitting height	Age groups represented in the data: 6-12y. Data collection year/years: 2007, 2012, 2017 Area/areas of the data collection (eg. national, regional): national Is the data part of COSI data: yes/no Anthropometrics (measured) : 6-12y: weight, height, BMI, waist circumference, body fat Lifestyle variables (questionnaire): physical activity, food, sleep, media time, health, quality of life SES (questionnaire): Highest degree/educational level of parents, occupational status	Belgian national food consumption survey 2014/15 Age groups represented in the data: All age groups from 3 to 64 years of age Data collection year/years: 2014/15 Area/areas of the data collection (eg. national, regional): data are nationally and regionally representative Is the data part of COSI data: no What anthropometric information is available: measured weight, measured height, BMI, waist circumference If only BMI categories are available, which	CRO-PALS study https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7246459/ Age groups represented in the data: 15-17 Data collection year/years: 2014 Area/areas of the data collection (eg. national, regional): regional Is the data part of COSI data: no Anthropometric information available: weight, height, BMI, waist circumference, sum of skinfolds

			Gabriela Radulian (gradulian@umf.ro) https://pubmed.ncbi.nlm.nih.gov/26630926/ A population-based cross-sectional study among elementary school children within the Healthy Traditions programme that is part of the EPODE International Network (EIN).Veronica Mocanu (veronica.mocanu@umfiasi.ro https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3726018/ Romanian COSI study contact Constanta Huidumac Petrescu constanta.huidumac@insp.gov.ro Additionally, 2 studies in schools in 2010-2011 Dolj and 2014 in Timis County: Timis STUDY - approx. 530 individuals measured in schools and kindergartens Age groups represented in the data: 3-18		of parents (2017 only) What anthropometric information is available: weight, height, BMI, waist circumference, body fat If only BMI categories are available, which criteria are used (WHO, IOTF, other): IOTF	criteria are used (WHO, IOTF, other): Not applicable	

			Data collection year/years: 2014 Area/areas of the data collection (eg. national, regional): regional Dolj STUDY - aprox 1500 individuals measured in schools and kindergartens Age groups represented in the data: 2-18 Data collection year/years: 2010-2011 Area/areas of the data collection (eg. national, regional): regional				
Anthropometric information	Weight, height, BMI, waist and hip circumferences for both datasets		Timis STUDY: weight, height, BMI, waist circumference, hip circumference Dolj STUDY: weight, height, BMI	Weight, height, BMI, waist circumference, a number of skinfolds, circumferences, widths, lengths, sitting height…			Weight, height, BMI, waist circumference, sum of skinfolds
mother's/father's highest degree/educational level (eg. high school, vocational training etc.)	COSI What is the highest level of education that you or your spouse or partner has completed? Please select only one answer for each of you. You; Spouse/ partner:		Timis STUDY: available Dolj STUDY: available	Available:(primary school, secondary school, more than secondary school) Only ages 11+ (primary school, 2-3 years secondary school, 4-5 years secondary school, 2-year higher education, university	Highest vocational/school qualification. Please fill in for both! MOTHER: FATHER: □ Compulsory schooling □ Compulsory schooling	Available, see detailed codebook, under "education"	Reported by a parent for both parents 1=no school 2=elementary school; 3=3-year vocational secondary school 4=4-year vocational secondary school; 5=grammar school; 6=bachelor's degree; 7=master's degree

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	Primary education or less (ISCED 0-1) Lower secondary education (ISCED 2) Upper secondary and post-secondary non-tertiary education (ISCED 3 and 4) Short-cycle tertiary education or Bachelor's or equivalent level (ISCED 5 and 6) Master's or Doctoral or equivalent level (ISCED 7 and 8) I don’t have a spouse/partner ENDS What is the highest educational attainment of the subject’s mother (or other female caretaker if the mother does not live with the subject)? 1) Less than primary education (less than 3-4 grades) 2) Primary education (less than 8-9 grades) 3) Basic education (8-9 grades)			degree, MA or PhD) Only ages 6 to 10	□ Teaching □ Teaching □Lehre with vocational baccalaureate □ apprenticeship with vocational baccalaureate □ University of Applied Sciences, Technikum □ University of Applied Sciences, Technikum □ University □ None □ Other		8=PhD; 9=I don't know

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	4) Secondary education 5) Vocational secondary education 6) Vocational higher education 7) Higher education (bachelor's degree, professional higher education) 8) Master's degree 9) Doctor's degree 10) Other, please specify What is the highest educational attainment of the subject's father (or other male caretaker if the father does not live with the subject)? 1) Less than primary education (less than 3-4 grades) 2) Primary education (less than 8-9 grades) 3) Basic education (8-9 grades) 4) Secondary education 5) Vocational secondary education						

	6) Vocational higher education 7) Higher education (bachelor's degree, professional higher education) 8) Master's degree 9) Doctor's degree 10) Other, please specify						
mother's/father's years of education	Not available		Timis STUDY: not available Dolj STUDY: available	Not available	Not available	Not available	Not available
mother's/ father's occupational status (eg. employed, unemployed etc.)	COSI What is the main occupation of you and your spouse/partner over the last 6 months? Please select one answer only for each of you. You; Spouse/partner Full-time domestic housework/homemaker Work full-time Work part-time Unemployed Full-time education Sick/disabled Something else: I don't have a spouse/partner ENDS		Timis STUDY: not available Dolj STUDY: not available	Available, only ages 11+	Do your parents work? Please fill in for both! MOTHER: FATHER: Yes/No	Available, see detailed codebook, under "employment"	Reported by a parent for both parents 1=entrepreneur, owner of business 2=employee (permanent job); 3 employee (permanent job); 4= employee (no contract) 5=craftsmen 6=agriculturist; 7=family business 8=unemployed (looking for first employment); 9= currently unemployed (previously employed, looking for employment) 10=unemployed (not looking for employment)11=retired; 12=housekeeper

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	Which of the following best describes the current status of the subject's mother (or other female caretaker if the mother does not live with the subject)? 1) Employed (including workers on a paid apprenticeship, paid parental leave (parental benefit), sick leave or annual leave, a sole proprietor, a working old-age pensioner) 2) Unemployed (including looking for a job) 3) Student (including on an unpaid apprenticeship) 4) Pensioner (including unemployed old-age pensioners, unemployed persons incapable of work etc.) 5) On an unpaid parental leave (staying at home with a child under 7 years of age, not receiving parental benefit or stopped						13=uncapable for work 14=other

	receiving parental benefit) 6) At home (unemployed) 7) Other, please specify Which of the following best describes the current status of the subject’s father (or other male caretaker if the father does not live with the subject)? 1) Employed (including workers on a paid apprenticeship, paid parental leave (parental benefit), sick leave or annual leave, a sole proprietor, a working old-age pensioner) 2) Unemployed (including looking for a job) 3) Student (including on an unpaid apprenticeship) 4) Pensioner (including unemployed old-age pensioners, unemployed persons incapable of work etc.) 5) On an unpaid parental leave						

	(staying at home with a child under 7 years of age, not receiving parental benefits or stopped receiving parental benefits) 6) At home (unemployed) 7) Other, please specify (e.g. a conscript)						
mother's/father's type of occupation (e.g. managerial, professional, clerical, etc.)	Not available		Timis STUDY: not available Dolj STUDY: not available	Not available	Not available	Yes, the following categories are used: 1 = Unemployed (e.g. pension, fulltime student, sickness or invalidity, …) 2 = Unskilled manual worker (e.g. taxi driver, agricultural worker, …) 3 = Half-skilled or unskilled manual worker (e.g. industrial worker without education) 4 = Skilled manual worker (e.g. technician with education)5 = Leading manual worker (e.g. foreman, …)	Reported by a parent for both parents 1=manager or owner of business 2=expert/specialist (e.g. engineer, scientist, professor, lawyer, artist); 3=technician (e.g. lab technician, nurse, machine officer) 4=clerk (e.g. secretary, office clerk); 5=craftsman (e.g. mason, watchmaker, locksmith); 6=service worker (e.g. cook, hairdresser, waiter, salesman); 7=qualified worker (e.g. driver, machine manager); 8= unqualified worker (e.g. garbage man, cleaner, street vendor); 9=agriculturist (e.g.

						6 = Self-employed and/or leading farmer (e.g. agriculturist) 7 = Self-employed without personnel (e.g. artisan, …) 8 = Self-employed with less than 10 personnel (e.g. merchant, …) 9 = Half- and unskilled non-manual work (e.g. shop assistant, office, public service, …) 10 = Skilled non-manual work (e.g. nurse, clerk in the private sector, …) 11 = Self-employed higher grade professionals (e.g. dentist, lawyer, …) 12 = Management, academics (e.g. company director, great entrepreneur, …) -1 = No answer -3 = Not applicable	farmer, fisherman…) 10=army or police personnel; 11=unknown
mother’s / father’s sector of	Not available		Timis STUDY: not available	Not available	Not available	Not available	Not available

occupation (e.g. Industry classification)			Dolj STUDY: not available				
parents'/household income, disposable income etc.	COSI – not available ENDS What is the monthly average net income of the subject's household? Please account for the average income of the past year and consider all of the possible sources of income listed below. 1) Less than 100 euros 2) 101-200 euros 3) 201-300 euros 4) 301-500 euros 5) 501-1000 euros 6) 1001-1500 euros 7) 1501-2000 euros 8) 2001-3000 euros 9) More than 3001 euros *Net income obtained from all sources – the amount received after deducting taxes: salary, entrepreneurial*		Timis STUDY: available Dolj STUDY: not available	Not available	Not available	Not available	Reported by a parent for both parents Monthly household income. Free entry, censored to approximately 13 000 Euro

	income, sole proprietor income, rent income, property income and dividends, old-age pension, pension for incapacity for work, child benefit, benefits for disabled people, unemployment benefit, survivor's pension, parental benefit, maintenance allowance (including undeclared maintenance allowance received from the other parent), subsistence benefit, caregiver's benefit, income tax recoverable, state or local government benefit.						
type of family (eg. nuclear family, reconstituted family, single parent etc.)	COSI – not available ENDS What is the subject's family model? 1) Living with two parents 2) Living with one parent 3) Living with neither parent		Timis STUDY: not available Dolj STUDY: not available	Indirectly, step father or step mother, only 11+	Not available	Not available	Reported by a parent 1=married/unmarried couple with children 2=single parent; 3=wider family with other relatives (e.g. grandparents); 4=multiple-member non-family household (e.g. roommates, friends); 5=other
size of family	COSI For the home where your child lives all or most of the time		Timis STUDY: not available Dolj STUDY: not available	Indirectly, number of brothers and sisters + parents, only 11+	Not available	Yes, household size (0-12 people)	Not available

	(>50%) please indicate the number of people, in each box, who live there: Mother Father Stepmother or girlfriend/partner) Stepfather or boyfriend/partner) Brother/stepbrother(s) Sister/stepsister(s) Grandfather(s) Grandmother(s) A foster home or children's home Someone or somewhere else (please specify):						
size of household-dwelling unit	COSI – not available ENDS – not available		Timis STUDY: not available Dolj STUDY: not available	Not available	Not available	Not available	Reported by a parent Free text entry
number of children in family (describe if children under school age, under 18 years etc. can be separated)	COSI – not available ENDS How many dependent children are in the subject's household (including the subject) ___ children Please specify the ages of the		Timis STUDY: not available Dolj STUDY: not available	Yes – number of brothers, number of sisters + their age, only 11+	Not available	Not available	Not available

	dependent children living in the subject's household:_						
form of housing	COSI – not available ENDS – not available		Timis STUDY: not available Dolj STUDY: not available	Not available	Not available	Not available	Not available
home ownership	COSI – not available ENDS – not available		Timis STUDY: not available Dolj STUDY: not available	Not available	Not available	Not available	reported by a parent 1=private ownership, acquired; 2=private ownership, inherited; 3=owned by grandparents or close relatives 4=state/town housing; 5=rented; 6=temporary lodging; 7=other
room density/living space	COSI – not available ENDS – not available		Timis STUDY: not available Dolj STUDY: not available	Not available	Not available	Not available	Not available
Family Affluence Scale (FAS)	COSI Please tick the box which best represents your household situation? Please tick one box. - We easily pass the month with our earnings - We pass the month without serious problems with our earnings - We have trouble meeting the ends the		Timis STUDY: not available Dolj STUDY: not available	Not available	- (HBSC, see above)	Not available	Not available

	month with our earnings - We barely meet the ends in the month with our earnings ENDS – not available						
migrant status	COSI – not available ENDS – not available		Timis STUDY: not available Dolj STUDY: not available	Not available		Country of birth of participant (Belgium, other EU member state, non EU member state) Country of birth of partner of the participant (Belgium, other EU member state, non EU member state) Nationality of participant (Belgium, other EU member state, non EU member state) Nationality of partner of the participant (Belgium, other EU member state, non EU member state) Language usually spoken at home (answer 1)(Dutch/French or other language)	Not available

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						Language usually spoken at home (answer 2)(Dutch/French or other language)	
ethnic minority status	COSI In what language(s) do you usually/mainly speak with your child at home? Estonian Russian Other language, please specify: ENDS What is the subject's home language? 1) Estonian 2) Russian 3) Other, please specify What is the subject's home language? Estonian Russian NA Other, please specify		Timis STUDY: not available Dolj STUDY: not available	Not available		Not available	Not available
any other SES related indicator, what?	COSI – not available ENDS – not available		Timis and Dolj STUDY: Urban rural, name of the county to be correlated with known economic	How well does your family do in comparison to your peers? 1-5 scale	In which country were you born? □ In Switzerland		Self-reported by adolescents through one item: "How would you compare your financial situation

			development for the region	Do you have your own room? How many times in the last 12 months have you been on family vacation? How many computers do you have in your family? Do you have a computer in your room? Do your monthly incomes suffice to fulfill the needs of your family?	□ In another country: In which country were your parents born? MOTHER FATHER □ In Switzerland □ In another country:		compared to your peers?" Likert scale 1–5 (1-Much lower than average; 2-Lower than average; 3-Average; 4-Higher than average; 5-Much higher than average).

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Overweight and obesity in children and adolescents by socioeconomic position of parents – a register-based study

Mäki P, Levälahti E, Lehtinen-Jacks S, Laatikainen T

Abstract

Background

The aim of study was to examine associations between SEP of parents and overweight and obesity in Finnish children and adolescents aged 2-17 years, based on data from two large administrative registers. The study also aimed to discover if register-based data on children's height and weight and SEP of parents could be used for national monitoring.

Methods

Data on children's measured heigth and weight were extracted from the Register of Primary Health Care Visits (Avohilmo) for years 2016-2018.

Overweight and obesity were defined according to the WHO growth reference criteria. Avohilmo data were linked on individual level to Statistic Finland's data on a SEP of adults living at the same address as a child.

Register-based data on height and weight and SEP of parents were available on 194 423 (100 216 boys and 94 207 girls) children and adolescents aged 2 to 17 years.

Results

Overweight and obesity were more common in children with parents having low education and low household's disposable money income compared with children with parents having high education and high household's disposable money income. The difference between the lowest and the highest levels of parental education or household's disposable money income and the obesity prevalence in children was larger than the differences between levels of parental education or household's disposable money income and the overweight prevalence.

Overweight and obesity were more common in all age groups of children living in rural areas compared with children living in urban areas.

Conclusions

Our findings confirmed previous studies' findings on increased risk of overweight and obesity in children and adolescents with low SEP of parents.

Linking data of administrative registers on children's height and weight and SEP of parents is a feasible and valid approach to monitore the prevalence of overweight and obesity in children and adolescents by SEP of parents.

Key words: children, overweight, obesity, socioeconomic position, health monitoring

Introduction

Childhood obesity is a major public health problem globally, also in Finland (1-3). Recent statistic showed that 29 precent of 2-16 years of age Finnish boys and 18 % of girls were living with overweight (including obesity), 9 % of boys and 4 % of girls with obesity (4,5).

Obesity in childhood or adolescence tends to continue into adulthood (6,7). Obesity is associated with several physical and psychosocial health concerns in childhood and later in adulthood (7). The majority of children and adolescents with obesity have other risk factors for arterial diseases in addition to obesity, and the risk increases as obesity becomes more severe (8-10). In addition, children and adolescents living with obesity are more likely to suffer bullying, social exclusion, low self-esteem, and body image dissatisfaction than peers with healthy weight (11-13).

Previous studies have shown that obesity is related with socioeconomic position (SEP), both in adults and children (14-16). Parent's education has been shown to have a strong, inverse association with childhood obesity in high-income countries, but the opposite relationship in most of the middle-income and low income countries (15,17). In general, children with low SEP in high-income countries and children with high SEP in low income countries are at higher risk of overweight than other SEP groups (15,18,19).

Finnish administrative registers include information on both measured height and weight in children and socioeconomic position of household/parents. In our previous study, we analysed the impact of a large set of register-based indicators on SEP of parents on childhood obesity and found parents' education and household income being the indicators most strongly predicted obesity risk in children and adolescents (20). In the present study we had two aims: 1) to examine associations between the parental SEP indicators, which most strongly predicted obesity risk of their offspring, and prevalence of overweight and obesity in children and adolescents aged 2-17 years, based on data from two Finnish administrative registers; and 2) to discover if register-based data on children's height and weight and SEP of parents could be used for national monitoring.

Methods

Study design and population

Data on children's heigth and weight were extracted from the Register of Primary Health Care Visits (Avohilmo). Avohilmo includes up-to-date data on primary health care visits, including measured height and weigth,collected via data transmission from electronic health records of primary health care units to Avohilmo, controlled by the Finnish Institute for Health and Welfare (THL). (21). Data extraction criteria were that a child had visited in child health clinic, school health care or student health care appointment between 1st of January 2016 and 31st of December 2018 and both height and weight were recorded during the visit. Variables extracted were date of birth, gender and all available height and weight measurements including measurement dates. The exact age was calculated based on the child's date of birth and the date of measurement of height and weight. The total sample size of the Avohilmo data was 645 931 children with 2 268 954 height and weight measurements in years 2016-2018. Children with implausible height and weight data (less than -4 or more than +4 SD of the WHO Growth Standards median) or BMI for age values (less than - 4 or more than 4 SD from the WHO Growth Standards median) were excluded from the data (25 892 children and 41307 weight and height measurements).

The children and adolescents who were 2-17 years of age and had at least one both height and weight measurement in 2018 (n=394 627) were chosen for the analyses. Each child in the Avohilmo database (n=387 623) was linked according to the child's personal identity number to data of Statistic Finland (from 1 January 2014 to 31 December 2018) on socioeconomic position of adults/parents who were living in the same address than the child. Data on SEP of parents' were not found for 7004 children and adolescents. Siblings, and children having either same mother or father, and families with two females or two males were excluded for the analysis (n=193 200).

The final data included data on measured height and weight and SEP of parents in 194 423 (100 216 boys and 94 207 girls) children and adolescents aged 2 to 17 years.

Both Finnish Institute for Health and Welfare (THL) and Statistics Finland have granted a permission to use and link data sets for the research. According to Finnish legislation, an ethics review on register-based research is not required.

Height and weight measurements

Avohilmo data on weight and height of children, is measured and recorded by health care professionals in child health clinics and school health care. Measurement technicques, equipments and calibration of equipments are guided by the manual for health professionals on physical measurements in healts check-ups of children (22). According to the manual of Avohilmo, weight is expressed without decimals as in kilograms or grams (depending on child's age) and height in centimeters (21).

Overweight and obesity were defined according to the WHO growth reference for children and adolescents (23,24), but also according to the cut-off points of Finnish growth standards (25). For children under five years of age the definition for overweight and obesity were a BMI-for-age value greater than + 2 SD and +3 SD above the WHO Child Growth Standard median, respectively (23). For children over five years overweight and obesity were defined as a BMI-for-age value greater than + 1 SD and +2 SD above the WHO Growth Reference median, respectively (24). Prevalence of overweight includes children with obesity. Corresponding results for overweight and obesity according to Finnish growth standards can be found as supplementary material.

Socioeconomic position (SEP)

SEP of parents was defined according to variables of Statistic Finland between 1st of January 2014 and 31st of December 2018. Data on SEP of parents were used from year 2017. If the information was missing in 2017, it was imputed using data from years 2014–2016 and/or from year 2018. The SEP indicators of parents, having the highest relative influence on obesity risk in children in our previous study (20), were selected for analysis; mother's and father's educational level of highest degree, household's disposable money income, father's/mother's age and municipality group of municipality of domicile according to the 2016 regional division.

Father's/mother's educational level of highest degree was classified into three categories: low, medium and high. The category of low education included parents who did not have a degree, ie they had completed at most primary school, medium level of education included parents who had completed secondary or high school or vocational school. The category of high education included parents who had a bachelor's degree, master's degree or higher degree.

Household's disposable money income was classified into three categories: low, middle and high. The category of low disposable money income included households with income under 1525 euros per month. Middle income from 1525 to 4065 and high income more than 4065 euros per month. Household's disposable money income was calculated taking into account the size of the household.

Municipality group of municipality of domicile according to the 2016 regional division was classified to three categories: urban, semi-urban and rural municipalities. In urban municipalities at least 90 % of the population lives in urban settlements or the population of the largest urban settlement is at least 15,000. In semi-urban municipalities 60 % -90 % of the population lives in urban settlements and the population of the largest urban settlement is 4,000 15,000. In rural municipalities less than 60 % of the population lives in urban settlements and the population of the largest urban settlement is less than 15,000 or 60 %-90 % of the population lives in urban settlements and in which the population of the largest settlement is less than 4,000 (26).

Statistical methods

Avohilmo's data on height and weight in children were linked with the Statistics Finland's data on socio-economic position of adults living with the same address as a child. The combined/linked? data were analyzed in the Statistics Finland's remote access system.

Miten imputointi tehtiin?

Analyses on prevalence of overweight and obesity and socioeconomic position were performed separately for boys and girls in four age groups: 2-6.99, 7-12.99, 13-15.99 and 16-17.99 year olds (table 1).

Prevalence of overweight and obesity were analysed by each SEP indicator (tables 2 and 3).

Results

Study population

Data on SEP of parents by children's age groups and gender are reported in Table 1.

Overweight and obesity in children and adolescents by SEP of parents

The prevalence of overweight and obesity were higher in boys than in girls and in older children compared with younger children. A total xx % of boys and % of girls had overweight (including obesity), Overweight and obesity were most common in 7-13 years old boys and girls (in boys 35 % and 15 %, in girls 29 % and 9 %, respectively) (tables 2 and 3).

The older the father or mother was, the more common the overweight and obesity were in boys and girls aged 2-7 years. There was no similar, consistent upward trend between the age of parents and overweight/obesity in children in the older age groups.

Overweight and obesity were more common in all age groups in boys and girls whose parents had low education and low household's disposable money income compared with children with parents having high education and high household's disposable money income, respectively. However, the difference between the lowest and the highest levels of parental education or household's disposable money income and the obesity prevalence in children was larger than the differences between levels of parental education or household's disposable money income and the overweight prevalence. When comparing the obesity prevalence among children with different levels of parental education, obesity was twice as common in boys and girls in all age groups in children with low-educated parents as in children with high educated parents. Obesity was at least twice as common in children of all age groups in families with low household's disposable money income as in children in families with high income (tables 2 and 3).

The prevalence of overweight and obesity were higher in all age groups in children living in rural areas compared with children living in urban areas (tables 2 and 3).

Discussion

This study is the first to provide a cross-sectional overview of the association between SEP of parents and overweight and obesity in children and adolescents aged 2 to 17 years, based on Finnish administrative register's data.

As many previous studies, conducted in high income countries (15,19,27), we found an inverse relationship between the prevalence of overweight and obesity in children and adolescents and SEP of parents. Overweight and obesity were more common in all age groups in children and adolescents whose parents had low education and low household's disposable money income compared with children of parents with high education and high household's disposable money income, respectively. Similar association between SEP and the prevalence of overweight and obesity in children has previously been observed in Finnish boys and girls, according to indicators of SEP of family (2,28,29) and also according to the adolescent's own social position (school achievement, school attendance) or the family's material affluence (28). As Magnusson et al (30) have concluded, there is also social inequalities on overweight and obesity in the Nordic countries, although the Nordic countries have socially egalitarian ideals and a reputation for low levels of inequality. By contrast, in low- and middle-income countries the relationship between SEP and obesity is reversed, obesity is more common among children with higher SEP (14,31).

In line with previous research, the prevalence of overweight and obesity in children and adolescents were higher in all age groups in children living in rural areas compared with children living in urban areas (2,3,30,32). Obesity in children was twice as common in rural municipalities as in urban municipalities. Similar results have been found in Sweden, where overweight and obesity in 6 to 9 years old children were approximately 2 and 3 times more prevalent in areas with lower compared with higher area-level education areas, which was explained by lower educational attainment in the rural areas. (30). Also, a Finnish large, prospective birth cohort study found that exposure to neighborhood socioeconomic disadvantage constitutes an important risk factor for the development of childhood obesity (33).

There are several both individual and societal factors behind obesity in children and adolescents, such as heredity, lifestyle habits, socioeconomic position and obesogenic living environment (7,15). In childhood, family and living environment play important roles in adopting, establishing and promoting healthy lifestyles through role modelling and support for engaging in healthy lifestyle habits (34-38). Previous Finnish studies has shown a socioeconomic gradient between parental SEP and lifestyle habits in childhood and adolescence (37,39-41). Parental lower SEP may negatively affect the psychosocial security experienced in families, for example due to job insecurity or living in poorer residential area (16).

The association is more complex in children and adolescents because they don’t have degree of education, occupation, or income of their own (27). Indicators commonly used to measure childhood SEP are indicators of parents’ SEP; parent’s education, occupation, and household income (27). Koivusilta et al have stressed that health differences between adolescents are an outcome of several mechanisms, not a direct result of economic inequality between families' socioeconomic position. They mention that adolescents are experiencing a transition from being a child living with parents' care to a more independent actor in a wider society. At that time adolescent's schooling, education, and family's material commodities could be important for adolescence as reflecting their own social position and the standard of living (28).

According to a systematic review, health behaviors contribute to the association between SEP and health outcomes, but that the contribution varies according to geographic location, sex, age, health outcomes and methodological differences between studies (42). The association between SEP and obesity is also complex and varies by several demographic (e.g., age, gender, ethnicity) or environmental (e.g., countries, urban/rural) factors (15). Furthermore, each SEP indicator have different background, measures differ, have often interrelated aspects of socioeconomic stratification and may be more or less relevant to different health outcomes and at different stages of life (27,43).

Nationwide data on the prevalence of overweight and obesity in Finnish children have been lacking until 2017, although possibilities for monitoring have existed for long (44). Finland has a comprehensive public health care system and almost all Finnish families with children use the child health clinic and school health care services (45,46). The provision of health services, such as health check-ups, is a mandatory for municipalities, but services are voluntary for families (45). This provides an excellent possibility to monitor children's growth and to identify children with high risk of obesity. In addition, regular growth monitoring of all children enables national monitoring of overweight and obesity in children, because the data on height and weight are transferred to the Avohilmo register.

In our previous studies, we have investigated possibilities to utilize Avohilmo register for monitoring the prevalence of overweight and obesity in Finnish children and have found Avohilmo to be a reliable source for monitoring (44,47). Since 2018, the prevalence of overweight and obesity in children and adolescents has been reported annually at the national, regional and municipal level as part of the reporting of the FinChild register (4,5). In this study, we linked data from two administrative registers to investigate associations between parental SEP and overweight and obesity in children and adolescents. Our findings were in line with previous studies' results on association between SEP of parents and childhood obesity, confirming that linking data of administrative registers offers a possibility to monitor the prevalence of overweight in children and adolescents according to the SEP of parents. The use of register-based data will probably also be cost-effective since health examination studies or questionnaires are not needed. The possibility for individual level linkage of register data and availability of various variables of socioeconomic position is quite unique. This enables that the Finnish monitoring system on overweight and obesity in children and adolescents (5,44,47) can be developed to cover also socioeconomic position of parents. To make this possible, further development is needed both to make the linking of data from different registers as flexible and up-to-date as possible and to improve the coverage of Avohilmo data on height and weight of children.

Strengths and limitations.

The main strength of the study is the large and comprehensive data from two administrative registers: the register of Primary Health Care Visits (Avohilmo) and Statistics Finland. Avohilmo includes data on measured height and weight of children and adolescents. The relationship between SEP and adiposity may differ according to measured or reported weight status and, especially in children, the criterion chosen for establishing the weight status cut-off points (15,27).

Statistics Finland's data on SEP of children's parents is collected from various national registers, for example from the Population Register and the Incomes Register, making SEP data more comprehensive and reliable than data collected through questionnaires. Parent's SEP information was found for almost all children, only about for 2 % of children information was not found in Statistic Finland's data. The advantage of registers is that using register data there is no bias such as in epidemiological studies, where the participation activity may be low in people with obesity orpeople with low education (30,48). In addition, there are not so many missing values, such as when asking children and adults itselves about sensitive information for example on education, professional status, income, etc.

However, there are also some limitations in the study. First, although the Avohilmo data collection has covered all outpatient primary health care delivered in Finland since 2011, the coverage of data on height and weight of children was approximately 40 % in 2018 (4). Because most children and families attend to health check-ups and children are measured regularly, the low coverage of height and weight data is mainly due to problems with the electronic health record and technical data transmission in use (47). The aim is that the coverage will reach it's full potential, over 90 %, in the near future. It requires good collaboration between public health service providers, producers of patient's electronic health records, and THL.

Furthermore, according to the Statistic Finland's data on adults living at the same address as a child, it is not possible to verify if adults are parents, biological parents or stepparents of the child. It is also difficult to ensure, whether the family is a nuclear family or a stepfamily. In addition, Statistics Finland's variable "educational level of the highest qualification/degree" includes only degrees in secondary education or higher. If the person has completed primary school and does not have a degree in secondary education, then the information on educational level is recorded as missing and those cannot be separated from persons without any education. However, in Finnish society it is very rare to be without primary school education. One limitation also is that the registry data does not include information on health behavior such as diet and physical activity.

Conclusion

Lower parental SEP was associated with overweight and obesity in children and adolescence in Finland.

Linking data of administrative registers on children's growth and SEP of parents is a potential, feasible and valid approach to monitore the prevalence of overweight and obesity in children and adolescents by SEP of parents.

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Conflict of Interest

None.

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Table 1. Sociodemographic characteristics of data on children and adolescents aged 2 to 17 years, %.

	Boys				Girls			
Age group	2–6.99	7–12.99	13–15.99	16–17.99	2–6.99	7–12.99	13–15.99	16–17.99
(N)	34,814	36,229	17,270	11,903	33,459	34,619	16,720	9,409
Father’s age								
< 30	12.2	2.3	0.5	0.1	12.4	2.4	0.5	0.2
30-34	27.9	10.4	2.1	0.8	27.3	10.3	2.4	1.0
35-39	32.0	24.3	9.0	4.0	32.4	24.3	9.6	4.4
40-44	17.8	30.2	23.5	14.4	18.0	30.1	23.4	15.1
45-49	6.7	19.2	30.2	29.4	6.5	19.2	29.5	30.1
>= 50	3.4	13.7	34.5	51.4	3.3	13.6	34.7	49.2
Missing (n)	3073	5174	3017	2220	2938	5051	3005	1789
Mother’s age								
< 30	22.4	4.8	0.2	0.1	22.1	4.5	0.2	0.1
30-34	32.2	16.3	4.2	0.8	32.7	16.3	4.3	1.1
35-39	29.6	29.1	14.1	7.4	29.3	29.1	15.0	7.8
40-44	13.0	29.2	29.3	21.0	13.0	29.4	29.2	22.5
45-49	2.6	15.7	30.7	33.5	2.7	15.5	30.6	33.7
>= 50	0.2	4.9	21.5	37.2	0.2	5.1	20.8	34.9
Missing (n)	113	800	586	468	98	582	517	301
Household's disposable money income								
Low	28.5	23.7	19.4	16.0	27.8	23.9	19.7	16,6

Middle	67.7	70.8	74.0	76.0	68.2	70.4	73.5	75.6
High	3.7	5.5	6.6	8.0	4.0	5.7	6.8	7.8
Missing (n)	319	1032	714	593	293	782	514	355
Father's educational level of highest qualification/degree								
Low	13.2	13.3	14.0	12.9	13.0	13.2	13.7	14.2
Middle	45.4	45.1	44.8	45.6	46.1	44.7	45.4	43.4
High	41.3	41.6	41.1	41.5	40.9	42.1	40.8	42.3
Missing (n)	2693	4978	2951	2178	2562	4896	2930	1747
Mother: educational level of highest qualification/degree								
Low	10.4	9.2	8.9	8.0	10.2	8.9	8.8	9.2
Middle	37.1	36.8	37.4	37.5	36.7	36.7	37.9	37.6
High	52.4	54.0	53.7	54.5	53.1	54.4	53.3	53.2
Missing (n)	112	798	584	468	95	582	516	301
Municipality group								
Urban	75.9	73.7	71.7	70.9	75.4	73.8	71.6	71.1
Semi-urban	14.6	15.4	16.9	16.5	14.7	15.5	16.8	16.2
Rural	9.5	10.9	11.4	12.6	9.9	10,7	11.6	12.6

Table 2. The prevalence of overweight (including obesity) in children and adolescents, by age group, gender and socioeconomic position of parents, %

	Boys				Girls			
Age group	2–6.99	7–12.99	13–15.99	16–17.99	2–6.99	7–12.99	13–15.99	16–17.99
(N)	34,814	36,229	17,270	11,903	33,459	34,619	16,720	9,409
Overweight	14.2	35.4	30.8	29.0	13.3	28.7	27.6	25.4
Father’s age								
< 30	10.9	33.8	23.3	NA	11.5	32.1	26.5	NA
30-34	12.2	31.1	31.6	20.5	11.9	29.4	30.9	21.9
35-39	14.0	33.1	32.2	32.4	12.5	26.8	30.6	25.6
40-44	14.6	32.5	28.4	30.7	13.4	26.3	26.9	27.1
45-49	18.5	36.7	30.2	27.3	16.2	28.9	25.1	24.8
>= 50	20.0	39.6	30.6	28.3	19.5	30.3	27.7	24.3
Mother’s age								
< 30	12.9	35.2	36.8	NA	12.8	32.6	43.3	NA
30-34	13.1	34.4	31.9	26.7	12.5	30.1	30.6	22.9
35-39	14.8	33.3	32.1	32.8	12.7	27.3	29.6	28.2
40-44	16.6	34.5	29.8	29.6	15.8	27.4	27.4	26.5
45-49	20.6	38.7	30.7	28.2	18.9	30.4	26.8	24.5
>= 50	25.8	42.9	31.2	28.6	27.1	30.7	27.1	25.2
Household's disposable money income								
Low	15.1	36.3	31.7	30.6	13.6	30.6	31.1	28.1
Middle	14.0	35.4	31.0	29.3	13.2	28.5	27.1	25.3

High	11.2	27.3	24.5	22.8	10.8	21.3	20.2	19.8
Father's educational level of highest qualification/degree								
Low	15.9	41.8	36.9	33.3	14.5	34.2	34.6	29.3
Middle	15.4	36.9	34.1	32.1	14.6	31.5	29.7	28.6
High	11.1	29.2	23.5	23.1	10.2	22.3	21.7	19.5
Mother: educational level of highest qualification/degree								
Low	16.8	41.1	37.7	32.9	15.1	34.5	34.7	29.2
Middle	16.4	39.6	34.9	32.4	15.5	33.1	30.8	29.4
High	12.2	31.3	26.8	26.0	11.3	24.7	24.2	22.0
Municipality group								
Urban	13.1	34.0	29.1	28.1	12.1	26.9	26.8	24.6
Semi-urban	17.0	38.6	33.5	30.8	16.0	33.0	27.7	26.0
Rural	19.1	40.2	38.1	31.7	17.8	35.0	32.3	29.7

Table 3. The prevalence of obesity in children and adolescents, by child's age, gender and socio-economic position of parents, %

	Boys				Girls			
Age group	2–6.99	7–12.99	13–15.99	16–17.99	2–6.99	7–12.99	13–15.99	16–17.99
(N)	3,4814	36,229	17,270	11,903	33,459	34,619	16,720	9,409
Obesity	4.2	14.8	12.6	11.6	3.4	8.9	8.2	7.7
Father's age								
< 30	3.0	12.3	9.6	NA	3.5	10.6	8.8	NA
30-34	3.0	12.9	14.1	8.2	2.6	8.7	8.6	8.2
35-39	4.1	12.9	14.4	13.8	3.0	7.7	9.8	9.6
40-44	4.5	12.8	10.4	12.1	3.3	7.5	8.2	7.2
45-49	5.7	15.0	12.0	11.0	5.3	8.8	7.2	7.2
>= 50	6.8	17.3	12.5	10.9	6.2	9.5	8.0	7.5
Mother's age								
< 30	3.8	16.7	21.1	NA	3.3	9.8	16.7	NA
30-34	3.8	14.0	14.2	12.2	3.0	9.5	10.6	7.3
35-39	4.2	13.5	13.6	12.3	3.1	8.0	10.2	10.4
40-44	5.0	14.1	11.2	12.8	4.9	8.4	8.0	8.3
45-49	6.8	16.9	12.4	10.7	5.4	9.7	7.5	6.8
>= 50	6.1	18.9	13.5	11.6	10.2	10.4	7.4	7.9
Household's disposable money income								
Low	4.8	16.7	14.0	14.5	4.0	10.7	10.3	9.8

Middle	4.0	14.4	12.6	11.6	3.2	8.5	7.9	7.7
High	2.0	8.9	7.1	5.0	2.0	4.4	4.1	4.1
Father’s educational level of highest qualification/degree								
Low	5.8	19.5	16.8	15.1	5.0	12.3	11.0	10.4
Middle	4.7	15.8	14.6	14.1	4.1	9.9	9.5	8.9
High	2.5	10.0	7.7	6.8	1.7	5.3	5.2	5.0
Mother: educational level of highest qualification/degree								
Low	6.2	21.3	18.0	16.2	5.1	13.5	11.1	11.1
Middle	5.3	18.1	16.1	15.1	4.6	11.3	10.7	10.1
High	2.9	11.3	9.2	8.5	2.3	6.4	5.9	5.6
Municipality group								
Urban	3.7	13.7	11.1	10.6	2.9	7.9	7.6	7.2
Semi-urban	5.5	17.2	15.2	14.3	4.7	11.0	8.7	8.6
Rural	6.1	18.5	17.6	13.6	5.4	12.5	11.4	9.4

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Review Article

Family socioeconomic status and childhood adiposity in Europe - A scoping review

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ABSTRACT

Childhood obesity is a considerable public health problem worldwide. In Europe, lower parental socioeconomic status (SES) relates to higher childhood adiposity. This scoping review strives to discover, which SES indicators are the most commonly used and meaningful determinants of childhood adiposity (greater level of continuous adiposity indicator, e.g. body mass index z-score, or overweight or obesity categorized by established definitions). The review focused on studies about European general populations from the 21st century (January 2000–April 2021) considering children and adolescents aged 0–17 years. PubMed and reference lists of articles were searched in February–April 2021. Total of 53 studies with 121 association analyses between different SES indicators and adiposity indicators, were identified and reviewed. Different SES indicators were grouped to 25 indicators and further to six indicator groups. The most used indicator was mother's education (n of association analyses = 24) and the most used indicator group was parental education (n of association analyses = 51). Of all association analyses, 55% were inverse, 36% were non-significant, and 8% were positive. Composite SES (80%), parental education (69%) and parental occupation (64%) indicators showed most frequently inverse associations with obesity measures (i.e. lower parental SES associating with higher adiposity), while parental income (50% inverse; 50% non-significant) and property and affluence (42% inverse; 50% nonsignificant) indicators showed approximately even number of inverse and non-significant associations. Instead, majority of parental employment (60%) indicators, showed non-significant associations and 33% showed positive associations (i.e. higher parental SES associating with higher adiposity). Despite some variation in percentages, majority of the associations were inverse in each age group and with different outcome categorizations. In girls and in boys, non-significant associations predominated. It seems that children with parents of higher SES have lower likelihood of adiposity in Europe. Parents' employment appears to differ from other SES indicators, so that having an employed parent(s) does not associate with lower likelihood of adiposity. Positive associations seem to occur more frequently in poorer countries. Criteria for uniform childhood SES and adiposity measures should be established and used in studies in order to be able to produce comparable results across countries.

1. Introduction

Obesity pandemic has reached alarming proportions and affects public health and economy globally. The pandemic does not concern only adults, but obesity has become a serious health risk also in children. According to estimations by the World Health Organization (WHO), overweight and obesity prevalence in children and adolescents aged 5–19 years, has risen from 4% in 1975 to over 18% in 2016 (World Health Organization, 2021). Moreover, 38.2 million children under the age of 5 years had overweight or obesity in 2019. Obesity rates vary between continents and countries; during recent decades, a former problem of developed and westernized countries has passed on to developing countries while rise in obesity rates in Europe has started to level off (NCD Risk Factor Collaboration (NCD-RisC), 2017; Inchley et al., 2020). According to the results of the WHO European Childhood Obesity Surveillance Initiative (COSI), overweight and obesity rates,

Abbreviations: BMI, body mass index; IOTF, International Obesity Task Force; SES, socioeconomic status; WHO, World Health Organization.

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however, vary considerably also in Europe, the rates being the highest in the Mediterranean region (WHO European Childhood Obesity Surveillance Initiative (COSI), 2021).

Children's body composition evolves along with aging and varies between boys and girls. Thus, children's weight status is usually expressed relative to same-sex peers. Several definitions for childhood overweight and obesity exist (Appendix Table A1). The International Obesity Task Force (IOTF) (Cole et al., 2000) and the WHO (de Onis and Lobstein, 2010; de Onis et al., 2007; WHO Multicentre Growth Reference Study Group, 2006) have defined age- and sex-specific cut-off points for overweight and obesity. In addition, several country-specific weight or body mass index (BMI) percentile cut-off points, waist circumference percentile cut-off points (McCarthy et al., 2001), and continuous adiposity variables (e.g. weight, BMI, BMI z-score, fat mass) have been employed. Hence, one uniform definition to enable fully comparable results is lacking.

Obesity is a result from positive energy balance, which usually derives from unfavorable lifestyle habits, i.e. dietary and physical activity habits, but also for instance sleep and sedentary behavior play a role (Verduci et al., 2021). In childhood, family, and growth environment play an important role in creating facilities for such habits and possible development of obesity (Verduci et al., 2021; Notara et al., 2020). In addition to lifestyle habits, some other factors, such as parent's overweight/obesity (Notara et al., 2020; Whitaker et al., 2010), prenatal smoking (Albers et al., 2018) and unfavorable prenatal diet (Meinila et al., 2021) have been associated with increased risk of childhood obesity. Conversely, breastfeeding seems to protect from extra weight (Verduci et al., 2021; Rito et al., 2019). In adults, socioeconomic status (SES) has been shown to have a strong inverse association with dietary and physical activity habits and obesity (Pampel et al., 2010) – the factors that contribute to an increased risk of childhood obesity. Children themselves don't have an actual SES, but usually parents' SES is used to represent children's SES.

Despite the recent European studies demonstrating childhood obesity to be levelling off (NCD Risk Factor Collaboration (NCD-RisC), 2017; Inchley et al., 2020), inequity in obesity appears to persist. Parental SES demonstrates a significant inverse gradient with childhood overweight and obesity in developed and high-income countries (Barriuso et al., 2015; Buoncristiano et al., 2021; Chung et al., 2016). Yet, in developing and medium to low income countries the association seems to have an opposite direction (Buoncristiano et al., 2021; Dinsa et al., 2012; Sobal and Stunkard, 1989). Several indicators of parental SES in relation to childhood adiposity have been examined in numerous original studies, systematic reviews, and meta-analyses (Notara et al., 2020; Barriuso et al., 2015; Chung et al., 2016). Commonly used family-level SES indicators include different indicators on parental education, occupation, employment, and household income, and various affluence indicators. Of these, parental education and occupation seem to be the strongest inverse indicators of childhood adiposity (Notara et al., 2020; Barriuso et al., 2015). However, more detailed information on which indicators associate most often with childhood adiposity, whether the association remains absent or becomes reversed with some indicators, whether definition and collection method of adiposity information count, and whether the associations are divergent among girls and boys and in different age groups, is needed. Hence, aims of this scoping review were to explore, which are the most used childhood SES and adiposity indicators in Europe during the 21st century, which indicators yield most frequently significant results, and whether the results show different distributions in different sub-populations (in boys and in girls and in different age groups) or according to different outcome categorizations (according to different adiposity definitions and according to collection method of adiposity information).

2. Methods

This study employed a scoping review method (Munn et al., 2018; Sucharew and Macaluso, 2019) to provide an overview on which SES and adiposity indicators have been used in studies covering SES disparities in childhood adiposity, and how these different SES indicators are associated with different adiposity indicators. As this review did not conduct research on human subjects, no approval from any ethical review board was applied.

A non-systematic literature search was conducted in February–April 2021 using PubMed and additionally searching reference lists of articles to retrieve possible missing articles. In PubMed, literature search and data extraction were conducted with combinations of the terms "child", "childhood", "adolescent", "adolescence", "obese", "obesity", "adiposity", "overweight", "socioeconomic", "SES", "education", "employment", "occupation", "income", "wealth", "affluence", "inequality", "inequalities", "disparity", "disparities" while using PubMed filters to exclude articles with only adult populations or articles published before 21st century. Inclusion criteria for original articles included: 1) European general population data, 2) Published and data collected between January 2000–April 2021 (trend and follow-up articles with earlier study points were included, but only results from the 21st century were utilized), 3) Participants aged 0–17 years, 4) Articles written in English, 5) Main exposure is a family-level SES indicator (excluding country-, area- or school-level indicators and indexes), and 6) Main outcome is childhood or adolescence adiposity indicator (e.g. weight, BMI, BMI z-score, waist circumference, fat mass, fat mass index, or fat percentage), overweight, obesity, or change in one of the preceding. Of the found articles, those not meeting some of the inclusion criteria were excluded. If several articles used same study data and same SES indicators, only the most recent or comprehensive article was included.

Characteristics of all original articles included are specified in an Appendix Table A2. Results are summarized in Tables 1–4: in Table 1, associations with individual SES indicators; in Table 2, associations with grouped SES indicators in boys and in girls; in Table 3, associations with grouped SES indicators in different age groups; and in Table 4, associations with grouped SES indicators according to different outcome definitions. In these tables, all cross-sectional, trend and follow-up results were combined, and, results were grouped into 'positive', 'no', and 'inverse' associations according to direction and statistical significance of the results. 'Positive' result denoted a finding when SES indicator received ascending values (higher SES) also adiposity indicator received ascending values (greater prevalence/odds/risk of excess adiposity). Conversely, 'inverse' result denoted a finding when SES indicator received ascending values, adiposity indicator received descending values. SES indicators' scale was determined so that higher level denoted longer education or higher degree, less manual or more expertise-demanding occupation, existing employment (vs. unemployed or not working for other reasons) or longer working hours, higher income, greater affluence or more properties. If in one study there were both statistically significant positive or inverse associations, and nonsignificant associations in different subgroups or with different obesity indicators, such studies were grouped according to significant results omitting nonsignificant findings.

3. Results

Altogether 53 original articles were selected covering data from 23 European countries (Table A2) (Bammann et al., 2013; Bibiloni Mdel et al., 2010; Bouthoorn et al., 2014; Bramsved et al., 2018; Farajian et al., 2013; Fernandez-Alvira et al., 2013; Gil and Takourabt, 2017; Grazuleviciene et al., 2017; Grøholt et al., 2008; Hargreaves et al., 2013; Hawkins et al., 2008; Hilpert et al., 2017; Huus et al., 2007; Iguacel et al., 2018; Keane et al., 2012; Khanolkar et al., 2012; Klein-Platat et al., 2003; Kleiser et al., 2009; Lamerz et al., 2005; Lazzeri et al., 2017; Lien et al., 2007; Lioret et al., 2009; Lissner et al., 2016; Magnusson et al., 2008; Matijasevich et al., 2009; Matthiessen et al., 2014; Mikolajczyk and Richter, 2008; Miqueleiz et al., 2014; Moschonis et al., 2010;

Table 1
Associations between SES indicators and childhood adiposity.

	Association with adiposity									
	Total n of association analyses	Positive[a]			No			Inverse[b]		
SES indicator[c]		References	n	%	References	n	%	References	n	%
Composite SES variables[d]	**5**	–	–	–	(Valerio et al., 2006)	1	20	(Bammann, et al, 2013) (Kleiser et al., 2009) (Lioret et al., 2009) (Stamatakis et al., 2010)	4	80
Parental education										
Both parents' education[e]	15	–	–	–	(Gil and Takourabt, 2017) (Salanave et al., 2009) (Sanchez-Cruz et al., 2018)	3	20	(Bammann, et al, 2013) (Bibiloni Mdel et al., 2010) (Bramsved et al., 2018) (Fernandez-Alvira et al., 2013) (Hilpert et al., 2017) (Lien et al., 2007) (Lioret et al., 2009) (Matthiessen et al., 2014) (Miqueleiz et al., 2014) (Nogueira et al., 2013) (Rodrigues et al., 2021) (Stuart and Panico, 2016)	12	80
Mother's education	24	(Patel et al., 2018) (Yardim et al., 2019)	2	8	(Farajian et al., 2013) (Lissner et al., 2016) (Moschonis et al., 2010) (Rotevatn et al., 2019)	4	17	(Bouthoorn et al., 2014) (Grazuleviciene et al., 2017) (Huus et al., 2007) (Keane et al., 2012) (Khanolkar et al., 2012) (Klein-Platat et al., 2003) (Lamerz et al., 2005) (Magnusson et al., 2008) (Matijasevich et al., 2009) (Matthiessen et al., 2014) (Nagel et al., 2009) (Oude Groeniger et al., 2020) (Ruijsbroek et al., 2011) (Semmler et al., 2009) (Valerio et al., 2006) (van den Berg et al., 2013) (van Vliet et al., 2015) (Veldhuis et al., 2013)	18	75
Father's education	12	(Patel et al., 2018)	1	8	(Farajian et al., 2013) (Klein-Platat et al., 2003) (Lamerz et al., 2005) (Lissner et al., 2016) (Matthiessen et al., 2014) (Moschonis et al., 2010)	6	50	(Huus et al., 2007) (Khanolkar et al., 2012) (Magnusson et al., 2008) (Nagel et al., 2009) (van Vliet et al., 2015)	5	42
All parental education indicators combined	***51***	–	***3***	***5.9***	–	***13***	***25.5***	–	***35***	***68.6***
Parental occupation										
Both parents' occupation[e]	15	(Patel et al., 2018)	1	7	(Lien et al., 2007) (Lioret et al., 2009) (Mikolajczyk and Richter, 2008) (Sanchez-Cruz et al., 2018) (Sweeting et al., 2008)	5	33	(Bammann, et al, 2013) (Bibiloni Mdel et al., 2010) (Gil and Takourabt, 2017) (Hargreaves et al., 2013) (Keane et al., 2012) (Ness et al., 2006) (Salanave et al., 2009) (Thibault et al., 2013) (Wijlaars et al., 2011)	9	60
Mother's occupation	4	–	–	–	(Farajian et al., 2013)	1	25	(Khanolkar et al., 2012) (Mutunga et al., 2006) (van Vliet et al., 2015)	3	75
Father's occupation	3	–	–	–	(Khanolkar et al., 2012)	1	33	(Farajian et al., 2013) (van Vliet et al., 2015)	2	67
All parental occupation indicators combined	***22***	–	***1***	***4.5***	–	***7***	***31.8***	–	***14***	***63.6***
Parental employment										
Both parents' employment[e]	3	–	–	–	(Sanchez-Cruz et al., 2018) (Taylor et al., 2005)	2	67	(Iguacel et al., 2018)	1	33
Mother's employment	5	(Hawkins et al., 2008) (Lissner et al., 2016) (Yardim et al., 2019)	3	60	(Farajian et al., 2013) (Lamerz et al., 2005)	2	40	–	–	–
Father's employment	3	(Lissner et al., 2016)	1	33	(Hawkins et al., 2008) (Lamerz et al., 2005)	2	67	–	–	–
Mother's duration of employment	1	–	–	–	(Hawkins et al., 2008)	1	100	–	–	–
Father's duration of employment	1	–	–	–	(Hawkins et al., 2008)	1	100	–	–	–
Mother's working hours	1	(Hawkins et al., 2008)	1	100	–	–	–	–	–	–
Father's working hours	1	–	–	–	(Hawkins et al., 2008)	1	100	–	–	–

(*continued on next page*)

Table 1 (*continued*)

SES indicator[c]	Total n of association analyses	Association with adiposity: Positive[a] References	n	%	No References	n	%	Inverse[b] References	n	%
All parental employment indicators combined	***15***	–	***5***	***33.3***	–	***9***	***60.0***	–	***1***	***6.7***
Parental income										
Both parents' income[e]	12	–	–	–	(Bramsved et al., 2018) (Farajian et al., 2013) (Keane et al., 2012) (Klein-Platat et al., 2003) (Lien et al., 2007)	5	42	(Bammann, et al, 2013) (Bouthoorn et al., 2014) (Matijasevich et al., 2009) (Moschonis et al., 2010) (Rotevatn et al., 2019) (Stamatakis et al., 2010) (Stuart and Panico, 2016)	7	58
Mother's income	1	–	–	–	(Magnusson et al., 2008)	1	100	–	–	–
Father's income	1	–	–	–	(Magnusson et al., 2008)	1	100	–	–	–
All parental income indicators combined	***14***	–	–	–	–	***7***	***50.0***	–	***7***	***50.0***
Properties and affluence										
FAS, wealth and affluence composite variables	4	–	–	–	–	–	–	(Lazzeri et al., 2017) (Lioret et al., 2009) (Mikolajczyk and Richter, 2008) (Sigmund et al., 2018)	4	100
House ownership	2	–	–	–	(Farajian et al., 2013) (Moschonis et al., 2010)	2	100	–	–	–
Living space/lack of space	2	–	–	–	(Lamerz et al., 2005) (Taylor et al., 2005)	2	100	–	–	–
Car ownership/n of cars	2	(Taylor et al., 2005)	1	50	(Farajian et al., 2013)	1	50	–	–	–
Persistent poverty	1	–	–	–	(Stuart and Panico, 2016)	1	100	–	–	–
Subjective perceptions on sufficiency of money	1	–	–	–	–	–	–	(Grøholt et al., 2008)	1	100
All properties and affluence indicators combined	***12***	–	***1***	***8.3***	–	***6***	***50.0***	–	***5***	***41.7***
Eligibility to free school meals	1	–	–	–	(Taylor et al., 2005)	1	100	–	–	–
Child's/adolescent's educational plans	1	–	–	–	–	–	–	(Grøholt et al., 2008)	1	100
All indicators combined	***121***		***10***	***8.3***		***44***	***36.4***		***67***	***55.4***

Underlined n and percentage values denote the most frequent association for SES indicator in question (not applied if only one study exists). Statistical significance not tested.

Abbreviations: FAS, Family Affluence Scale; SES, socioeconomic status;

[a] Positive association denotes associations where while SES indicator receives ascending levels, also adiposity indicator receives ascending levels. This category includes studies where there are only statistically significant positive associations or both significant positive and nonsignificant associations in different subgroups or with different adiposity indicators.

[b] Inverse association denotes associations where while SES indicator receives ascending levels, adiposity indicator receives descending levels. This category includes studies where there are only statistically significant negative associations or both significant negative and nonsignificant associations in different subgroups or with different adiposity indicators.

[c] Higher level in SES indicator denotes: Longer education or higher degree, less manual or more expertise-demanding occupation, existing employment or longer working hours, higher income, greater affluence or more properties

[d] Excluding composite variables based only on wealth and affluence.

[e] Variable is based on higher or lower level of either parent or composite variable from both parents' levels.

Mutunga et al., 2006; Nagel et al., 2009; Ness et al., 2006; Nogueira et al., 2013; Oude Groeniger et al., 2020; Patel et al., 2018; Rodrigues et al., 2021; Rotevatn et al., 2019; Ruijsbroek et al., 2011; Salanave et al., 2009; Sanchez-Cruz et al., 2018; Semmler et al., 2009; Sigmund et al., 2018; Stamatakis et al., 2010; Stuart and Panico, 2016; Sweeting et al., 2008; Taylor et al., 2005; Thibault et al., 2013; Valerio et al., 2006; van den Berg et al., 2013; van Vliet et al., 2015; Veldhuis et al., 2013; Wijlaars et al., 2011; Yardim et al., 2019). Number of participants in the studies ranged approximately between 300 and 20,000. Age of the participants in the studies varied from newborns to teenagers. Cross-sectional ($n = 34$), follow-up ($n = 10$) and trend ($n = 9$) study settings were employed. In this review, all results of different settings are combined in same summaries. Likewise, results produced with different statistical methods and presented in different measures of association are combined. The results from the final adjustment model are utilized.

In almost all studies, SES indicators were self-reported by participants' parents or participants themselves. In only three studies SES data was obtained from registers. Individual SES indicators were grouped to

Table 2
Associations between SES indicators and childhood adiposity according to sex.

SES indicator[c] according to sex[c]	Total n of association analyses	Association with adiposity: Positive[a] References	n	%	No References	n	%	Inverse[b] References	n	%
Boys										
Composite SES variables[d, e]	1	–	–	–	–	–	–	(Stamatakis et al., 2010)	1	100
Parental education[d]	9	(Patel et al., 2018)	1	11	(Farajian et al., 2013) (Lissner et al., 2016)	2	22	(Bibiloni Mdel et al., 2010) (Lien et al., 2007) (Matijasevich et al., 2009) (Matthiessen et al., 2014) [f] (Miqueleiz et al., 2014) (van Vliet et al., 2015)	6	67
Parental occupation[d]	6	(Patel et al., 2018)	1	17	(Bibiloni Mdel et al., 2010) (Farajian et al., 2013) (Lien et al., 2007) (Sweeting et al., 2008)	4	67	(van Vliet et al., 2015)	1	17
Parental employment[d]	3	(Lissner et al., 2016)	1	33	(Farajian et al., 2013) (Taylor et al., 2005)	2	67	–	–	–
Parental income[d]	4	–	–	–	(Farajian et al., 2013) (Lien et al., 2007) (Matijasevich et al., 2009) (Farajian et al., 2013) (Taylor et al., 2005)	3	75	(Stamatakis et al., 2010)	1	25
Properties and affluence[d]	4	–	–	–	(Farajian et al., 2013) (Taylor et al., 2005)	2	50	(Lazzeri et al., 2017) (Sigmund et al., 2018)	2	50
All indicators combined	***27***		***3***	***11.1***		***13***	***48.1***		***11***	***40.7***
Girls										
Composite SES variables[d, e]	1	–	–	–	–	–	–	(Stamatakis et al., 2010)	1	100
Parental education[d]	9	(Patel et al., 2018)	1	11	(Farajian et al., 2013) (Lien et al., 2007) (Lissner et al., 2016) (Matthiessen et al., 2014) (van Vliet et al., 2015)	5	56	(Bibiloni Mdel et al., 2010) (Matijasevich et al., 2009) (Miqueleiz et al., 2014)	3	33
Parental occupation[d]	6	(Patel et al., 2018)	1	17	(Lien et al., 2007) (Sweeting et al., 2008)	2	33	(Bibiloni Mdel et al., 2010) (Farajian et al., 2013) [f] (van Vliet et al., 2015) [f]	3	50
Parental employment[d]	3	(Lissner et al., 2016)	1	33	(Farajian et al., 2013) (Taylor et al., 2005)	2	67	–	–	–
Parental income[d]	4	–	–	–	(Farajian et al., 2013) (Lien et al., 2007)	2	50	(Matijasevich et al., 2009) (Stamatakis et al., 2010)	2	50
Properties and affluence[d]	4	[f] (Taylor et al., 2005) [f]	1	25	(Farajian et al., 2013)	1	25	(Lazzeri et al., 2017) (Sigmund et al., 2018)	2	50
All indicators combined	***27***		***4***	***14.8***		***12***	***44.4***		***11***	***40.7***

Underlined percentage values denote the most frequent association for SES indicator in question (not applied if only one study exists). Statistical significance not tested.
Abbreviations: SES, socioeconomic status;

[a] Positive association denotes associations where while SES indicator receives ascending levels, also adiposity indicator receives ascending levels. This category includes studies where there are only statistically significant positive associations or both significant positive and nonsignificant associations in different subgroups or with different adiposity indicators.

[b] Inverse association denotes associations where while SES indicator receives ascending levels, adiposity indicator receives descending levels. This category includes studies where there are only statistically significant negative associations or both significant negative and nonsignificant associations in different subgroups or with different adiposity indicators.

[c] Higher level in SES indicator denotes: Longer education or higher degree, less manual or more expertise-demanding occupation, existing employment or longer working hours, higher income, greater affluence or more properties

[d] All variables in category in question

[e] Excluding composite variables based only on wealth and affluence.

[f] Several variables in the same study in the same indicator group: Significant association acknowledged, and nonsignificant association disregarded.

25 indicators (Table 1) and further to six indicator groups: composite SES indicators, parental education, parental occupation, parental employment, parental income, properties and affluence (Tables 1–4).

Several different continuous adiposity indicators (i.e. weight, BMI, BMI-z-score, fat mass, fat mass index), weight change or overweight/obesity indicators were used in the studies. Overweight/obesity were defined using the International Obesity Task Force (IOTF) cut-off points (Cole et al., 2000), the WHO cut-off points based on percentiles or standard deviations (SD) (de Onis and Lobstein, 2010; de Onis et al., 2007; WHO Multicentre Growth Reference Study Group, 2006), country-specific percentile cut-off points, or waist-circumference percentile cut-off points (McCarthy et al., 2001).

A total of 121 association analyses between SES indicators and adiposity indicator, weight change or overweight/obesity were reviewed. When combining all association analyses together, 55% were inverse (higher value in SES indicator associated with lower adiposity status), 36% were non-significant and 8% were positive (higher value in SES indicator associated with higher adiposity status) (Table 1, Fig. 1). The most used individual indicator was maternal education (24 association analyses) which also had most commonly inverse association with outcome measures when considering number of associations (18 inverse/4 no/2 positive associations). When considering percentages of the associations, composite SES indicators, both parents' education, mother's education, mother's occupation and wealth and affluence composite indicators showed most strong inverse associations with outcome measures (75% or more of the associations inverse). Non-significant associations occurred mostly with father's education, both parents' employment, and father's employment indicators. Only

Table 3
Associations between SES indicators and childhood adiposity according to age groups.

SES indicator[c] according to age groups	Total n of association analyses	Association with adiposity: Positive[a] References	n	%	No References	n	%	Inverse[b] References	n	%
0–10 years										
Composite SES variables[d, e]	3	–	–	–	(Valerio et al., 2006)	1	33	(Bammann, et al, 2013) (Stamatakis et al., 2010)	2	67
Parental education [d]	21	(Patel et al., 2018)	1	5	(Lissner et al., 2016) (Miqueleiz et al., 2014) (Rotevatn et al., 2019) (Salanave et al., 2009)	4	19	(Bammann, et al, 2013) (Bouthoorn et al., 2014) (Bramsved et al., 2018) (Grazuleviciene et al., 2017) (Hilpert et al., 2017) (Huus et al., 2007) (Keane et al., 2012) (Lamerz et al., 2005) [f] (Magnusson et al., 2008) (Nagel et al., 2009) (Nogueira et al., 2013) (Rodrigues et al., 2021) (Ruijsbroek et al., 2011) (Valerio et al., 2006) (van den Berg et al., 2013) (Veldhuis et al., 2013)	16	76
Parental occupation[d]	7	(Patel et al., 2018)	1	14	–	–	–	(Bammann, et al, 2013) (Keane et al., 2012) (Ness et al., 2006) (Salanave et al., 2009) (Thibault et al., 2013) (Wijlaars et al., 2011)	6	86
Parental employment[d]	4	(Hawkins et al., 2008) [f] (Lissner et al., 2016)	2	50	(Lamerz et al., 2005)	1	25	(Iguacel et al., 2018)	1	25
Parental income[d]	7	–	–	–	(Bramsved et al., 2018) (Keane et al., 2012) (Magnusson et al., 2008)	3	43	(Bammann, et al, 2013) (Bouthoorn et al., 2014) (Rotevatn et al., 2019) (Stamatakis et al., 2010)	4	57
Properties and affluence[d]	1	–	–	–	(Lamerz et al., 2005)	1	100	–	–	–
All indicators combined	***43***		***4***	***9.3***		***10***	***23.3***		***29***	***67.4***
10–17 years										
Composite SES variables[d, e]	–	–	–	–	–	–	–	–	–	–
Parental education[d]	10	–	–	–	(Farajian et al., 2013)	1	10	(Bibiloni Mdel et al., 2010) (Fernandez-Alvira et al., 2013) (Klein-Platat et al., 2003) [f] (Lien et al., 2007) (Matijasevich et al., 2009) (Miqueleiz et al., 2014) (Oude Groeniger et al., 2020) (Semmler et al., 2009) (van Vliet et al., 2015) [f]	9	90
Parental occupation[d]	7	–	–	–	(Lien et al., 2007) (Mikolajczyk and Richter, 2008) (Mutunga et al., 2006) (Sweeting et al., 2008)	4	57	(Bibiloni Mdel et al., 2010) (Farajian et al., 2013) [f] (van Vliet et al., 2015) [f]	3	43
Parental employment[d]	2	–	–	–	(Farajian et al., 2013) (Taylor et al., 2005)	2	100	–	–	–
Parental income[d]	4	–	–	–	(Farajian et al., 2013) (Klein-Platat et al., 2003) (Lien et al., 2007)	3	75	(Matijasevich et al., 2009)	1	25
Properties and affluence[d]	6	(Taylor et al., 2005) [f]	1	17	(Farajian et al., 2013)	1	17	(Grøholt et al., 2008) (Lazzeri et al., 2017) (Mikolajczyk and Richter, 2008) (Sigmund et al., 2018)	4	67
All indicators combined	***29***		***1***	***3.4***		***11***	***37.9***		***17***	***58.6***
0–17 years [g]										
Composite SES variables[d, e]	2	–	–	–	–	–	–	(Kleiser et al., 2009) (Lioret et al., 2009)	2	100
Parental education[d]	9	(Yardim et al., 2019)	1	11	(Gil and Takourabt, 2017) (Moschonis et al., 2010) (Sanchez-Cruz et al., 2018)	3	33	(Khanolkar et al., 2012) (Lioret et al., 2009) (Matthiessen et al., 2014) [f] (Stuart and Panico, 2016) (van Vliet et al., 2015) [f]	5	56
Parental occupation[d]	7	–	–	–	(Lioret et al., 2009) (Sanchez-Cruz et al., 2018)	2	29	(Gil and Takourabt, 2017) (Hargreaves et al., 2013) (Khanolkar et al., 2012) [f] (Thibault et al., 2013) (van Vliet et al., 2015)	5	71
Parental employment[d]	2	(Yardim et al., 2019)	1	50	(Sanchez-Cruz et al., 2018)	1	50	–	–	–
Parental income[d]	2	–	–	–	–	–	–	(Moschonis et al., 2010) (Stuart and Panico, 2016)	2	100
Properties and affluence[d]	3	–	–	–	(Moschonis et al., 2010) (Stuart and Panico, 2016)	2	67	(Lioret et al., 2009)	1	33
All indicators combined	***25***		***2***	***8.0***		***8***	***32.0***		***15***	***60.0***

Underlined percentage values denote the most frequent association for SES indicator in question (not applied if only one study exists). Statistical significance not tested.
Abbreviations: SES, socioeconomic status;

[a] Positive association denotes associations where while SES indicator receives ascending levels, also adiposity indicator receives ascending levels. This category includes studies where there are only statistically significant positive associations or both significant positive and nonsignificant associations in different subgroups or with different adiposity indicators.

[b] Inverse association denotes associations where while SES indicator receives ascending levels, adiposity indicator receives descending levels. This category includes studies where there are only statistically significant negative associations or both significant negative and nonsignificant associations in different subgroups or with different adiposity indicators.

[c] Higher level in SES indicator denotes: Longer education or higher degree, less manual or more expertise-demanding occupation, existing employment or longer working hours, higher income, greater affluence or more properties

[d] All variables in category in question

[e] Excluding composite variables based only on wealth and affluence.

[f] Several variables in the same study in the same indicator group: Significant association acknowledged, and nonsignificant association disregarded.

[g] Age-range varying between 0 and 17 years and not fitting into other age-categories.

mother's employment showed commonly positive associations with outcome. When looking into indicator groups, indicators belonging to the parental education indicator group were most frequently used (51 association analyses). Parental education and parental occupation groups showed the most inverse associations with outcome, parental income indicators showed even number of inverse and non-significant associations, and parental employment group and properties and affluence group showed mostly non-significant associations (Fig. 1).

A total of 14 studies presented results separately for girls and boys with altogether 27 association analyses for each sex (Table 2). In these summaries, results are presented only for grouped SES indicators due to more limited number of association analyses. When combining all association analyses, in boys 48% were non-significant, 41% were inverse and 11% were positive, while in girls 44% were non-significant, 41% were inverse and 15% were positive. Parental education was the most frequently used SES indicator in these studies (9 association analyses for each sex). In boys, parental education indicator group showed mostly inverse associations, whereas in girls, parental occupation and properties and affluence groups showed a slight majority of inverse associations. Rest of the indicator groups showed mostly non-significant associations or even number of non-significant and inverse associations.

The included studies presented results according to relatively heterogenous age-groups. In this review the age groups were roughly categorized into 0–10 year-olds, 10–17 year-olds, and 0–17 year-olds (i.e. heterogenous age-group: age-range varying between 0 and 17 years and not fitting into the other age-categories) (Table 3). Concerning the younger age-group, 43 association analyses were conducted with 67% being inverse, 23% non-significant and 9% positive. The older age-group totaled 29 association analyses, and the corresponding percentage values were 59%, 38% and 3%. Respectively, of 25 association analyses in the heterogenous age-group, the percentage values were 60%, 32% and 8%. The most frequently used SES indicator in each age-group was parental education, which also showed most commonly inverse associations in each group. Parental occupation showed most commonly inverse associations in the younger age-group and in the heterogenous age-group, but not in the older age group where the associations were most commonly non-significant.

The IOTF cut-offs were the most used criteria to define overweight/obesity with 31 studies utilizing the criteria. Of these studies, altogether 27 studies with 54 association analyses for different SES indicators presented results for overweight (including obesity) and 17 studies with 22 association analyses for obesity (Table 4). Among studies using IOTF-defined overweight as an outcome, when combining all association analyses, 57% were inverse, 41% were non-significant, and 0.2% were positive. Respective percentages for IOTF-defined obesity were 77% (inverse), 23% (non-significant), and 0% (positive). With both outcomes, composite SES indicators, parental education, and parental occupation showed most commonly inverse associations, while parental income and properties and affluence showed most commonly non-significant associations. Moreover, parental employment and childhood overweight showed most commonly non-significant associations, while association analyses with childhood obesity were non-existent. Noteworthy was, that all 11 association analyses between parental education and IOTF-defined obesity were inverse.

Altogether eight studies with 16 association analyses employed childhood overweight or obesity definitions based on WHO criteria (Table 4). Due to relatively small number of association analyses, scrutiny of such studies was conducted combining overweight and obesity outcomes. A slight majority of all association analyses showed an inverse association between SES indicators and overweight/obesity outcomes defined according to the WHO criteria (38%), with nearly thirds showing non-significant (31%) and positive (31%) associations.

The results were also categorized according to a collection method of adiposity information (Table 4). The information was collected by measurements in 41 studies and by participants' or parents' self-reports in 12 studies. The studies using measured adiposity information contained 77 association analyses between SES indicators and outcomes: 60% were inverse, 31% were non-significant and 9% were positive. Composite SES indicators, parental education, parental occupation, and parental income showed most frequently inverse associations, while parental employment and properties and affluence indicators showed most non-significant associations. The studies with self-reported adiposity information contained 16 association analyses between SES indicators and outcomes of which 75% were inverse and 25% were non-significant.

According to The World Bank classification (The World Bank, 2022) most of the studies included were conducted based on populations from high-income countries, and only three utilized data entirely or partly from upper-middle-income economies (Lissner et al., 2016; Patel et al., 2018; Yardim et al., 2019). All these three studies yielded mostly positive and some non-significant associations between SES indicators (parental education, occupation and employment) and adiposity.

4. Discussion

The aim of this scoping review was to summarize information on socioeconomic inequalities in childhood adiposity in Europe in the 21st century, to explore which SES and adiposity indicators are commonly used, which indicators yield commonly inverse associations, and whether the distribution of results differs according to different subpopulations or categorizations of outcome variables. Findings of this review affirmed results of the previous studies and reviews indicating an inverse association between SES and childhood adiposity in Western and high-income countries, so that children with parents with lower SES have greater likelihood of adiposity (Barriuso et al., 2015; Buoncristiano et al., 2021; Chung et al., 2016). Moreover, this review revealed differences in associations depending on SES indicator used, on sex and age of the population, and on categorization and measurement method of the outcome variable.

In line with previous literature, this review demonstrated different parental education and occupation indicators to be the commonly used SES indicators, and of the different indicators, education showed frequently inverse associations with childhood adiposity (Notara et al., 2020; Barriuso et al., 2015; Shrewsbury and Wardle, 2008). Excess

Table 4
Associations between SES indicators and childhood adiposity according to different categorizations.

SES indicator[c] according to different outcome categorizations	Total n of association analyses	Association with adiposity: Positive[a] References	n	%	No References	n	%	Inverse[b] References	n	%
Adiposity according to IOTF										
OW (including OB)										
Composite SES variables[d, e]	3	–	–	–	–	–	–	(Bammann, et al, 2013) (Lioret et al., 2009) (Stamatakis et al., 2010)	3	100
Parental education[d]	22	–	–	–	(Bramsved et al., 2018) (Farajian et al., 2013) (Gil and Takourabt, 2017) (Keane et al., 2012) (Moschonis et al., 2010) (Salanave et al., 2009) (Sanchez-Cruz et al., 2018) (Stuart and Panico, 2016)	8	36	(Bammann, et al, 2013) (Grazuleviciene et al., 2017) (Huus et al., 2007) (Khanolkar et al., 2012) (Klein-Platat et al., 2003) [f] (Lien et al., 2007) (Lioret et al., 2009) (Matthiessen et al., 2014) [f] (Miqueleiz et al., 2014) (Nagel et al., 2009) (Rodrigues et al., 2021) (Ruijsbroek et al., 2011) (van Vliet et al., 2015) [f] (Veldhuis et al., 2013)	14	64
Parental occupation[d]	11	–	–	–	(Keane et al., 2012) (Lien et al., 2007) (Lioret et al., 2009) (Sanchez-Cruz et al., 2018)	4	36	(Bammann, et al, 2013) (Farajian et al., 2013) [f] (Gil and Takourabt, 2017) (Khanolkar et al., 2012) [f] (Salanave et al., 2009) (Thibault et al., 2013) (van Vliet et al., 2015)	7	64
Parental employment[d]	4	(Hawkins et al., 2008) [f]	1	25	(Farajian et al., 2013) (Sanchez-Cruz et al., 2018)	2	50	(Iguacel et al., 2018)	1	25
Parental income[d]	9	–	–	–	(Bramsved et al., 2018) (Farajian et al., 2013) (Keane et al., 2012) (Klein-Platat et al., 2003) (Lien et al., 2007)	5	56	(Bammann, et al, 2013) (Moschonis et al., 2010) (Stamatakis et al., 2010) (Stuart and Panico, 2016)	4	44
Properties and affluence[d]	5	–	–	–	(Farajian et al., 2013) (Moschonis et al., 2010) (Stuart and Panico, 2016)	3	60	(Grøholt et al., 2008) (Lioret et al., 2009)	2	40
All indicators combined	***54***	–	***1***	***0.2***	–	***22***	***40.7***	–	***31***	***57.4***
OB										
Composite SES variables[d, e]	2	–	–	–	–	–	–	(Kleiser et al., 2009) (Stamatakis et al., 2010)	2	100
Parental education[d]	11	–	–	–	–	–	–	(Bramsved et al., 2018) (Huus et al., 2007) [f] (Keane et al., 2012) (Miqueleiz et al., 2014) (Nagel et al., 2009) [f] (Nogueira et al., 2013) (Oude Groeniger et al., 2020) (Rodrigues et al., 2021) (Ruijsbroek et al., 2011) (Stuart and Panico, 2016) (Veldhuis et al., 2013)	11	100
Parental occupation[d]	2	–	–	–	–	–	–	(Keane et al., 2012) (Thibault et al., 2013)	2	100
Parental employment[d]	–	–	–	–	–	–	–	–	–	–
Parental income[d]	4	–	–	–	(Bramsved et al., 2018) (Keane et al., 2012) (Stuart and Panico, 2016)	3	75	(Stamatakis et al., 2010)	1	25
Properties and affluence[d]	3	–	–	–	(Grøholt et al., 2008) (Stuart and Panico, 2016)	2	66.7	(Lazzeri et al., 2017)	1	33.3
All indicators combined	***22***	–	–	–	–	***5***	***22.7***	–	***17***	***77.3***
Adiposity according to WHO criteria[g]										
OW or OB										
Composite SES variables[d, e]	–	–	–	–	–	–	–	–	–	–
Parental education[d]	7	(Patel et al., 2018) (Yardim et al., 2019)	2	29	(Lissner et al., 2016) (Rotevatn et al., 2019) (Sanchez-Cruz et al., 2018)	3	43	(Bibiloni Mdel et al., 2010) (Matijasevich et al., 2009)	2	29
Parental occupation[d]	3	(Patel et al., 2018)	1	33	(Sanchez-Cruz et al., 2018)	1	33	(Bibiloni Mdel et al., 2010)	1	33
Parental employment[d]	3	(Lissner et al., 2016) (Yardim et al., 2019)	2	67	(Sanchez-Cruz et al., 2018)	1	33	–	–	–
Parental income[d]	2	–	–	–	–	–	–		2	100

(continued on next page)

Table 4 (*continued*)

SES indicator[c] according to different outcome categorizations	Total n of association analyses	Association with adiposity: Positive[a] References	n	%	No References	n	%	Inverse[b] References	n	%
Properties and affluence[d]	1	–	–	–	–	–	–	(Matijasevich et al., 2009) (Rotevatn et al., 2019) (Sigmund et al., 2018)	1	100
All indicators combined	***16***	–	***5***	***31***	–	***5***	***31***	–	***6***	***38***
Collection method of adiposity information										
Measured OW or OB										
Composite SES variables[d, e]	5	–	–	–	(Valerio et al., 2006)	1	20	(Bammann, et al, 2013) (Kleiser et al., 2009) (Lioret et al., 2009) (Stamatakis et al., 2010)	4	80
Parental education[d]	31	(Patel et al., 2018) (Yardim et al., 2019)	2	6	(Farajian et al., 2013) (Lissner et al., 2016) (Moschonis et al., 2010) (Rotevatn et al., 2019) (Salanave et al., 2009) (Sanchez-Cruz et al., 2018)	6	19	(Bammann, et al, 2013) (Bibiloni Mdel et al., 2010) (Bouthoorn et al., 2014) (Bramsved et al., 2018) (Fernandez-Alvira et al., 2013) (Hilpert et al., 2017) (Keane et al., 2012) (Khanolkar et al., 2012) (Klein-Platat et al., 2003) [f] (Lamerz et al., 2005) [f] (Lioret et al., 2009) (Magnusson et al., 2008) (Matijasevich et al., 2009) (Nagel et al., 2009) (Nogueira et al., 2013) (Oude Groeniger et al., 2020) (Rodrigues et al., 2021) (Semmler et al., 2009) (Stuart and Panico, 2016) (Valerio et al., 2006) (van den Berg et al., 2013) (van Vliet et al., 2015) (Veldhuis et al., 2013)	23	74
Parental occupation[d]	15	(Patel et al., 2018)	1	7	(Lioret et al., 2009) (Mutunga et al., 2006) (Sanchez-Cruz et al., 2018) (Sweeting et al., 2008)	4	27	(Bammann, et al, 2013) (Bibiloni Mdel et al., 2010) (Farajian et al., 2013) [f] (Hargreaves et al., 2013) (Keane et al., 2012) (Khanolkar et al., 2012) [f] (Ness et al., 2006) (Salanave et al., 2009) (Thibault et al., 2013) (van Vliet et al., 2015)	10	67
Parental employment[d]	8	(Hawkins et al., 2008) [f] (Lissner et al., 2016) (Yardim et al., 2019)	3	38	(Farajian et al., 2013) (Lamerz et al., 2005) (Sanchez-Cruz et al., 2018) (Taylor et al., 2005)	4	50	(Iguacel et al., 2018)	1	13
Parental income[d]	12	–	–	–	(Bramsved et al., 2018) (Farajian et al., 2013) (Keane et al., 2012) (Klein-Platat et al., 2003) (Magnusson et al., 2008)	5	42	(Bammann, et al, 2013) (Bouthoorn et al., 2014) (Matijasevich et al., 2009) (Moschonis et al., 2010) (Rotevatn et al., 2019) (Stamatakis et al., 2010) (Stuart and Panico, 2016)	7	58
Properties and affluence[d]	6	[f] (Taylor et al., 2005) [f]	1	17	(Farajian et al., 2013) (Lamerz et al., 2005) (Moschonis et al., 2010) (Stuart and Panico, 2016)	4	67	(Lioret et al., 2009)	1	17
All indicators combined	***77***		***7***	***9.1***		***24***	***31.2***		***46***	***59.7***
Parents' or participants' self-reported OW or OB										
Composite SES variables[d, e]	–	–	–	–	–	–	–	–	–	–
Parental education[d]	7	–	–	–	(Gil and Takourabt, 2017)	1	14	(Grazuleviciene et al., 2017) (Huus et al., 2007) (Lien et al., 2007) (Matthiessen et al., 2014) [f] (Miqueleiz et al., 2014) (Ruijsbroek et al., 2011)	6	86
Parental occupation[d]	4	–	–	–	(Lien et al., 2007) (Mikolajczyk and Richter, 2008)	2	50	(Gil and Takourabt, 2017) (Wijlaars et al., 2011)	2	50
Parental employment[d]	–	–	–	–	–	–	–	–	–	–
Parental income[d]	1	–	–	–	(Lien et al., 2007)	1	100	–	–	–
Properties and affluence[d]	4	–	–	–	–	–	–	(Grøholt et al., 2008) (Lazzeri et al., 2017) (Mikolajczyk and Richter, 2008) (Sigmund et al., 2018)	4	100
All indicators combined	***16***	–	–	–		***4***	***25.0***		***12***	***75.0***

Underlined percentage values denote the most frequent association for SES indicator in question (not applied if only one study exists). Statistical significance not tested. Abbreviations: IOTF, International Obesity Task Force; OB, obesity; OW, overweight; SES, socioeconomic status; WHO, World Health Organization.

[a] Positive association denotes associations where while SES indicator receives ascending levels, also adiposity indicator receives ascending levels. This category includes studies where there are only statistically significant positive associations or both significant positive and nonsignificant associations in different subgroups or with different adiposity indicators.

[b] Inverse association denotes associations where while SES indicator receives ascending levels, adiposity indicator receives descending levels. This category includes studies where there are only statistically significant negative associations or both significant negative and nonsignificant associations in different subgroups or with different adiposity indicators.

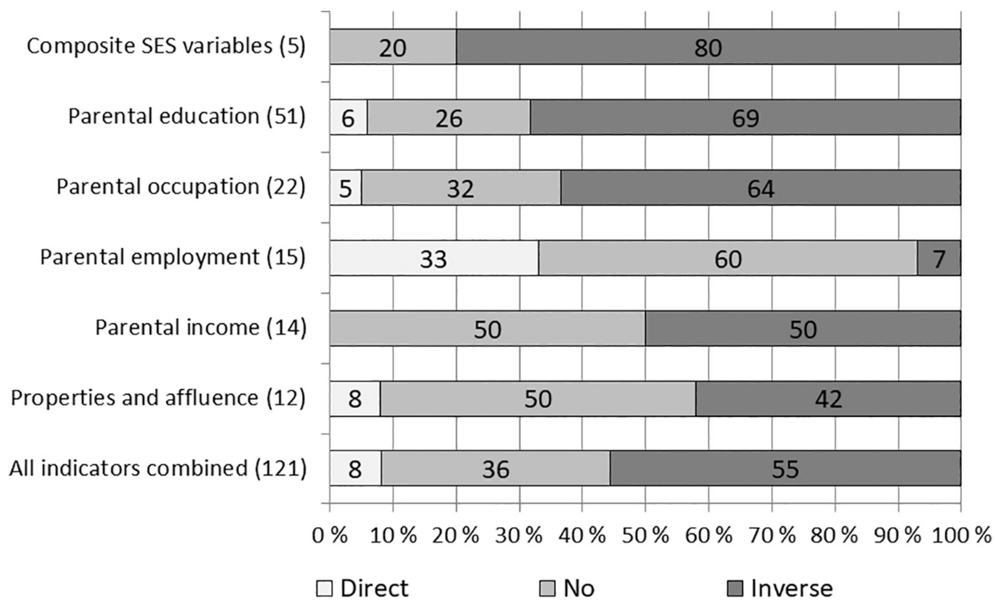
[c] Higher level in SES indicator denotes: Longer education or higher degree, less manual or more expertise-demanding occupation, existing employment or longer working hours, higher income, greater affluence or more properties

[d] All variables in category in question

[e] Excluding composite variables based only on wealth and affluence.

[f] Several variables in the same study in the same indicator group: Significant association acknowledged, and nonsignificant association disregarded.

[g] Variation in definition of OW/OB; cut-off points were based on percentiles or SD 's, or continuous z-BMI score was used.



* Positive association: while SES indicator receives ascending levels, also adiposity indicator receives ascending levels. Inverse association: while SES indicator receives ascending levels, adiposity indicator receives descending levels. The figures in the parentheses denote number of association analyses in the group in question.

Fig. 1. Proportions (%) of directions of associations* between different SES indicator groups and adiposity.

weight was common in children whose both parents had low education or mother had low education, while father's education seemed to be less related to child's weight. Adiposity was more common among children whose parents had lower occupational status independent of occupation indicator. Composite SES indicators used in the studies included various combinations of variables, most, however, comprising education and occupation, and income or affluence variables. These indicators resulted in mostly aligned inverse associations with outcomes, adiposity being less frequent in children with higher SES.

Previous studies have suggested that mechanisms that explain the inverse associations between SES and adiposity in adults are mostly derived from poorer lifestyle habits (e.g. diet and physical activity) among individuals with low SES (Pampel et al., 2010). According to Pampel et al. (Pampel et al., 2010), the pathways that lead to such poorer lifestyle habits among individuals of poorer SES include for instance, using unhealthy habits as "self-medication" while coping and facing stressors in daily life; not experiencing one would gain advantage from adopting healthy lifestyle habits; lack of knowledge on healthy lifestyle habits and how excess weight gain could be prevented; and lack of self-efficacy or aid to pursue healthier lifestyle habits. Further, one possible explanation is use of lifestyle habits as means of intentional "class distinction" from other SES groups including, especially among women, greater pressures to be thin in higher SES groups (Pampel et al., 2010). Moreover, it is possible that genetic factors or same latent traits (e.g. self-control, intelligence) affect both development of SES and life-style behaviors, and thus, obesity (Pampel et al., 2010). The same mechanisms have been regarded to apply to children through their parents' behavioral patterns. Children are directly affected by parents' lifestyle habits (e.g. meal patterns and quality of foods provided to children), but they also learn and adopt the habits of their parents. Indeed, a socioeconomic gradient appears between parental SES and lifestyle habits in childhood and adolescence with poorer habits occurring more frequently in children with lower parental SES (Cameron et al., 2012; Cameron et al., 2015; Hanson and Chen, 2007).

Parental BMI mediates the association between parental SES and childhood adiposity (Mech et al., 2016). Van Vliet et al. (van Vliet et al., 2015) concluded that one important explanation for higher obesity prevalence among children with low SES originates from higher obesity prevalence among parents with low SES, and such parents' tendency to use their own overweight/obesity as reference point to child's weight development and difficulty to categorize own child with excess weight as overweigh/obese. In addition to familial impact, neighborhood, school, and peers affect adopting lifestyle habits (Hanson and Chen, 2007). It is probable, however, that different SES indicators are associated with adiposity via different mechanisms, and of the SES indicators, education seems to be most strongly associated with lifestyle habits that contribute to risk of obesity (Barriuso et al., 2015).

Indeed, in this review, income and different properties and affluence indicators did not show that explicit gradients with childhood adiposity than education did, but approximately half of the findings were inverse and half non-significant. Previous reviews have drawn aligned conclusion (Shrewsbury and Wardle, 2008; El-Sayed et al., 2012). Drewnowski and Specter (Drewnowski and Specter, 2004) suggested that for individuals with low income, foods with high energy-density may appear appealing due to their inexpensiveness, palatability, and them providing maximum energy per the least cost. The reason, however, for lack of coherent inverse associations, similar to education indicators, may stem from income not being that consistently related to knowledge and values related to healthy lifestyle than education is. It seems that high parental education affects more strongly to development of healthy lifestyle habits than high parental occupation or income do, possibly due to strong association between education and health literacy skills (Stormacq et al., 2019).

Noteworthy was that only one of the reviewed studies (Iguacel et al., 2018) showed an inverse association between parental employment indicators and childhood adiposity, but most of the associations were non-significant and a third of the analyses found a positive association. Of the single indicators, especially mother's employment showed a strong positive gradient in adiposity. However, this may partly be due to two of such studies utilizing data entirely or partly from upper-middle-income economies (Lissner et al., 2016; Yardim et al., 2019) in which the gradient between SES and childhood adiposity tends to be reverse (Buoncristiano et al., 2021; Dinsa et al., 2012; Sobal and Stunkard, 1989). Yet, it is also possible, that parental, and especially mother's employment as such differs from other SES-indicators. While higher parental education and occupational status may decrease the risk of overweight/obesity in children by greater knowledge and emphasis of healthy lifestyles, mother's employment status or longer working hours ensues in shorter time to spend with children and potentially poorer premises for children to learn healthy lifestyle habits to promote normal growth. Moreover, early post-natal return to work may denote shorter breastfeeding period, and use of other feeding practices, which has been shown to increase the risk of excess weight gain in childhood (Verduci et al., 2021; Rito et al., 2019).

SES indicators used in the reviewed studies have a great variety; entirely different indicators may represent different aspects of SES (e.g. parental education, parental occupation, family income), but also different indicators within same indicator groups show variety (e.g. maternal or paternal or the highest parental education, education based on school years or a degree, categorization of e.g. school years). Different SES indicators may yield divergent results, which must be considered when interpreting the results. In this review, lower frequency of use of some SES indicators may also result in higher likelihood of chance in summaries of findings. Use of harmonized and compatible SES indicators would simplify the comparisons between studies and countries. Only three of the reviewed studies utilized SES data that was obtained from registers, while other studies used parents' or participants' self-reported information. More wide-spread use of register-based variables could potentially enable comparisons better. However, variation exists in recording of the SES information between countries.

In the reviewed studies presenting results separately for boys and for girls, in both sexes, non-significant results outnumbered inverse findings. The predominance of non-significant results in these analyses may be due to a chance in smaller number of studies. In a review by Shrewsbury and Wardle (Shrewsbury and Wardle, 2008), a slight majority of sex-stratified studies showed inverse findings in boys and in girls. When looking into associations of individual SES indicators in boys and girls in this review, it, however, seemed that while parental education showed commonly non-significant results in girls, in boys, it was inversely associated with adiposity. It has been suggested that in adults, women experience greater pressures to be normal weight or thin than men do, and those with higher SES experience greater pressures than those with lower SES (Pampel et al., 2010; Sobal and Stunkard, 1989). Presumably, same mechanisms may apply to children and teenagers via their parents' attitudes and peers' influence. Overweight and obesity are more common in underage boys than in girls (WHO European Childhood Obesity Surveillance Initiative (COSI), 2021) and even though boys may not experience that great pressure to be thin, it is possible that in particular among boys, parental education with parents' knowledge and attitudes impacting family lifestyle habits create steeper gradient in obesity prevalence. Conversely, in girls with already lower prevalence of obesity and generally greater pressures to be thin, the obesity prevalence differences between groups may be less notable resulting in non-significant findings. In addition, Van Vliet et al. (van Vliet et al., 2015) suggested that earlier maturation of girls and thus, being less affected by their parents and more by their peers, could be one explanation for the lack of association in girls. On the contrary, a previous review noted that an inverse association between SES and adiposity was more common in girls than in boys (Barriuso et al., 2015).

Summaries of this review suggest that higher SES is more consistently associated with lower risk of adiposity in younger children than in older children and adolescents. Previous reviews have drawn aligned (Shrewsbury and Wardle, 2008) conclusions, but also opposite summations with the inverse association being stronger in older children (Barriuso et al., 2015). In this review, strong inverse gradient between parental education and childhood adiposity seems, however, to persist in later childhood as well, but the association between parental occupation and adiposity appears less coherent. Parental SES being more strongly associated with adiposity in younger children, seems plausible as in smaller children, family lifestyle habits have a greater impact on children's lifestyle and weight development, whereas in older children sources outside family, e.g. peers, begin to have a greater impact on development of lifestyle habits and weight (Hanson and Chen, 2007).

The summarized results according to the IOTF overweight/obesity criteria (Cole et al., 2000) showed more consistent inverse associations compared with the results from the studies using the WHO criteria (de Onis and Lobstein, 2010; de Onis et al., 2007; WHO Multicentre Growth Reference Study Group, 2006). This may be due to the WHO criteria generally yielding higher prevalences of overweight/obesity than the IOTF criteria, which thereby recognizes somewhat more severe forms of overweight and obesity (Rolland-Cachera, 2011). In agreement with this theory, in this study, SES seemed to be more strongly associated with IOTF-defined obesity than with overweight. Also, previous studies have indicated that the inverse association between SES and adiposity appears stronger with more severe forms of obesity as an outcome (Barriuso et al., 2015). As studies using different adiposity indicators and criteria may yield diverse results, use of identical outcomes is preferable.

The number of studies utilizing parents' or participants' self-reported adiposity data was relatively small making it not plausible to compare these summarized results of single indicator groups. When combining all such association analyses, however, the results suggested that inverse association between SES and adiposity is more common when using self-reported adiposity information than when using measured information, which is in line with some previous findings (Barriuso et al., 2015). Chau et al. (Chau et al., 2013) indicated that in teenagers, self-reported BMI is affected by under-reporting and may be unreliable tool to measure excess adiposity in teenagers. Secondly, the same study showed that measured BMI is more often affected by refusal than self-reported BMI, and both under-reporting and refusals are dependent on certain socioeconomic, health-related, and behavioral factors. Thus, as has been done in majority of the studies, measured adiposity information should be preferred when possible.

The positive associations between SES and adiposity indicators were mainly found in studies utilizing data from upper middle-income countries (Lissner et al., 2016; Patel et al., 2018; Yardim et al., 2019) which agrees with findings from other studies from low or middle-income countries (Buoncristiano et al., 2021; Dinsa et al., 2012; Sobal and Stunkard, 1989). Thus, when considering only studies from high-income countries, the frequency of inverse associations grew even stronger. Consistent with this, in an article based on the IDEFICS study, Bammann et al. (Bammann et al., 2013) concluded that divergence in the SES-obesity gradient between European countries is dependent on regional mean income and the country-specific Human development index. Even though majority of the reviewed studies utilized data from high-income countries, these countries cannot be considered equal in terms of being less deprived. Nordic countries have generally more comprehensive welfare systems than many Eastern, Central and Southern Europe countries. For instance, free and wholesome school meals are served in Finland and in Sweden, which may mitigate SES disparities in nutrition and consequently in childhood adiposity. Thus, being poor in different high-income European countries may denote to relatively different degrees of deprivation. Despite these differences the inverse association between parental SES and childhood obesity appeared parallel. Hence, it can be presumed that even though deprivation may reach different distances across Europe, even relative deprivation derived from lower SES predisposes children to higher risk of obesity.

Strengths of this scoping review include examination of associations between SES indicators and childhood adiposity indicators according to several different SES indicators (individual and grouped indicators), corresponding scrutiny in various subpopulations (sex, age groups), and according to different overweight/obesity categorizations and data collection methods.

Some methodological issues that should be considered, however, exist as well. As this review is a scoping but not a systematic review, its purpose was not to create a summary and a meta-analysis of the findings but an overview of which different parental SES or childhood adiposity indicators are used in the literature, whether the associations seem divergent using these indicators, and whether they are divergent in different sub-populations or according to different outcome categorizations. This review summarized results from different study settings and statistical analyses making the overview of results relatively heterogenous. Variety, more specifically, in the adjustment models of the included studies, may cause distortion in the summarized results; part of the studies used comprehensive adjustment for confounding factors while part showed unadjusted results possibly yielding more commonly significant results, and potentially affected by confounding factors. As adjustment models in the reviewed studies showed major diversity, the results were not categorized and summarized according to them in this review. Moreover, this review did not exclude studies according to number of participants. It may be that in larger studies, statistical significance is reached easier. Hence, these methodological differences between included studies should be considered in the interpretation of the results of this review. The results, however, seem plausible compared with previous systematic reviews (Barriuso et al., 2015; Shrewsbury and Wardle, 2008).

This review included only studies on general child populations of the respective European countries including varieties of different ethnicities and did not present results separately for any ethnic/race groups. Thus, the summary results may be affected by proportions on ethnic minorities in the original studies to differing extent, as not in all studies ethnicity/race was adjusted for. In addition to lower SES groups, obesity and unhealthy lifestyle have been shown to be more common in ethnic minorities (Delva et al., 2006). Further, Shrewsbury and Wardle (Shrewsbury and Wardle, 2008) concluded that in black children, no association between SES and adiposity emerged. Both SES and adiposity indicators may distribute differently but also represent different features in different ethnic groups, which should be taken into account.

Finally, this review concentrated only on family-level SES indicators omitting school, neighborhood, area, or country-level indicators. Such area-level indicators have shown mostly aligned inverse associations with adiposity as family-level indicators (El-Sayed et al., 2012). In this study, however, they were omitted due to an aim to concentrate on more personal family-level indicators.

5. Conclusions

Even though in part of the European countries childhood obesity prevalence seems to have plateaued or even decreased (WHO European Childhood Obesity Surveillance Initiative (COSI), 2021), SES inequalities in adiposity persist, and according to part of the studies, continue to widen (Chung et al., 2016). Childhood obesity constitutes a considerable public health problem, as it has been associated with several physical and psychosocial conditions in childhood but also later in adulthood. In childhood, obesity contributes to increased risk of worse general health and health related quality of life, worse psychosocial functioning, weight stigma, and specific physical and mental health disorders such as asthma, cardiovascular dysfunction, attention deficit hyperactivity disorder (ADHD), and depression (Tsiros et al., 2009; Ma et al., 2021; Shan et al., 2020; Halfon et al., 2013; Cote et al., 2013; Rao et al., 2020). Long-term associations of childhood obesity include increased risk of certain elevated adult cardiovascular disease risk factors, diabetes, coronary heart disease, certain cancers, and premature mortality (Umer et al., 2017; Reilly and Kelly, 2011; Llewellyn et al., 2016). Childhood obesity also tends to persist into adulthood (Simmonds et al., 2016). Consequently, childhood obesity remains one of the most notable public health problems, and studies addressing specific determinants of it that could aid in targeting the epidemic, such as parental SES indicators are justified.

Findings of the present review affirmed previous findings on inverse SES inequalities in childhood adiposity in Western and high-income countries and showed that differences exist in associations depending on SES indicator used, on sex and age of the population, and on categorization and measurement method of the outcome variable. As divergence exists in both parental SES indicators and childhood adiposity indicators, findings and conclusions drawn from such analyses may show a relatively heterogenous picture of the study question. Heterogeneity seems considerable especially in used SES indicators, but it exists also in the use of childhood adiposity indicators, albeit not that notably. Different SES indicators represent different aspects of SES, and different adiposity criteria yield divergent prevalences of overweight and obesity. These issues should be considered when interpreting the results. In Europe, harmonization of used indicators would be advisable to enhance comparability of results between countries. As considerable differences exist in e.g. the welfare systems of the European countries, careful consideration, however, is needed to decide whether and how country-specific characteristics related to e.g. income or educational level of each country, should be taken into account in such harmonization.

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Laura Sares-Jäske: Conceptualization, Methodology, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review

& editing. **Annina Grönqvist:** Data curation, Investigation, Writing – review & editing. **Päivi Mäki:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Hanna Tolonen:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Tiina Laatikainen:** Conceptualization, Methodology, Funding acquisition, Writing – review & editing, Supervision, Project administration.

Declaration of Competing Interest

None.

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The association of socioeconomic position and childhood obesity in Finland: a registry-based study

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Abstract

Objective. To identify what dimensions of socioeconomic position (SEP) are most closely associated with childhood obesity in Finland, leveraging population-wide data among the whole child population aged 2 to 17 years in Finland.

Design. Registry-based study.

Setting. Data from several administrative registries covering the whole of Finland were used. Data on height and weight measurements in 2018 were obtained from the Register of Primary Health Care visits and data on sociodemographic and socioeconomic indicators (2014–2018) from Statistics Finland.

Participants. 2–17-year-old children with valid height and weight measurements performed at the child health clinic or school health care in 2018 (final n=194 423).

Main outcome measures. Obesity was defined according to the WHO growth reference curves. Sociodemographic and socioeconomic indicators were linked on individual level for adults (both parents) who lived in the same household (42 predictors). Boosted regression model was used to analyze the contribution of SEP to obesity.

Results. From socioeconomic indicators, annual household income (12.6%) and mother's and father's educational level (12.6% and 8.1%, respectively) had the highest relative influence on obesity risk. The relative influence of a child's sex was 7.7%.

Conclusions. The parents' SEP was inversely associated with obesity among the offspring. A remarkable number of objective SEP indicators was analysed with parents' education and household income finally being the indicators most strongly associated with obesity among children. In future research, more attention should be paid to reliable and objective ways of measuring educational status and income rather than on developing new SEP indicators. Administrative registries with information on both health care and on socioeconomic indicators can in future provide better opportunities to assess the influence of SEP on various health risks.

Introduction

Obesity is a globally growing challenge even among children (1,2). Like most health risk factors, obesity is not evenly distributed in the populations, socioeconomic status being one of the key determinants influencing its risk. It is observed that in low-income countries high socioeconomic position (SEP) mostly increases the risk of obesity while in high-income countries, the risk is increased among those with low SEP (3-7).

As SEP is a descriptive term for the position of a person in society, it is dependent on various societal factors. Even though it is commonly classified based on occupational, economic, and educational criteria (8), also other factors such as ethnicity, literacy, and cultural characteristics are related to SEP (9). Thus, determining SEP and comparisons between populations are challenging (10,11). Even more, regarding children, SEP needs to be designated based on parents' or family's characteristics (11,12). This complicates the operationalization of childhood SEP as the indicators can be created in various ways utilizing either information related to one or both parents and/or the household as a whole (7,13).

Researchers have also identified challenges in collecting reliable socioeconomic data. Sosioeconomic data can be collected from different data sources and using different methodology. Information from administrative registries, from questionnaires having self-reported data and information relying on neighborhood statistics may often be discordant (14). In addition, even the key socioeconomic indicators such as education, occupation, and income are not interchangeable and are differently affected by other factors, such as culture, and thus do not necessarily measure the same exposure (10,11,15,16).

Income data have been seen to be especially affected by different reporting biases, even more so in low-income settings (17). For income, three main problems with self-reported survey information have been identified: 1) Many forms of income exist, and people may not count all of them, which leads to misreporting, 2) income may be considered as sensitive information which may lead to high proportion of item non-response in surveys, and 3) people may be prone to overreport their income (social desirability bias) (11,14,18-20).

The wide-ranging administrative, population-based registries in Finland and the possibility of linking data on individual level from several registry sources using the personal identity code give possibility to use objective data sources for examining the associations of socio-demographic and socio-economic characteristics of children and their families and the risk of childhood obesity. The aim of this study was to analyse the impact of a large set of registry-based indicators of SEP on childhood obesity, based on measured height and weight, among the whole child population aged 2 to 17 years in Finland. This study was carried out within the framework of the STOP project (http://www.stopchildobesity.eu/).

Material and methods

Study population

Data of children were achieved from the Register of Primary Health Care visits (Avohilmo) for all 2–17-year-old children who had visited child health clinic or school health care between 1st of January and 31st of December 2018. This registry includes real time data on health care visits and treatments collected from primary health care in the public sector. Health care visits are regular, cover almost all children, and include assessment of health and development of children including standardized height and weight measurements (21,22). From local and regional electronic health records (EHRs) data on height and weight are transferred electronically to the Register of Primary Health Care visits. Since 2011, the data collection has covered all health centers and municipalities in Finland. Notwithstanding, the coverage of data collection of height and weight of children was approximately 40% in 2018 (23).

Information extracted for the current study included sex, date of birth, and all available height and weight measurements with measurement date. We calculated deviation statistics for height and weight values extracted from the Register of Primary Health Care visits using Finnish growth standard as reference values (relative to weight by sex and height, height by sex and age, BMI by sex and age) (24). Height and weight measurements with deviation values outside [-4,4] boundary were excluded. Also, sex and age specific weight index (ISO-BMI) was calculated based on Finnish growth standard. Height and weight measurements resulting in ISO-BMI≥50 were also excluded. As a result, the number of children who were 2–17 years of age in 2018 and had at least one valid height and weight measurement in 2018 was 394 627.

Socio-economic indicators

Socioeconomic indicators were obtained from Statistics Finland for adults (both parents) who lived in the same household with a child covering years 2014–2018. An extensive amount of information related to socioeconomic position was extracted from the registries including parents' age, native language, country of birth, marital status, classification of socioeconomic group, educational level of highest qualification/degree, educational field of highest qualification/degree, occupational status, employed/unemployed, code of occupation, size of family, size of household-dwelling unit, number of children in the family and information whether there are children under 3, 7, 14 and 18 years old in the family, family type, municipality group of municipality of domicile according to the 2016 regional division, region according to the 2016 regional division, mode of housing, living space, annual household's disposable money income, earned total income in state taxation, total capital income, housing benefits, and debts in total. Data on socioeconomic position of parents were used from year 2017. If this information was missing, it was imputed using data from years 2014–2016 and/or from year 2018. In addition, for adolescents aged ≥16 years, the type of their current education was obtained (a) adolescent in high school, b) adolescent in vocational school).

Many variables related to SEP had several categories. Based on logistic regression analyses on binary obesity outcome, some parental multinomial categorical variables were classified to fewer classes: region (from 19 categories to four categories), occupational status (from eight to three categories), educational field of highest qualification/degree (from 12 to four categories for fathers and to three categories for mothers) and classification of socioeconomic group for mother/father (from 19 categories to five categories for fathers and to four categories for mothers, occupational code from eleven to five categories). Variables like age, income, size of family etc. were kept in the analyses as continuous variables. Additional dichotomous indicators informing whether each parent was living in the same household as the child were created using the addresses of a child and parents (i) proportion of households with mother, ii) proportion of households with father.

Children with missing data on SEP from Statistics Finland were excluded (n=7004). Also, siblings and children having either same mother or father as well as children with two male or two female adults in the household were excluded (n=193 200), so each child and parent was only once in the data. The number of families with two male or two female adults was 374. The final data included 194 423 children. The used variables and their distributions are presented in Table 1.

Table 1. Subject characteristics

	n[1]	Mean (sd) / %
Child's age	194 423	9.6 (4.6)
Child's sex, proportion of girls, %	194 423	48.5
Annual household's disposable money income (€)	194 282	60 814 (63 618)
Proportion of households with children <14 years of age, %	180 108	54.7
Child: municipality class, %	194 423	
City		73.8
Urban		15.5
Rural		10.7
Proportion of households with mother, %	194 423	97.7
Proportion of households with father, %	194 423	81.6
Father's age	168 156	41.6 (8.1)
Mother's age	190 958	39.2 (7.4)
Father: degree of highest education, %	169 498	
No qualification		13.3
Vocational		43.3
Specialised vocational		1.9
Lowest tertiary		6.8
Bachelor's degree		16.2
Master's degree		16.3
Doctor's degree		2.2
Mother: degree of highest education, %	190 967	
No qualification		9.4
Vocational		36
Specialised vocational		1.1
Lowest tertiary		8.7
Bachelor's degree		22.1
Master's degree		21
Doctor's degree		1.8
Proportion of adolescents (age≥16 years) in high school, %	21 205	41.9
Proportion of adolescents (age≥16 years) in vocational school, %	21 205	24.1

[1]Total n available for analyses

Definition of obesity

For the analyses, obesity was defined according to the WHO growth reference curves (25,26). For children under five years of age the definition for obesity is weight-for-height greater than 3 standard deviations above the WHO Child Growth Standards median and for children over 5 years greater than two standard deviations above the WHO Growth Reference median.

Statistical analyses

Most of the categorical predictor variables on SEP were imputed using values from previous years. In case no previous individual data were available, data from 2018 were used. Adolescents' own education was imputed using values from previous years. For continuous predictors, individual trends were fitted and used for prediction of missing values. For continuous predictor data with only one observation, one trend line was fitted and used for prediction of missing values.

The analyses were carried out using a randomly selected modeling data: training data (n=155 479) and validation data (n=38 944, 20% of the training data).

A machine learning model, boosted regression model, was used to analyze the contribution of parents' and family's socioeconomic characteristics to children's obesity defined as a binary variable (27). The analyses were carried out with R-package Generalized Boosted Regression Models (GBM). GBM was run using 10-fold cross validation i.e. automatically selecting test data for every 10 folds which was specified as 20% random sample of the training data set. Finally, over-fitting was avoided by using the so called early-stopping-rule which means that optimal number of ensemble models were chosen by the GBM program.

For model performance evaluation, deviance and relative influences of predictors were used, and area under roc curve (AUC) and percentage of model deviance explained (pseudo-R2) were calculated. Based on cross validation, AUC and deviance values were expected to have very small differences between the training and validation datasets. Also, model performance of the GBM model in the excluded dataset was evaluated.

Logistic regression approximation of boosted regression prediction was used to calculate contributions of predictors as differences from mean predicted obesity prevalence.

Patient and Public Involvement

No patients were involved in setting the research question, study design, outcome measures, or the conduct of the study. This study is solely based on data from Finnish administrative registries.

Results

Boosted regression modelling and model accuracy evaluation

The full model had 42 predictors included as 73 variables due to splitting of the original multinomial categorical variables into three or more indicator variables. None of the predictors had zero influence. The optimal number of ensemble models was 1530 selected out of the prespecified 2000 models by using a cross-validation method. The final model had 12 predictors as 12 variables, of which none had zero influence and the optimal number of ensemble models was 1237 selected. The area under ROC curve (AUC) of the full model was 0.724 in the validation dataset which was 0.025 lower than in the training dataset and 0.018 lower than in the excluded dataset. In the final model of the validation dataset, the AUC was 0.718, which was 0.018 lower than in the training dataset (0.003 lower than in the excluded dataset). The difference of AUC between the full model and the final model in validation dataset was 0.006. The difference between the full and final model AUCs was tested separately in 16 age groups (for ages 2–17) and none of the tests was significant at p= 0.001 level.

The difference in AUC by sex was not significant (p=0.108). The AUC was higher for 2–6-year-old children (0.782) than for 7–17-year-old children (0.655) (p-value<0.0001).

Predicted risk and observed prevalence of childhood obesity

The Figure 1 illustrates the predicted risk of obesity and the observed prevalence of obesity based on the training dataset. The modelling resulted in practically same obesity estimates with the observed prevalences. The risk of being obese was about 1% among children under five years of age but increased to 5–11% among children between 5 to 7 years of age. The risk of being obese was highest among children before puberty being 9.8% among girls and 17.4% among boys. During and after puberty and related growth spurt, the risk of being obese declined to about 8% in girls and 12% in boys.

Relative influence of predictors on childhood obesity

Table 2 shows the relative influence of the final 12 predictors. The age of the child had the highest relative influence (39.1%) on the risk of being obese. From socioeconomic indicators, annual household income (12.6%) and mother's and father's educational level of highest degree (12.6% and 8.1%, respectively) had the highest relative influence on obesity risk with higher risk among the lower household's disposable money income and education level groups. Relative influence of child's sex was 7.7% the risk being higher among boys. In addition to factors related to education and income, also the number of children under 14 years of age in the family, mother's and father's age, child in high school and municipality class (relative influence 0.9%–5.3%) influenced obesity risk. Two additional variables were included in the model, indicators of mother or father living in same address, but both had a very low influence on obesity risk (<0.3%).

Table 2. The relative influence of socio-demographic and socio-economic indicators on childhood obesity

	Relative influence	**Direction**
Child's age	39.2	2–11: +, 12–15: -, 16–17: +
Mother: degree of highest education	12.6	-*
Annual household's disposable money income	12.6	-
Father: degree of highest education	8.1	-
Child's sex	7.7	Girls: -
Father's age	5.3	+
Any children <14 years of age	5.2	If yes: -
Mother's age	4.6	+
Municipality class	3.4	+ (for a more rural municipality)
Adolescent (age≥16 years) in high school	0.9	If yes: -
Mother lives in the same household	0.2	If yes: -
Father lives in the same household	0.1	If yes: -

*) Special vocational education almost equal to vocational education

Based on multivariate logistic approximation, there were three significant interactions when entered separately to the model with all main effects: age of father*annual household income, age of mother*annual household income and age of child*degree of highest education of father. Only one interaction was significant when entered in full final model with main effects and interactions: age of father*annual household income.

Boosted regression model effects were approximated using multiple logistic regression model for child and family predictor main effects (Figure 2) and parental main effects and interaction of father's age and annual household income (Figure 3) excluding variables for mother or father living in the same household.

Continuous variables annual household income, mother's and father's age and child's age were included as categorical. Some of the category effects which were similar on obesity prevalence were combined for graphical representation. Based on logistic regression model, the prevalence was between 0.3% and 34.0% in the used training dataset. In the original boosted regression model, the prevalence was between 0.7% and 66.7%. The prevalence >34.0% (516 predictions) can be interpreted as outliers in prevalence prediction distribution.

Figures 2 and 3 represent the contribution of model predictors to obesity prevalence. For example, the mean effect of being a girl in the multivariate model on obesity prevalence is about 3.5% points less than the overall mean obesity prevalence (8.6%). Having a mother aged >39 years has a mean effect, which is about 2% points higher than the overall mean prevalence. 5-year-old boys with no younger siblings and parents <30 years of age, living in an urban area, annual household income over 60 000 euros with mother's highest educational qualification bachelor's degree and father's highest educational qualification master's degree have 1.5% (=4.5+0+0+0+2-0.5-4-3.5) lower obesity prevalence than an average child. The wider the line for the predictor is, the greater is the multivariate contribution of a predictor.

The same applies to interaction for father's age*annual household income, which was categorized to six age groups and to three to six income groups. Children with fathers over 49 years of age has the highest annual household income contribution and children with fathers under 40 years of age (separated to three groups) has the lowest annual household income contribution. Child's age, mother's highest educational qualification and annual household income with father's age over 45 years (separated into two groups) has the highest contribution to children's obesity prevalence.

Discussion

Our study based on objective data from Finnish administrative registry sources showed that child's age and sex and his/her parents' SEP are strong predictors of obesity in childhood. Altogether 42 registry-based predictors were included in the analyses. Mother's educational level and annual household income were the two socio-economic indicators with the highest relative influence on the risk of obesity among the offspring. Childhood obesity was inversely associated with the included SEP indicators, i.e. the risk of obesity was higher among children with lower parental SEP. The number of children in our analyses was remarkable (n=387 623) and enabled sophisticated utilization of statistical methods such as machine learning models.

Several large Finnish national individual-level registry data sources were utilized in the analyses. For height and weight information, measured data from the Register of Primary Health Care visits were used. The measurements have been carried out by trained health care professionals at child health clinics or at school health care using standardized measurement protocols (28). Finland has a comprehensive public health care system and almost all families with children use these services (21,22) The provision of health services, such as health check-ups, is mandatory for municipalities, but services are voluntary and free of charge for families. The coverage is extremely high among children from all socio-economic groups eliminating the non-response bias commonly seen in survey data (21). In addition to providing an excellent data source, using registry data from health monitoring of children is cost effective because there are no additional data collection costs.

The data for the parents' and families' sociodemographic and socio-economic indicators were obtained from Statistics Finland and included information from several Finnish registries. Data from all included registries were linked on individual level using the personal identity code. Again, such data are much more objective compared with self-reported data and do not suffer awareness or social desirability bias. Furthermore, individual and household level SEP indicators used in this study are generally seen as more reliable and less tricky to interpret than area-based indicators, which may underestimate the association between SEP and a health outcome (29,30).

Although theoretically the whole child population aged 2–17 years was included, the final coverage of height and weight data on Finnish children in the was only around 40% in 2018 (23). The imperfect coverage is due to challenges in data transfer across different softwares used in primary health care across the country. Therefore, despite the incomplete geographical coverage, the data were highly representative for different socio-economic groups and the selection bias is minimal.

The age of a child was the most significant predictor of childhood obesity in our study. A remarkable shift in the prevalence of obesity at the age of five was seen. The shift was related to the inherent characteristics of the WHO definition of childhood obesity, which is different for children under and over five years of age (25,26). The risk of being obese was only about one percent among children under five years of age but increased to 5–11% among children between 5 to 7 years of age. Previous studies have shown differences between various childhood obesity definitions pointing to higher prevalence rates with the WHO definition compared with the International Obesity Task Force (IOTF), and national French, Italian as well as Finnish references

(31-33). Therefore, the selection of childhood obesity definition directly affects the resulting prevalences, and the differences between the definitions are important to acknowledge when comparing results from different studies or countries.

Previous studies have suggested that in high-income countries, the parents' lower SEP is associated with higher risk of childhood obesity, whereas the direction of the association is the opposite in low- or middle-income countries (3,4,7). Our results from Finland, a high-income country located in northern Europe, support the earlier research literature with consistent inverse association of parents' SEP and obesity among the offspring. In our study, both parents' educational level had an influence on the risk of a child to be obese. However, the association was somewhat stronger for mother's educational level.

In our data among 2–17-year-old Finnish children, also the annual household income after taxes was a significant indicator of childhood obesity. In previous literature, wealth and family income indicators have been observed to be associated with other health-related outcomes as well, such as mortality (34). Whenever feasible to measure, these indicators would be valuable in studies examining the association of SEP and health behaviour or other health-related outcomes. Most often, however, education is used as the main SEP indicator, as it has proven to be more straight-forward to assess. However, the indicators of education and income are not interchangeable, which justifies the use of separate indicators for the different dimensions of SEP such as education, occupation and household income (35). The information on income is regarded as rather sensitive information and therefore, is challenging to inquire in surveys (11,36). In surveys, income questions tend to have relatively high item non-response rates (20). In a large study on the socioeconomic differences in overweight of children in 24 countries from the WHO European Region, self-reported data on SEP indicators were used, and the authors discussed that reporting bias may have occurred particularly for family-perceived wealth (3). In our study, on the contrary, the information on income, namely the annual household income, was obtained from reliable administrative registry sources and thereby, the challenges related to misreporting or item non-reporting were overcome.

The magnitude of data available for the analyses of the current study was remarkable. Using the unique personal identity code given to every Finnish resident, we were also able to link each child's height and weight data to registry data of their parents and household. We obtained data including information on the family composition, household disposable money income and parents' educational level, among others from the abundant registries of Statistics Finland. The influence of a multitude of SEP indicators on childhood obesity were analysed. However, we observed that finally, the indicators which most strongly predicted obesity among children and were selected to the final model were those which quite commonly have been reported in previous studies, namely the parents' educational level and household income. The results of our study thereby support the use of these indicators also in future studies.

To conclude, the commonly used indicators of family SEP, education and income, were most strongly associated with childhood obesity. Thus, in future research, more attention should be paid to ensure standardized, reliable and objective measures of educational status and household income rather than putting effort on developing new SEP indicators. Furthermore, development of administrative registries including information on both health care and socioeconomic indicators can provide excellent opportunities to assess the influence of SEP on various health risks in future. This is also a cost-effective way of data collection. However, comprehensive data sources, possibilities to link data on individual level and high capacity and secure cloud computing platforms to analyse the data following the data protection rules are needed for efficient use of registry data. EU proposal on European Health Data Space regulation is a step towards this.

Summary boxes

What is already known on this topic

- Childhood obesity is a growing global challenge.

- In low-income countries, high socioeconomic position (SEP) is often associated with an increased risk of obesity, while in high-income countries, obesity risk is more often increased among those with low SEP.

- For children, different indicators of parents', households', or neighborhoods' SEP have been found to be associated with childhood obesity, but indicators are often selected opportunistically and we have a limited understanding of the relative strength of the association of childhood obesity with different indicators.

What this study adds

- Of a remarkable number of analysed socioeconomic indicators, parents’ education and household income were the indicators most strongly associated with obesity among children.

- Administrative registries with information on both health care and on socioeconomic indicators may be useful in assessing the influence of SEP on various health risks, given the use and linkage of the registries are possible for health research purposes.

Ethics approval

Permission to use the registry data was obtained from the registry owners. All phases of the study were carried out following the World Medical Association’s Declaration of Helsinki. The Finnish legislation (Act 552/2019) does not require informed consent for registry-based research, when the study is solely based on registries and the study is considered to be of public health importance.

Data sharing statement

Data are not publicly available.

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Footnotes

Contributors:

TL, PM, EL, HT, FS and ME designed the study. EL had access to all the data and performed all statistical analyses. EL is the guarantor and takes responsibility for the content of the study. EL, PM and TL contributed to data acquisition and to checking the data. FS and ME provided methodological guidance for the study. TL wrote the first draft of the manuscript. LP was responsible for writing the later manuscript version as well as the final version of the manuscript. All authors evaluated and interpreted the results of the analyses. All authors read and commented on the manuscript. All authors gave final approval for the version to be submitted. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Transparency statement

The lead authors affirm that the manuscript is an honest, accurate, and transparent account of the study being reported. No important aspects of the study have been omitted. There were no significant discrepancies from the study as originally planned.

Competing interests

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: all authors had financial support from the STOP project for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

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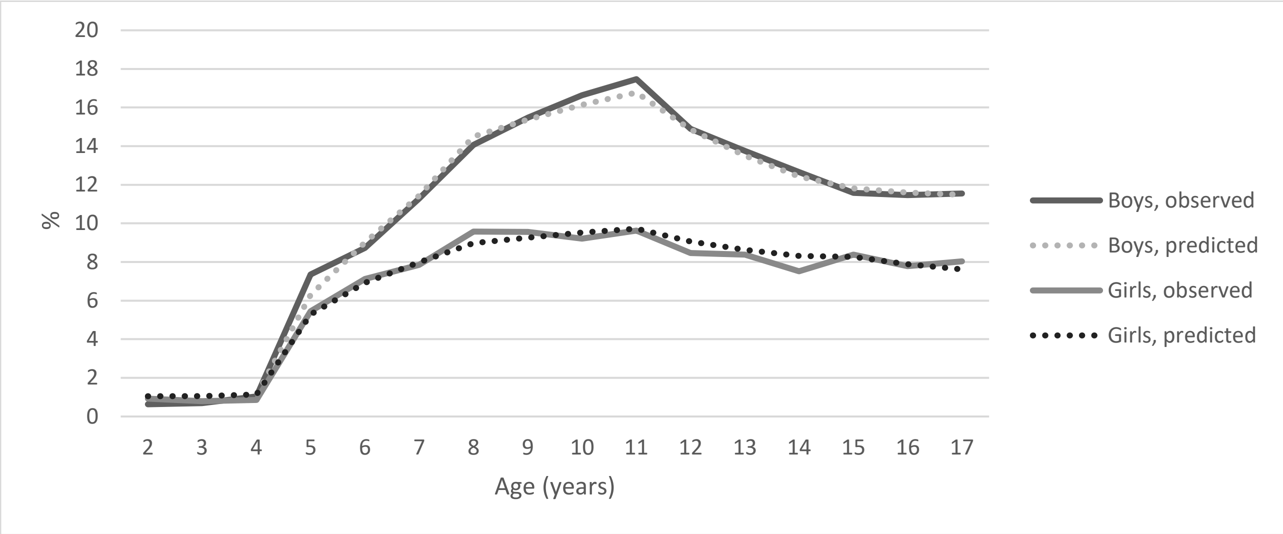

Figure 1. The predicted risk and the observed prevalence of obesity (%) among children according to the WHO criteria by age and sex in the large register-based data from Finland in 2018.

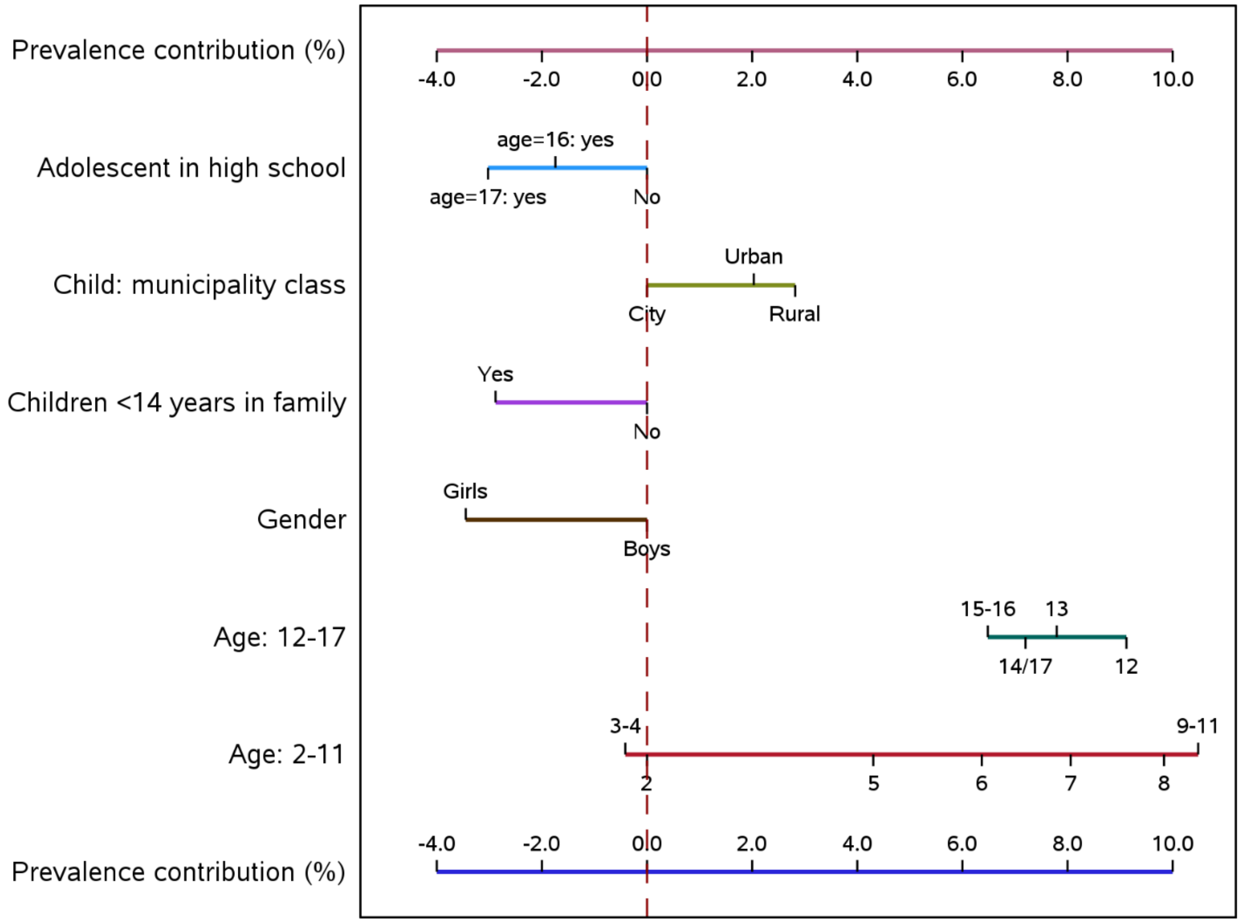

Figure 2. Contributions of child and family predictors to obesity prevalence (mean prevalence=8.6%).

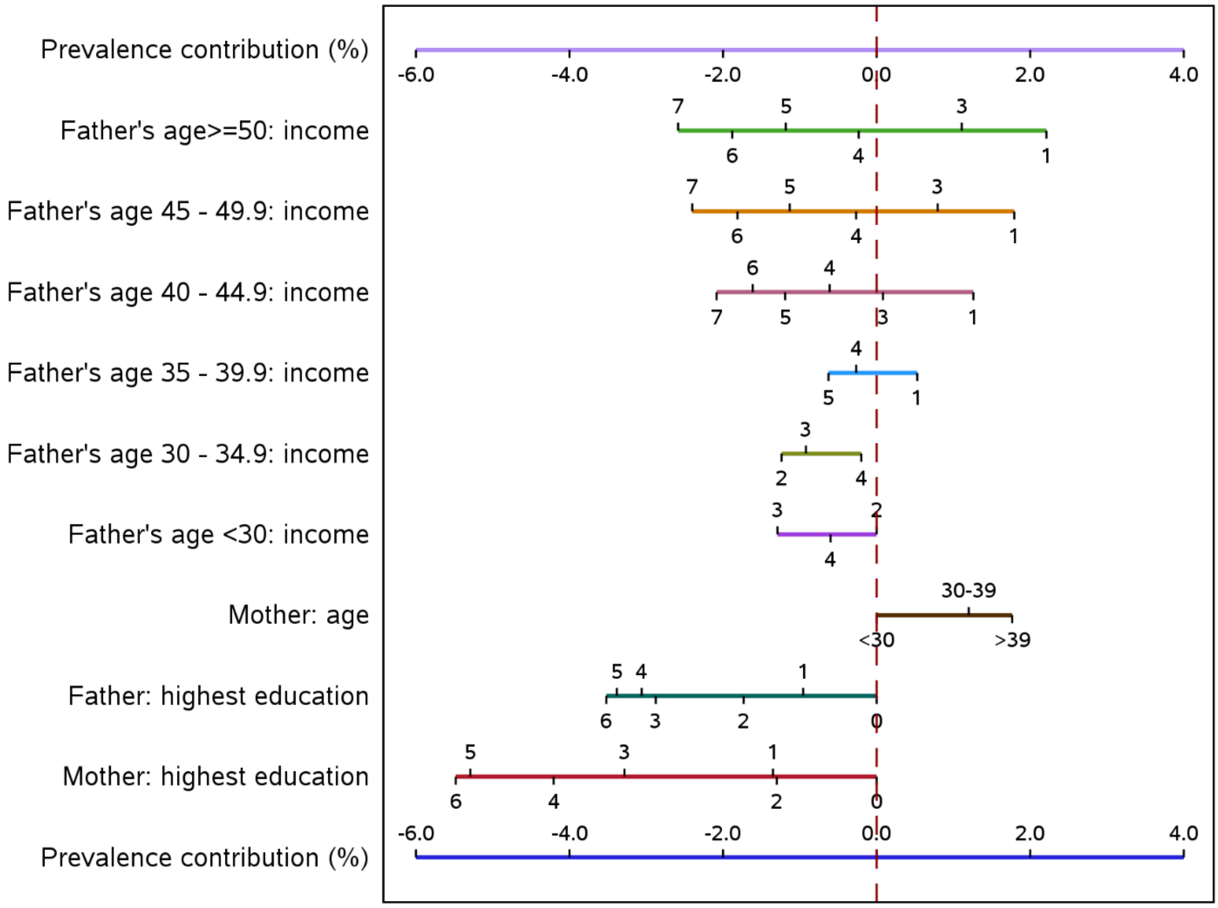

Figure 3. Contributions of parental predictors and interaction of father’s age and annual household income (mean prevalence=8.6%).

Parental education categories: 0 = no qualification, 1 = vocational education, 2 = special vocational education, 3 = lowest tertiary, 4 = bachelor’s degree, 5 = master’s degree, 6 = doctoral education.

Annual household income categories (€): 1 = <30 000, 2= 30 000–39 999.99, 3= 40 000–59 999.99, 4= 60 000–69 999.99, 5= 70 000–79 999.99, 6= 80 000–99 999.99, 7= ≥ 100 000.

When “father’s age 35–39.9”, categories 2 and 3 were recoded into 4, and categories 6 and 7 were combined into 5. When “father’s age 30–34.9” or “father’s age <30”, category 1 was recoded to 2 and categories 5–7 were recoded into 4. When “father’s age 40–44.9”, “father’s age 45–49.9” or “father’s age >=50”, category 2 was recoded into 3.

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Measuring Child Socio-Economic Position in Birth Cohort Research: The Development of a Novel Standardized Household Income Indicator

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Abstract: The assessment of early life socioeconomic position (SEP) is essential to the tackling of social inequalities in health. Although different indicators capture different SEP dimensions, maternal education is often used as the only indicator in birth cohort research, especially in multi-cohort analyses. Household income, as a direct measure of material resources, is one of the most important indicators, but one that is underused because it is difficult to measure through questionnaires. We propose a method to construct a standardized, cross-cohort comparable income indicator, the "Equivalized Household Income Indicator (EHII)", which measures the equivalized disposable household income, using external data from the pan-European Union Statistics on Income and Living Conditions (EUSILC) surveys, and data from the cohorts. We apply this method to four studies, Piccolipiù and NINFEA from Italy and ELFE and EDEN from France, comparing the distribution of EHII with other SEP-related variables available in the cohorts, and estimating the association between EHII and child body mass index (BMI). We found that basic parental and household characteristics may be used, with a fairly good performance, to predict the household income. We observed a strong correlation between EHII and both the self-reported income, whenever available, and other individual socioeconomic-related variables, and an inverse association with child BMI. EHII could contribute to improving research on social inequalities in health, in particular in the context of European birth cohort collaborative studies.

Keywords: socioeconomic position; income; birth cohorts; children

1. Introduction

Socioeconomic inequalities in health have been reported consistently for several outcomes, across the life course and in both low/middle- and high-income countries [1–3]. There is evidence that socioeconomic disadvantages in early life not only affect child health but have long-term effects also on adult health independently of adult circumstances [3]. Assessing early life socioeconomic position (SEP) and studying its long-term health influences are therefore essential to tackle population social inequalities in health and to control for confounding when studying outcomes that are strongly socially shaped.

Birth cohort studies follow participants from their fetal life and have the potential to collect information on parental and household social and economic indicators at different time points from the pre-conception period onwards. Such studies are ideally suited to investigate infancy/childhood SEP, which is determined by the SEP of the family of origin. SEP can be measured both at the geographical level, through deprivation indexes, and at an individual level, through different potential indicators; in this paper we will focus on the latter. The individual indicators most commonly used in epidemiological research and potentially available in birth cohorts include education, occupation-based measures and income. Moreover, data on housing characteristics (e.g., size, tenure status), which are measures of material circumstances, are often collected in birth cohorts but rarely employed as main SEP indicators [4].

Maternal education is often used as the only proxy of child SEP [5–9], as it is easy to collect, even retrospectively, it is quite stable over time, it is less affected by childbearing than occupation and income, and it is fairly comparable across different populations and countries, although not across different generations [10]. However, each single indicator (e.g., maternal education, occupation, income) captures different, likely correlated, dimensions of the child SEP [4,8,9,11–13]. Using maternal education only, which can be considered as a measure of intellectual resources, might therefore not be the best choice for some research questions (e.g., when studying an outcome strongly influenced by economic/material resources), might be insufficient to control for confounding when SEP is a strong potential confounder of an exposure-outcome relationship, and cannot capture individual changes in SEP over time [10]. Parental occupational based measures, which reflect social standing/prestige and access to economic resources [11], are sometimes used as an alternative or, more rarely, as an additional indicator of child SEP [14,15]. In particular, employment status and occupational class can be collected in birth cohort studies.

The household disposable income is potentially one of the most important single indicators of the child SEP, as it is a direct measure of material resources. However, accurately measuring family income through interviews or self-administered questionnaires might be a difficult task due to several issues. First, income is considered a sensitive matter, and therefore the proportion of (informative) missing values might be higher than for education or occupation; second, it might be difficult for the person who completes the questionnaire to accurately report the income for all family members, increasing the likelihood of measurement errors; finally it is difficult to account for non-salary incomes (e.g., benefits, allowances) and taxes. Moreover, comparing income across populations and studies might be complex, as different studies might collect different types of income (e.g., family disposable income vs. income from work only, net vs, gross etc.) and at different points in time (e.g., before or after birth). This is particularly relevant in the context of international collaborative studies, where it is essential to have harmonized comparable SEP indicators over the different studies.

In this paper we propose, describe and discuss a method for constructing a standardized and comparable cohort-specific household income indicator for child SEP to be used in European birth cohort studies. The indicator uses external data from the pan-European surveys "European Union Statistics on Income and Living Conditions" (EUSILC) [16] and internal data from the cohorts and is constructed using only basic parental and household characteristics, typically available in birth cohort studies, as no actual income data are needed. In this paper we apply this method to four birth cohorts from two different countries, Italy and France.

2. Materials and Methods

2.1. Data

We used data from the EUSILC survey and from four birth cohort studies. Details on the EUSILC data and on cohort-specific inclusion criteria and study protocols are available in the Supplementary Material.

2.1.1. EUSILC

EUSILC [16] is a survey that collects from 2005 onwards comparable annual microdata at both individual and household level in representative samples of persons aged at least 16 years in 28 European Union States, as well as Iceland, Norway and Switzerland. Individual data can be linked to household data and vice versa. EUSILC has both a cross-sectional and a longitudinal component, but for this study we used the cross-sectional data only. The sample data are based on a nationally representative probability sample of the population residing in private households within the country. The EUSILC survey as data resource for epidemiological research has been described previously [17].

2.1.2. Piccolipiù

Piccolipiù is an Italian multicentre cohort, involving five centers (Turin, Trieste, Firenze, Viareggio, and Roma) that have recruited from 2011 to 2015 about 500 newborns each (1000 in Roma) for a total of approximately 3400 newborns [18].

Data on tenure status, house size (number of rooms), family size, cohabitation status and on parental age, education, occupational status, jobs coded using the ISCO-88 (International Standard Classification of Occupations) classification and country of birth are available. Information on self-reported monthly net total family income in Euros (<1000, 1000–1499, 1500–1999, 2000–2499, 2500–2999, 3000–3999, 4000–4999, 5000–5999, ≥6000; "don't know") at the time of completion of the 12-months follow-up questionnaire is also available. Moreover, using the geocoded home addresses at recruitment, the value of a geographical deprivation index has been assigned to each Piccolipiù participant. This is a nationwide deprivation index at municipality and census block level, based on the 2001 Census Italian data [19].

Child weight and height data are collected at each follow-up questionnaire. For this paper we used the measures gathered at the 2- and 4-year follow-up visits, restricting the analyses to those children with body mass index (BMI) measured between 20 and 28 months and 46 and 54 months of age, respectively.

2.1.3. NINFEA

NINFEA is an internet-based birth cohort study recruiting pregnant women, started in 2005 in the city of Turin and then extended to the rest of Italy (www.progettoninfea.it) [20]. For this paper we used the NINFEA database version 09.2018 that consists of 6625 mothers and 7423 pregnancies.

Data on dwelling type, house size (m^2), family size, maternal cohabitation status, age, education, country of birth, occupational status, jobs code according to the ISCO-88, and on paternal education, occupational status and mother tongue are available for the baseline period. As for Piccolipiù, the value of the geographical-based deprivation index has been assigned to each NINFEA participant on the basis of the address of residence at recruitment.

Child weight and height data, used to derive the BMI, are collected at each follow-up questionnaire. For this paper we used the 18-month and 4-year measures.

2.1.4. ELFE

ELFE is a French national birth cohort, that consists of 18,040 mothers and 18,329 babies born in 2011 [21].

The parental and household social data analyzed in this study were collected at the 2-months telephone survey. These include: dwelling type, tenure status, number of rooms, household size, maternal cohabitation status, age, education, country of birth and occupational status (coded according to the French Profession et social category and converted into ISCO-88 codes). Total household gross income was collected as well as perceived financial hardship and bank overdraft frequency over the last year. Weight and height were reported by the interviewed parent. Predicted weight and height at 2 years of age were calculated using previously modelled trajectories from the Jenss–Bayley model [22], and were used to derive the predicted BMI.

2.1.5. EDEN

The EDEN mother-child cohort study was designed to assess pre- and post-natal determinants of child growth, development and health [23]. In brief, between 2003 and 2006, 2002 pregnant women (<24 gestational weeks) aged 18–45 year were recruited at Nancy and Poitiers university hospitals.

Parental and household social data were collected during pregnancy (24–28 gestational weeks) or at delivery and included: dwelling type, tenure status, number of rooms, household size, maternal cohabitation status, age, education, country of birth, occupational status, ISCO-88 job codes, and on paternal age, education, country of birth, occupational status and ISCO-88 job codes. The mother also reported net household income, perceived financial hardship (ranging 0 to 3) and bank overdraft frequency over the last year.

Weight and height were measured by previously trained midwives at birth, 1, 3, and 5 years. Additionally, mothers filled in self-administered questionnaires at 4 months, 8 months and 1, 2, 3, 4 and 5 years where they reported measured growth data available in their child's health booklet. Using all available collected data, predicted weight and height at 2 and 4 years were calculated using previously modelled trajectories from the Jenss–Bayley model [22].

2.2. The Equivalized Household Income Indicator (EHII)

Among the income measures available in EUSILC, we selected the total disposable household income, which is the sum of the gross personal income components of all household members and the gross income components at household level minus regular taxes on wealth, regular inter-household cash transfer paid and tax on income and social insurance contributions [16]. The personal income components include gross employee cash or near cash income, company car, gross cash benefits or losses from self-employment—including royalties, pensions received from individual private plans, benefits for unemployment, old-age, survivor, sickness and disability, and education-related allowances. The gross income components at household level include income from rental of a property or land, family/children related allowance, housing allowances, regular inter-household cash transfers received, interests/dividends/profit from capital investments in unincorporated business and income received by people aged under 16. In order to account for differences in the household size and composition, we derived the equivalized income as the ratio between the total disposable household income and the equivalized household size. The latter is available in the EUSILC database and is calculated as the sum of the weights given to all the members of the household: 1 to the first adult; 0.5 to the second and each subsequent person aged 14 and over; and 0.3 to each child aged under 14 [24].

We derived the cohort-specific EHII according to the following steps (which are further explained below): (i) identification of the potential predictors of the equivalized household disposable income available both in the country-specific EUSILC database and in the specific cohort; (ii) selection of the EUSILC analysis samples to develop and validate the prediction model (iii) construction of the prediction model; (iv) evaluation of the model performance. The regression coefficients obtained from the prediction model were then applied to the cohort data to derive the EUSILC-based income indicator.

The prediction models are cohort- and period-specific as they depend on the information available in the cohort at the different time points. In this paper we derived the income indicator for the baseline period, i.e., before or during pregnancy or at birth depending on the cohort.

2.2.1. Predictors

We selected as potential predictors the EUSILC household and personal variables likely to be available in birth/pregnancy cohorts. The personal data included age, educational level, occupational status, ISCO code, country of birth, marital status and cohabitation status (living with/without a partner); while the household variables were dwelling type, tenure status, number of rooms, and family size. Until 2011, EUSILC coded jobs using the first 2 digits of the ISCO-88 classification, while the first 2 digits of the ISCO-08 classification were used from 2011 onwards. For the 2011 survey both versions are available. For this study we used the 1-digit variables only.

2.2.2. Analysis Sample

The model for each cohort was constructed using the EUSILC data of the country of the cohort (i.e., Italy-EUSILC survey data for Piccolipiù and NINFEA, French-EUSILC survey data for ELFE and EDEN). The household was the unit of analysis; all households including at least one child (16-years old or younger) and his/her mother were included. Households with 8 or more members, households with errors in the id variables and households with very atypical/rare family structure (e.g., two or more family units living together) were excluded (0.2% in both 2011 Italian and French database). Moreover, household with an equivalized total disposable income below/above the lower/upper limits, where the lower limit is Q1−1.5×I IQR and the upper limit is Q3+1.5×IQR (Q1 and Q3 indicates the 25th and 75th percentiles respectively and IQR the interquartile range) were excluded (about 5% and 3% of the Italian and French samples respectively). In EUSILC, for each household member, the identification code of his/her father, mother and partner are available if they live in the same household. This identification code was used to link personal data of the mother and, if present, of the father with the household data for each selected household.

Due to the EUSILC sampling frame and sample selection methods, a non-zero probability of selection is assigned to every individual and household in the target population. To account for this sampling scheme, household weights were taken into account in the statistical analyses.

For the development of the prediction model we used the 2011 survey data, because in that survey jobs were coded using both ISCO-88 and ISCO-08 codes. In Italy and France, as well as in most of the other countries, the survey has been conducted using a rotational design, with one-quarter of the sample rotating from one year to the next; for this reason, we used as a validation set the data from 2015 (temporal validation), which are completely independent from those from 2011. In order to validate the models, we used the ISCO-08 codes in both the developmental and validation sets, but we used the ISCO-88 codes when we estimated—in the 2011 data—the coefficients to derive the predicted index, as most birth cohorts in Europe coded jobs using the ISCO-88 classification.

2.2.3. Model Building

The equivalized total disposable household income has a severely positively skewed distribution (p-values from the skewness/kurtosis test for normality in the French and Italian analysis sample < 0.0001). Therefore, we used multivariable linear regression models with log-transformation of the outcome. For each cohort, we identified the EUSILC variables available in the cohort for at least 90% of the subjects to be used as predictors. These variables were formatted in EUSILC to match the categorization available in the cohort. To avoid missing values by design, inactive subjects, who do not have, by definition, an ISCO code for the occupation were assigned to the most frequent ISCO class. The same approach was used for the paternal variables for the households with a single mother. Different shapes of the relationship of the continuous variables with the outcome were evaluated. Prediction models were performed using a complete case analysis approach.

2.2.4. Model Performance

The overall model performance was assessed based on the value of the R^2 statistics, that was calculated both for the 2011 and the 2015 model. Calibration was examined using the calibration plots (scatter plot of the observed outcomes by decile of the predicted outcomes) and the calibration slope, where the latter reflects the combined effect of overfitting on the development data and true temporal differences in the coefficients.

2.2.5. Derivation of the EHII in Each Cohort

To derive the EHII for each cohort member, the regression coefficients obtained in the developmental data were applied to the individual cohort data. As the focus is typically on the rank rather than on the absolute value of the income, in particular for studies using data from different countries, we categorized the predicted log-transformed EHII using the quintiles as the cut-offs. To obtain the value of the EHII on the original scale accounting for non-linearity in the log-transformation we back-transformed it using the following approach: (i) we added to the predicted income (log-euro) a draw from the estimated distribution of the error term, for each individual, and then exponentiate it; (ii) we repeated this step 100 times; (iii) we took the average of the 100 mean values. Absolute values should be interpreted as the equivalized total disposable household income a family with those specific characteristics would have had in 2011.

2.2.6. Analysis of the EHII

We described the distribution of the available predictors and of other SEP-related variables within each cohort-specific predicted EHII quintile. Moreover, we estimated the association between the EHII in quintiles and continuous BMI at 2 and 4 years of age in the four cohorts using linear regression models.

3. Results

Although with different level of detail, the following predictors were available in all four birth cohorts analyzed: maternal age, cohabitation status, country of birth, educational level, occupational status and occupational code; paternal/partner country of birth, educational level and occupational status; and household size. Moreover, paternal/partner age and occupational code, and household tenure status were available in all cohorts except NINFEA; dwelling type was available in all cohorts except Piccolipiù; and maternal marital status was available in the French cohorts only.

The value of the R^2 statistic obtained when fitting the model in the developmental data (2011 surveys) reflected the amount of data available, being equal to 0.45, 0.41, 0.53 and 0.51, for the Piccolipiù, NINFEA, ELFE and EDEN cohorts respectively. When the models were validated using the 2015 data, the values of the R^2 statistic decreased slightly to 0.42, 0.39, 0.52 and 0.51, while the calibration slopes were equal to 0.96, 0.96, 1.01 and 0.98 respectively, indicating a good temporal validation. The Supplementary Figures S1–S4 show the calibration plots, that is the scatter plot of the mean observed log-income vs. mean predicted log-income by decile of the predicted outcome. Supplementary Tables S1–S4 report the coefficients obtained from the four models. The paternal/partner country of birth was not included in the Piccolipiù and NINFEA models as this variable had no impact on the prediction capability and was missing for approximately 4% of the subjects in each cohort, while the dwelling type was not included in the EDEN model due to a large amount of missing data. In all models parental age was included as a continuous variable.

The directions and magnitudes of the coefficients of the single predictors were consistent across the four studies; living with a partner, being born in the country of the cohort, having a higher education, being employed/self-employed, owning the house, living in a bigger house and having a lower household size were positively associated with the EHII. These data are reflected in the results shown in Table 1, where the cohort-specific quintiles of the EHII are described in terms of the available predictors: among those predicted to have the highest income there are no households with a single mother, or with an unemployed parents in all cohort, the majority (from 86% to 98%) have parents with a post-secondary education or higher, and almost (from 94% to 100%) all have parents born in the country of the cohort (Table 1). The variables excluded from the prediction models because of missing values (i.e., paternal country of birth for the Italian cohorts and dwelling type in EDEN) are included in this table.

Table 1. Description of the cohort-specific predicted income quintiles in terms of the available predictors.

	Cohort-Specific Quintiles of the Predicted Equivalized Total Disposable Household Income																			
	Piccolipiù (*n* = 3105)					**NINFEA (*n* = 6980)**					**ELFE (*n* = 13,544)**					**EDEN (*n* = 1815)**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
	% [a]					% [a]					% [a]					% [a]				
Household																				
Dwelling type [b]																				
Detached	–	–	–	–	–	24.5	21.0	16.0	15.3	9.8	40.1	59.5	66.0	67.1	58.9	51.6	69.3	76.8	78	78.3
Semi-detached	–	–	–	–	–	15.0	16.3	16.6	15.6	14.4	5.4	1.4	1.3	1.4	1.5	30.0	21.8	20.3	19.8	18.3
Flat	–	–	–	–	–	56.2	61.0	66.3	68.3	75.1	54.5	39.1	32.7	31.5	39.6	18.4	8.9	2.94	2.26	3.43
Other kind	–	–	–	–	–	4.3	1.7	1.1	0.8	0.7	–	–	–	–	–	–	–	–	–	–
Tenure status																				
Owner	42.8	64.1	76.3	82.3	94.2	–	–	–	–	–	13.4	42.8	60.5	71.8	81.3	11.3	33.3	51.2	60.1	79.1
Tenant	49.9	27.7	18.1	15.8	4.2	–	–	–	–	–	41.3	38.2	28.3	21.4	15.6	77.1	63.4	45.5	37.5	20.1
Tenant reduced rate	–	–	–	–	–	–	–	–	–	–	40.7	13.7	5.8	2.1	0.7	–	–	–	–	–
House for free	7.3	8.2	5.6	1.9	1.6	–	–	–	–	–	4.6	5.3	4.4	4.7	2.4	11.6	3.3	3.3	2.5	0.8
Number of rooms [c]																				
1–2	26.4	18.5	16.3	15.5	10.0	8.2	6.5	4.9	4.4	2.8	12.7	6.4	3.9	3.6	1.8	15.7	6.9	5.5	1.4	1.1
3	34.8	39.0	35.8	34.6	34.0	62.3	60.6	64.0	59.4	54.2	29.3	23.9	21.3	17.2	18.0	36.1	32.8	24.8	23.1	14.3
4	23.2	24.8	30.1	28.0	27.0	19.5	20.4	20.5	22.3	22.8	27.3	27.2	27.6	24.7	25.8	28.4	32.8	34.4	29.5	25.3
5	9.2	10.8	11.4	14.8	19.3	10.0	12.5	10.6	13.9	20.2	17.1	22.5	23.5	26.4	25.4	10.4	16.5	20.1	26.7	26.5
≥6	6.4	6.9	6.4	7.1	9.7	–	–	–	–	–	13.6	20.0	23.7	28.1	29.0	9.4	11.0	15.2	19.3	32.8
Household size																				
2	1.0	2.3	0.2	0.0	0.0	28.9	8.6	0.1	0.0	0.0	6.1	2.8	0.6	0.0	0.0	7.2	4.4	3.3	1.1	3.9
3	33.0	48.3	58.9	62.3	68.0	25.9	49.1	64.5	63.9	79.8	29.3	38.5	40.7	46.1	53.1	31.1	37.7	44.6	46.6	51.2
4	37.7	37.0	32.5	31.4	28.6	23.9	26.6	28.0	27.1	18.0	30.6	37.9	40.9	40.2	33.9	27.8	40.5	36.7	36.6	34.5
5	16.4	9.3	7.1	5.0	2.6	11.8	9.9	5.2	6.7	1.9	19.9	15.5	14.3	11.1	10.7	22.3	12.4	9.9	12.7	8.5
≥6	11.9	3.1	1.3	1.3	0.8	9.5	5.8	2.2	2.3	0.3	14.1	5.3	3.5	2.6	2.3	11.6	5.0	5.5	3.0	1.9
Maternal																				
Single mothers	8.2	4.5	0.2	0.0	0.0	37.8	9.0	0.0	0.0	0.0	22.1	4.0	0.8	0.0	0.0	23.4	5.23	1.38	0.0	0.0
Separated/Divorced/Widow	–	–	–	–	–	–	–	–	–	–	4.9	3.3	2.0	1.2	1.6	3.0	3.6	2.2	0.8	2.8
Country of birth																				
Italy/France	77.9	91.3	94.9	96.1	98.9	88.5	96.4	96.4	98.4	99.9	77.9	90.9	93.6	94.4	94.3	90.9	95.9	96.4	97.2	97.8
Other EU	13.2	5.6	3.5	3.1	0.5	7.9	2.2	2.6	1.2	0.1	1.4	2.2	2.6	2.6	3.5	0.0	1.1	0.6	0.6	1.4
Other	8.9	3.1	1.6	0.8	0.6	3.6	1.4	1.0	0.4	0.0	20.7	6.9	3.8	3.0	2.2	9.1	3.0	3.0	2.2	0.8

Table 1. *Cont.*

	Cohort-Specific Quintiles of the Predicted Equivalized Total Disposable Household Income																			
	Piccolipiù (*n* = 3105)					**NINFEA (*n* = 6980)**					**ELFE (*n* = 13,544)**					**EDEN (*n* = 1815)**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Education																				
≤primary	1.3	0.0	0.0	0.0	0.0	0.9	0.1	0.0	0.0	0.0	9.4	1.4	0.2	0.1	0.0	25.1	6.6	2.4	0.6	0.0
lower secondary	33.7	15.9	5.5	1.0	0.3	18.1	6.4	1.7	0.5	0.1	50.6	24.3	5.5	1.4	0.2	46.0	39.9	18.2	1.9	0.6
upper secondary	51.0	63.3	56.2	33.6	12.4	50.0	52.9	42.8	16.5	5.0	29.4	36.1	20.3	7.8	1.9	24.0	28.2	27.3	10.2	0.8
≥post-secondary	14.0	20.8	38.3	65.4	87.3	31.0	40.7	55.5	83.0	94.9	10.6	38.2	74.0	90.7	97.9	4.9	25.3	52.1	87.3	98.6
Occupation [d]																				
employed	40.7	76.5	80.7	80.7	82.9	44.1	72.1	83.9	83.2	85.9	31.8	69.6	83.6	90.3	93.4	21.2	79.1	85.7	94.8	100
self-employed	7.3	11.6	15.0	17.7	17.1	10.2	13.3	12.8	16.6	14.1	1.7	3.5	5.1	6.9	6.6	–	–	–	–	–
unemployed	19.3	5.5	2.4	0.6	0.0	19.4	7.6	0.4	0.1	0.0	29.0	18.0	7.7	2.3	0.0	32.5	11.6	7.44	2.48	0.0
domestic task	29.5	3.5	0.3	0.0	0.0	17.8	1.7	0.0	0.0	0.0	34.0	7.6	3.1	0.4	0.0	31.7	3.86	4.68	1.38	0.0
other	3.2	2.9	1.6	1.0	0.0	8.5	5.3	2.9	0.1	0.0	3.5	1.3	0.5	0.1	0.0	14.6	5.51	2.2	1.38	0.0
ISCO88 [e]																				
0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.1	0.0	0.0	–	–	–	–	–	–	–	–	–	–
1	7.4	11.0	10.3	10.6	5.0	10.7	8.9	6.2	7.5	3.4	0.0	1.3	3.0	6.8	18.2	0.0	0.6	1.1	3.9	4.9
2	4.4	11.3	21.6	36.3	54.8	17.4	20.8	27.5	42.7	53.9	0.8	8.6	25.7	42.7	56.1	0.0	1.9	4.4	11.3	30.0
3	6.0	9.0	11.8	16.2	15.0	7.4	8.5	10.6	11.1	9.4	68.7	37.5	33.9	29.5	17.4	24.5	24.0	42.7	62.0	61.2
4	9.7	24.2	34.9	30.8	24.6	26.4	41.5	50.3	36.5	33.2	4.6	16.8	24.4	16.1	7.6	20.4	32.5	38.3	17.9	3.6
5	48.3	37.1	18.4	4.9	0.6	23.2	15.5	4.1	1.7	0.0	13.1	19.6	8.2	3.1	0.3	38.8	32.5	11.0	3.6	0.3
6	0.3	0.0	0.3	0.0	0.0	0.3	0.2	0.2	0.0	0.0	0.3	0.8	0.2	0.2	0.0	0.3	0.3	0.3	0.5	0.0
7	2.4	2.2	1.2	0.5	0.0	2.9	1.9	0.4	0.4	0.1	4.4	5.7	2.4	0.8	0.3	6.3	5.5	1.4	0.8	0.0
8	3.0	2.6	1.5	0.5	0.0	1.7	1.6	0.4	0.0	0.0	0.8	1.1	0.4	0.3	0.0	2.2	1.6	0.5	0.0	0.0
9	18.5	2.6	0.0	0.0	0.0	10.0	1.1	0.2	0.1	0.0	7.3	8.6	1.8	0.5	0.1	7.5	1.1	0.3	0.0	0.0
Age (mean)	31.5	33.6	34.1	34.9	35.8	31.3	32.8	33.5	34.2	34.8	28.8	30.4	31.4	31.9	33.0	26.8	29.2	30.2	30.7	31.2
Paternal																				
Country of birth [f]																				
Italy/France	79.8	95.5	97.5	96.2	96.3	91.5	96.9	97.9	97.6	97.8	80.0	90.5	93.6	94.8	95.5	89.5	92.0	95.6	93.9	95.0
Other EU	11.9	2.9	0.7	2.8	2.6	8.5	3.1	2.1	2.4	2.2	1.8	1.8	1.7	1.6	2.4	0.6	1.9	1.1	0.3	2.2
Other	8.3	1.6	1.8	1.0	1.1	–	–	–	–	–	18.2	7.7	4.7	3.6	2.1	9.9	6.1	3.3	5.8	2.8
Education																				
≤primary	2.1	1.1	0.2	0.0	0.0	2.9	0.6	0.0	0.0	0.0	8.1	2.7	1.5	0.1	0.0	17.1	14.3	7.7	3.6	0.8
lower secondary	47.5	34.6	20.0	3.2	0.6	37.6	34.2	12.7	0.2	0.0	35.8	34.1	23.6	10.7	1.6	36.6	39.7	26.4	19.3	3.3
upper secondary	44.1	52.0	66.1	55.6	10.7	44.0	46.6	74.5	47.6	1.6	46.2	36.8	31.6	13.4	2.8	39.7	28.1	29.5	16.5	3.1
≥post-secondary	6.3	12.3	13.7	41.2	88.7	15.5	18.6	12.8	52.2	98.4	9.9	26.4	43.3	72.8	95.6	6.6	17.9	36.4	60.6	92.8

Table 1. *Cont.*

	Cohort-Specific Quintiles of the Predicted Equivalized Total Disposable Household Income																			
	Piccolipiù (*n* = 3105)					**NINFEA (*n* = 6980)**					**ELFE (*n* = 13,544)**					**EDEN (*n* = 1815)**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Occupation [d]																				
employed	54.9	63.3	71.0	77.5	80.0	85.3	93.7	98.5	98.7	99.9	71.6	79.6	82.5	85.7	95.3	81.8	92.6	94.8	98.3	100
self-employed	31.1	34.1	28.7	22.2	20.0	–	–	–	–	–	8.6	14.4	13.5	12.7	4.7	–	–	–	–	–
unemployed	13.2	1.8	0.0	0.0	0.0	9.5	2.6	0.1	0.0	0.0	16.8	5.0	3.0	0.6	0.0	14.0	3.3	2.7	1.1	0.0
other	0.8	0.8	0.3	0.3	0.0	5.2	3.7	1.4	1.3	0.1	3.0	1.0	1.0	0.0	0.0	4.2	4.1	2.5	0.6	0.0
ISCO88 [e]																				
0	2.1	0.7	1.8	2.3	1.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1	14.2	15.4	16.8	19.1	13.4	–	–	–	–	–	1.1	3.6	6.5	11.0	22.4	0.3	0.8	2.5	2.5	10.7
2	3.2	6.5	9.1	19.5	52.6	–	–	–	–	–	0.9	4.7	11.4	22.5	64.4	0.3	0.8	6.1	9.1	42.1
3	6.7	11.1	19.1	20.5	13.4	–	–	–	–	–	53.2	33.0	33.0	35.7	8.9	36.1	20.7	35.0	49.5	39.4
4	6.6	11.7	14.7	23.2	15.8	–	–	–	–	–	2.8	5.4	7.6	7.5	2.1	10.5	16.0	18.2	15.2	4.7
5	15.0	17.2	11.0	4.4	1.0	–	–	–	–	–	5.5	7.7	7.5	4.3	0.6	4.1	7.5	4.7	6.9	1.1
6	1.7	1.0	1.0	0.3	0.2	–	–	–	–	–	2.0	3.2	1.5	0.1	0.0	0.5	5.2	3.0	0.0	0.0
7	27.2	22.5	13.1	3.6	0.0	–	–	–	–	–	21.9	27.2	21.3	12.0	1.2	34.4	35.8	22.0	14.3	1.4
8	10.7	8.1	11.0	6.6	1.8	–	–	–	–	–	6.5	6.9	5.8	3.2	0.1	6.6	6.6	4.1	1.4	0.0
9	12.6	5.8	2.4	0.5	0.0	–	–	–	–	–	6.1	8.3	5.4	3.7	0.3	7.2	6.6	4.4	1.1	0.6
Age (mean)	35.0	36.7	37.0	37.7	38.2	–	–	–	–	–	34.1	32.7	33.4	33.6	34.4	30.5	31.7	32.0	32.8	33.3

[a] Colum percentage; [b] In ELFE and EDEN detached = house, semi-detached = flat in a big building, flat = flat in a small building; [c] In NINFEA the last class is ≥5; [d] In EDEN the employed and self-employed classes are combined; [e] In ELFE and EDEN class 0 (Armed forces) is not available, in EDEN classes 1 (Legislators, senior officials and managers) and 2 (Professionals) are combined; [f] In NINFEA the paternal country of birth information is based on paternal mother tongue and two classes are available: Italian vs. Other.

The mean values of the EHII back-transformed in Euros are equal to 1758, 1807, 1895, and 1725 € in the Piccolipiù, NINFEA, ELFE and EDEN cohorts respectively.

Figures 1–4 displays the distribution of the predicted quintiles in terms of the other available cohort-specific SEP-related variables: self-reported monthly net family income at 12 months and geographical deprivation index in Piccolipiù (Figure 1); geographical deprivation index in NINFEA (Figure 2); self-reported income at 2 months, bank overdraft and perception of financial situation in ELFE (Figure 3); and self-reported income at recruitment, bank overdraft and number of hardships in EDEN (Figure 4). In all cohorts, and in particular in the French studies, there was a strong correlation between the self-reported income, as collected by questionnaires, and the EHII. There was a clear association also between the other individual SEP-related variables available in the French cohorts and the EHII: for example, the proportion of those reporting to have experienced a bank overdraft often or several times over the last 12 months in EDEN was 39% among those with the lowest predicted income and about 13% among those in the highest quintile (Figure 4), while the corresponding proportions of those answering no bank overdraft were approximately 30% vs. 65%, with very similar results in the ELFE cohort (Figure 3). Consistent findings were observed when analysing the "perceived financial situation" variable in ELFE and the "number of financial hardships" variable in EDEN. The association between the EHII and the geographical deprivation index, available in the Italian cohorts, was weaker. In Piccolipiù 26% of those predicted to have the lowest income were resident in the least deprived area according to the geographical index compared with 38% among those predicted to have the highest income (Figure 1). The corresponding figures in NINFEA were 20% vs. 30% (Figure 2).

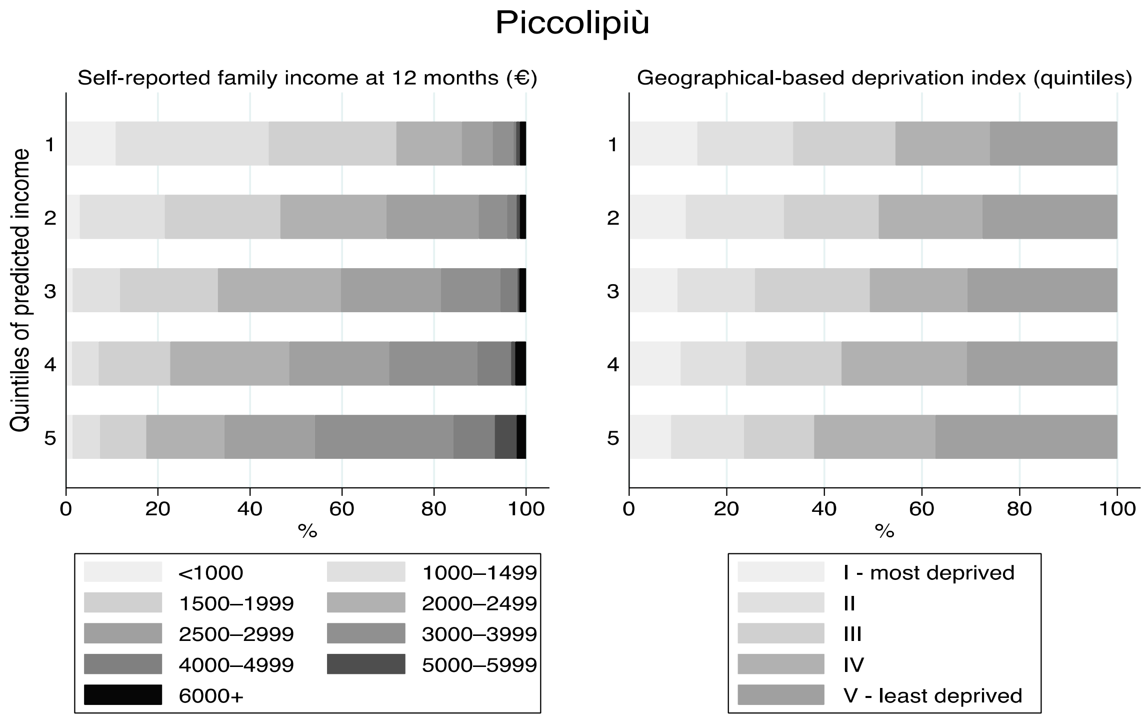

Figure 1. Distribution of the socioeconomic position (SEP)-related variables available in the Piccolipiù cohort by quintiles of the predicted income.

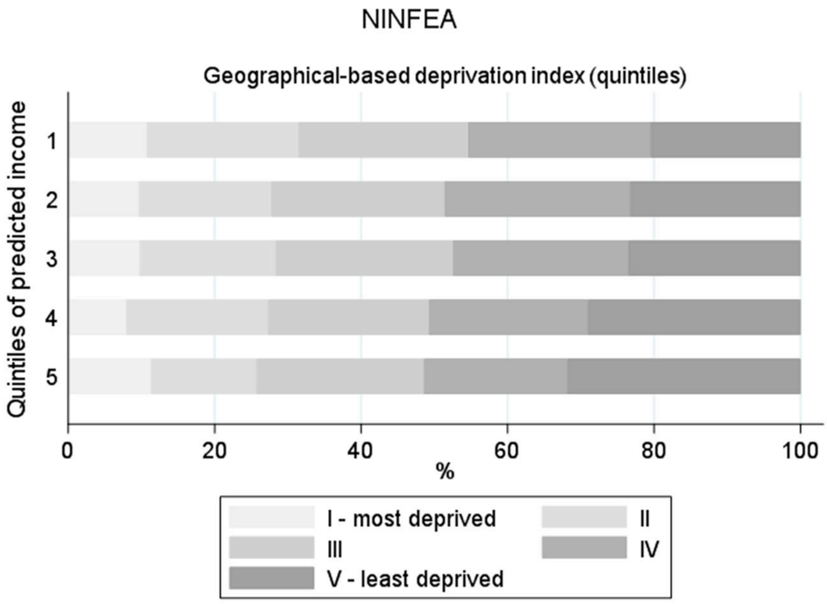

Figure 2. Distribution of the SEP-related variables available in the NINFEA cohort by quintiles of the predicted income.

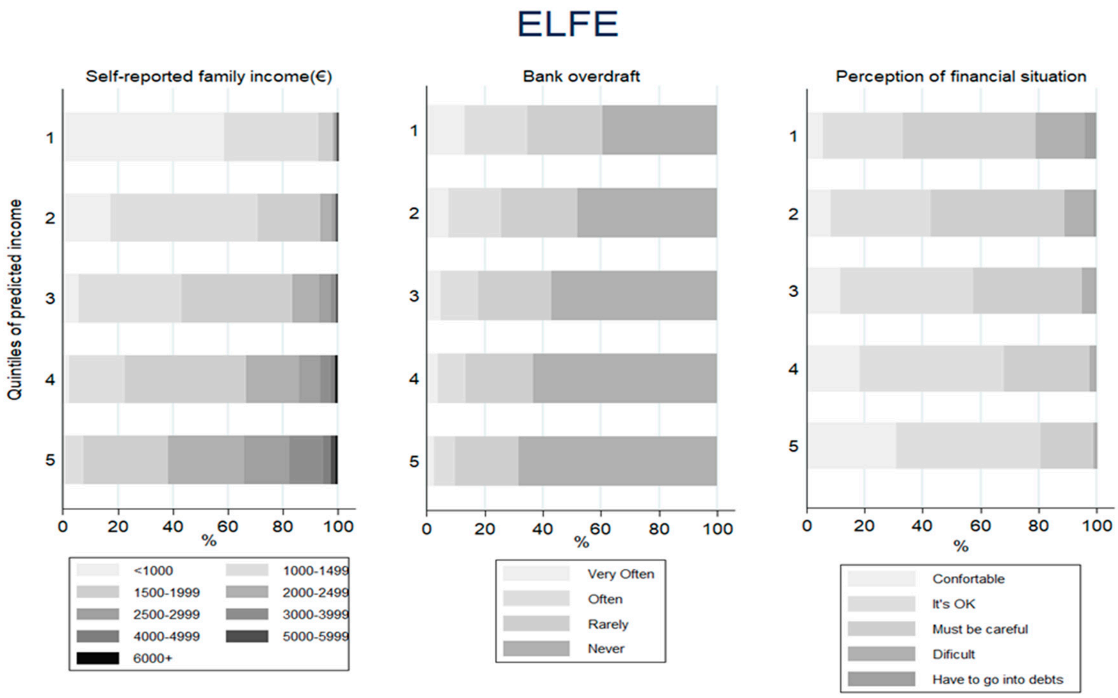

Figure 3. Distribution of the SEP-related variables available in the ELFE cohort by quintiles of the predicted income.

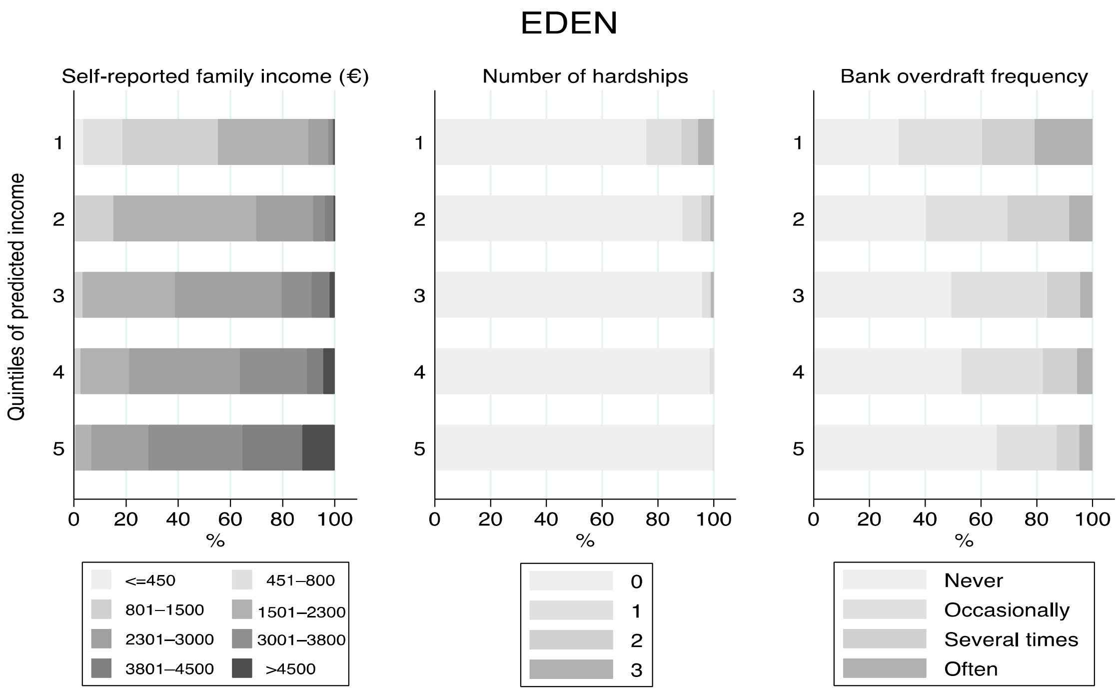

Figure 4. Distribution of the SEP-related variables available in the EDEN cohort by quintiles of the predicted income.

Finally, Table 2 shows the estimates of the crude associations of maternal education (categorized in three levels) and of the EHII (in quintiles) with child BMI at two and four years of age separately in each cohort (BMI at four years of age is not available in ELFE, while BMI at 18 months and not at 24 months is available in NINFEA). In all cohorts we observed an inverse association of the EHII with BMI at both two and four years of age, with the exception of NINFEA at 18 months; additionally, maternal education was inversely associated, but with less consistent results across the cohorts. Adjustment for maternal education did not affect the associations between the EHII and BMI at two years, while slightly attenuated the effects at 4 years of age (data not shown).

Table 2. Associations between predicted income (quintiles) and child BMI at 2 and 4 years of age by cohort.

	Piccolipiù (n = 1675) [a]			NINFEA (n = 4530) [a,b]			ELFE (n = 12,069)			EDEN (n = 1685)		
	Coef	*95% CI*	*p-Trend*	*Coef*	*95% CI*	*p-Trend*	*Coef*	*95% CI*	*p-Trend*	*Coef*	*95% CI*	*p-Trend*
BMI at 2 Years of Age												
Maternal education												
≤lower secondary	−0.08	−0.35; 0.20		−0.13	−0.38; 0.12		0.05	−0.03; 0.13		0.04	−0.12; 0.21	
secondary	–		0.01	–		0.24	–		0.03	–		0.08
≥post-secondary	−0.24	−0.39; −0.08		0.03	−0.08; 0.13		−0.06	−0.12; 0.01		−0.07	−0.22; 0.08	
Predicted income												
1	–			–			–			–		
2	−0.19	−0.45; 0.06		0.01	−0.15; 0.18		−0.08	−0.16; 0.00		−0.05	−0.23; 0.13	
3	−0.15	−0.40; 0.10	0.001	−0.13	−0.29; 0.03	0.84	−0.13	−0.21; −0.05	<0.001	−0.15	−0.33; 0.02	0.013
4	−0.29	−0.53; −0.04		0.02	−0.13; 0.18		−0.16	−0.24; −0.08		−0.15	−0.33; 0.02	
5	−0.43	−0.68; −0.19		0.01	−0.15; 0,17		−0.18	−0.26; −0.10		−0.20	−0.37; −0.02	
BMI at 4 Years of Age												
Maternal education												
≤lower secondary	0.25	−0.04; 0.55		0.10	−0.19; 0.40					0.01	−0.16; 0.18	
secondary	–		0.11	–		0.01				–		0.012
≥post-secondary	−0.03	−0.21; 0.14		−0.15	−0.27; −0.03					−0.15	−0.3; 0	
Predicted income												
1	–			–						–		
2	−0.14	−0.42; 0.15		−0.24	−0.42; −0.05					0.02	−0.16; 0.21	
3	−0.08	−0.36; 0.19	0.05	−0.22	−0.40; −0.04	0.03				−0.11	−0.29; 0.07	0.001
4	−0.17	−0.45; 0.10		−0.18	−0.36; 0.00					−0.15	−0.33; 0.03	
5	−0.27	−0.54; −0.00		−0.26	−0.44; −0.09					−0.25	−0.43; −0.07	

[a] The sample size for the analysis at 4 years of age decreases to 1237 in Piccolipiù and 3761 in NINFEA; [b] In NINFEA weight and height data are available at 18 months and not at 24 months.

4. Discussion

This paper describes a method for constructing a new standardized and comparable household income indicator (EHII) for child SEP to be used in birth cohort studies. The method is applied in four birth cohorts from two countries, Italy and France, and the derived EHII is described comparing its distribution with that of other SEP-related variables and estimating the cohort-specific associations between the EHII and infant and childhood BMI. The paper shows that using basic parental and household characteristics, typically available in birth cohort studies, it is possible to predict the household income with a fairly good prediction model performance (R^2 ranging between 0.41 and 0.53). The models were validated and the directions and magnitudes of the coefficients of the single predictors were consistent across the four studies. There was also a strong correlation between the predicted income and both the self-reported income, as collected by questionnaires, and the other individual SEP-related variables available (bank overdraft, perception of financial situation and number of hardships). The association between the EHII and the geographical deprivation index, available in the Italian cohorts only, was weaker. Finally, in all cohorts we observed an inverse association between the EHII quintiles and BMI, an outcome known to be strongly socially shaped [25].

The proposed method has some limitations. First, the models being cohort-specific, as they depend on the availability of the predictors in each cohort, model misspecification varies across the different studies. Furthermore, in its current version, we are not accounting for the prediction model error. Finally, being based on EUSILC this indicator cannot be used in non-European studies, although the approach can be applied to all countries where a survey/database similar to EUSILC exist.

The proposed EHII has several implications for epidemiological studies: (i) it allows to have a standardized and comparable child SEP indicator over different studies, (ii) it can be derived for all studies that are based in those European countries (n = 31) that are included in the EUSILC survey; (iii) it gives a measure of the household income, a domain which is otherwise very difficult to assess through questionnaires; (iv) it captures a SEP dimension different from and complementary to the one captured by the educational level.

Being based on external data from the EUSILC surveys, which are conducted in several European countries using the same design and procedures, the EHII allows obtaining a harmonized family income measure over different European populations. This is an essential need in the context of international collaborative studies. Other cross-country comparable composite SEP indicators have been proposed in the epidemiological literature, although none is focused on the household income. Among these the European Socio-Economic Classification is an occupational based index used as a SEP indicator in the H2020 LIFEPATH project [13]; the European Deprivation Index [26] is an ecological indicator constructed from the EUSILC survey and therefore in principle applicable to all European studies, even if the neighborhood/ecological deprivation likely affects health outcome through different mechanisms than the individual SEP. The household disposable income is one of the most important individual single indicators of child SEP, but is difficult to obtain through questionnaires; for example, in this study household income was available in all cohorts except NINFEA, but only in ELFE was assessed thoroughly. It follows that, mainly because of feasibility issues, epidemiological studies involving several birth cohorts typically use maternal education as the only indicator of SEP. Maternal education however might be insufficient to capture the multidimensionality of health inequalities or to control for confounding when SEP is an important potential confounder. Moreover, maternal education is practically stable over time, and, even when it changes, it may only increase, while the EHII is expected to vary over time and can capture longitudinal variations in SEP. The fact that the EHII is sensitive to longitudinal changes is of particular importance when studying the potential impact of economic crises that can hit strata of the population differently. Finally, the EHII can be used not only to measure child SEP within the framework of birth cohort research, but could contribute also to other epidemiological areas, as, for example, when it comes to population health surveys or adult cohorts.

5. Conclusions

The development of the equivalized household income indicator, contributes to improving the research on social inequalities in health, in particular in the context of European birth cohort collaborative studies, where it is essential to have harmonized comparable SEP indicators over the different studies.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/17/5/1700/s1, Figure S1: Calibration plot for the Piccolipiù model, Figure S2: Calibration plot for the NINFEA model, Figure S3: Calibration plot for the ELFE model, Figure S4: Calibration plot for the EDEN model, Table S1: Piccolipiù prediction model, Table S2: NINFEA prediction model, Table S3: ELFE prediction model, Table S4: EDEN prediction model.

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Validation of a standardised income indicator (EHII) to predict childhood obesity: evidence from Finnish register data

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STOP Roundtable
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1

EHII – Equivalized Household Income Indicator

- A new standardized and comparable household income indicator for use across European studies, **based on external data from the pan-European surveys - European Union Statistics on Income and Living Conditions (EUSILC), and internal data from the studies.**
- Developed within the framework of the H2020 **LifeCycle and STOP projects**, and now available in approx 20 European studies.
- *Pizzi C et al. "Measuring Child Socio-Economic Position in Birth Cohort Research: The Development of a Novel Standardized Household Income Indicator", Int J Environ Res Public Health, 2020.*

2

EUSILC

- **Cross-sectional and longitudinal survey to collect comparable annual microdata at both individual and household level**
  - **Household:** housing conditions, material deprivation and aggregated income data
  - **Individual**: basic demographic data, education information, limited health data, labour force data
- Samples of persons aged 16 years or older in **28 European Union States as well as Iceland, Norway and Switzerland** (~500,000 European residents annually)
- Data collection began in 2003 in few countries with subsequent expansion across Europe (in 2005 and 2011)

3

Construction of the the EHII

- **Step 1: Identification of "common variables"**, i.e. those variables available both in the study and in EUSILC
  - **Potential useful predictors**: marital status, parental age, citizenship and education; self-defined occupation/type of employment contract; ISCO codes, house type/property/size
- **Step 2**: **Choice of the aggregated income measure** of interest:
  - **Total disposable household income**(employee/self-employment income, pensions, benefits, allowances, company car, income from rental, interests/dividends/profit **minus** taxes on wealth, income and social insurance contributions), **equivalized in term of household size and composition**

4

Construction of the the EHII

- **Step 3: Construction of the index**
  i. The available "common variables" in the EUSILC database (2011) are categorized to match the structure of the variables in the study
  ii. The chosen income is regressed on these "common variables"
  iii. The prediction capability of the model is assessed using the R^2 statistics and the model is validated using EUSILC independent data (2015)
  iv. When appropriate (see point iii.) the regression coefficients derived from ii. are applied to the study data to derive the EHII

- Prediction capability/level of misspecification is study-specific

5

Finnish data

- Sample included 2-17-years old children who have visited child health clinic or school health care between 1st of January 2018 and 31st of December 2018.
- Socioeconomic indicators were received from Statistic Finland for adults who live in the same household with a child at end of year 2017.
- Obesity and overweight were calculated using the WHO criteria.
- Weight and height measurements from the National Outpatient Register on Primary Health Care Services (Avohilmo) were used for calculations.
- Sample included 2-17-years old children who have visited child health clinic or school health care between 1st of January 2018 and 31st of December 2018.
- Final merged data had 194423 unrelated children (no siblings or half-siblings were included) which has missing data on socioeconomic indicators.

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PREDICTORS (model 1)

- Mother NOT living with a partner (No/Yes)
- Mother: previous marriage (No/Yes)
- Maternal country of birth (Finland/Other)
- Paternal/partner country of birth (Finland/Other)
- Maternal education (Lower secondary/Upper secondary/Tertiary)
- Paternal/partner education (Lower secondary/Upper secondary/Tertiary)
- Maternal occupational status (Employed/Self-employed/Unemployed/Other)
- Paternal/partner occupational status (Employed/Self-employed/Unemployed/Other)
- Maternal ISCO 08 (Managers/Professionals/Technicians and Associate Professionals/Clerical Support Workers/Service and Sales Workers/Skilled Agricultural, Forestry and Fishery Workers+Craft and Related Trades Workers/Plant and Machine Operators, and Assemblers+Elementary Occupations+Armed Forces Occupations)
- Paternal/partner ISCO 08 (Managers/Professionals/Technicians and Associate Professionals/Clerical Support Workers+Service and Sales Workers/Skilled Agricultural, Forestry and Fishery Workers/Craft and Related Trades Workers/Plant and Machine Operators, and Assemblers+Elementary Occupations+Armed Forces Occupations)
- Maternal age (mean= 39.3, std= 7.41)
- Paternal/partner age (mean= 41.6, std= 7.19)
- Family size (2/3/4/5/6+)
- Constant

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Model 2 – Model 8

- Model 2: maternal and paternal education excluded
- Model 3: maternal and paternal occupational status excluded
- Model 4: maternal and paternal occupational code excluded
- Model 5: maternal and paternal occupational status and code excluded
- Model 6: all paternal predictors excluded
- Model 7: household size excluded
- Model 8: mother living without partner –indicator excluded

8

Consistency of household income variable with EHII predictions

Prediction	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Regression coefficient (b)	1.082	1.128	1.117	1.035	1.063	1.033	1.093	1.125
Constant	7.624	7.624	7.624	7.621	7.621	7.620	7.624	7.624
N	184169	184169	184169	188362	188362	187565	184169	184169
r2	0,425	0,420	0,364	0,377	0,321	0,339	0,375	0,382
rmse	0,356	0,358	0,375	0,373	0,389	0,384	0,372	0,370

LOGincome = constant + b * (prediction - mean(prediction)) + e
b: regression coefficient; e: residual

LOGincome = log (Ikturaha_c_k /12/weight)

Ikturaha_c_k: income variable from Statistics Finland, which is annual income variable (after taxes). LOGincome is calculated mean for each month.

Weight is the approximation for LOG-euro equivalised total disposable household income weight:
- 1.0 to the first adult
- 0.5 to the second and each subsequent person aged 14 and over
- 0.3 to each child aged under 14
- 0.4 to each child with age unknown

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Household income variable – EHII model 1 prediction

	Income variable		Model 1 prediction	
Decile	N	range	N	range
1.	18982	0e - 1204e	18419	722,4e - 1281,77e
2.	18982	1204,01e - 1442e	18420	1281,8e - 1487,91e
3.	18982	1442,01e - 1651e	18420	1487,92e - 1641,51e
4.	18982	1651,01e - 1847e	18420	1641,52e - 1794,52e
5.	18982	1847,01e - 2043e	18420	1794,53e - 1932,01e
6.	18982	2043,01e - 2259e	18420	1932,02e - 2086,54e
7.	18982	2259,01e - 2505e	18420	2086,55e - 2266,41e
8.	18982	2505,01e - 2840e	18420	2266,42e - 2457,95e
9.	18982	2840,01e - 3443e	18420	2457,96e - 2709,44e
10.	18983	>3443,01e	18420	>2709,44
missing	135		5757	

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Obesity (WHO) household income / EHII prediction deciles

Obesity (WHO)	Household income	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Income deciles									
1	1	1	1	1	1	1	1	1	1
2	1.077*	0.932*	1.004	1.006	0.951	1.032	0.925*	0.978	0.904**
3	1.033	0.918**	0.912**	0.933*	0.962	0.988	0.842***	0.835***	0.913**
4	1.034	0.809***	0.833***	0.821***	0.768***	0.847***	0.803***	0.798***	0.866***
5	0.984	0.817***	0.814***	0.873***	0.813***	0.932*	0.790***	0.832***	0.844***
6	0.953	0.710***	0.741***	0.741***	0.812***	0.786***	0.747***	0.653***	0.726***
7	0.933	0.642***	0.738***	0.647***	0.608***	0.636***	0.570***	0.668***	0.605***
8	0.898**	0.514***	0.536***	0.540***	0.551***	0.602***	0.541***	0.455***	0.562***
9	0.723***	0.431***	0.477***	0.508***	0.411***	0.420***	0.461***	0.364***	0.447***
10	0.578***	0.361***	0.387***	0.478***	0.446***	0.496***	0.445***	0.313***	0.338***
_cons	0.101***	0.131***	0.125***	0.123***	0.127***	0.120***	0.131***	0.135***	0.129***
N	189821	184199	184199	184199	188394	188394	187597	184199	184199
r2_pseudo	0,004	0,013	0,011	0,009	0,011	0,011	0,009	0,017	0,013
			*)	p<.05;	**)	p<.01;	***)	p<.001	

Logistic model: log(p(obesity)/(1 - p(obesity)) = constant + b1*decile1 + b2*decile2 + ... + b10*decile10

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