

ORIGINAL RESEARCH ARTICLE

Predicting the development of overweight and obesity in children between 2.5 and 8 years of age: The prospective ABIS study

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Summary

Background: A relationship between overweight and obesity early in life and adolescence has been reported. The aim of this study was to track changes in overweight/obesity in children and to assess risk factors related to the persistence of overweight/obesity between 2.5 and 8 years.

Study design: Children who participated in all three follow-ups at 2.5, 5 and 8 years in the prospective cohort All Children in Southeast Sweden (ABIS) ($N = 2245$, 52.1% boys and 47.9% girls) were classified as underweight, normal, overweight or with obesity, and changes within categories with age were related to risk factors for development of obesity in a multivariate analysis.

Results: The prevalence of overweight and obesity between 2.5 and 8 years was 11%–12% and 2%–3%, respectively. Children with normal weight remained in the same category over the years, 86% between 2.5 to 5 years and 87% between 5 and 8 years. Overweight and obesity at 5 and 8 years were positively related to each other ($p < 0.0001$ for both). High level of TV watching at 8 years and high maternal body mass index (BMI) when the child was 5 years were related to lower probability to a normalized ISO-BMI between 5 and 8 years of age ($p < 0.05$ for both).

Conclusion: Children with ISO-BMI 18.5 to 24.9 remain in that range during the first 8 years of life. Children with overweight early in life gain weight and develop obesity, and children with obesity tend to remain with obesity up to 8 years of age. TV watching and high maternal BMI were related to lower probability to weight normalization between 5 and 8 years of age. A multidisciplinary approach to promote dietary and physical activity changes in the entire family should be used for the treatment and prevention of overweight and obesity in early childhood.

KEYWORDS

children, obesity, risk factors, tracking

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1 | INTRODUCTION

The prevalence of overweight and obesity among Swedish preschool children born between the years 1997–2002 has been reported to be 12.9%–22.3% and 2.3%–4.5%, respectively.^{1–5} A normal growth pattern is one of the most basic indicators for children's health, and hence, it has been monitored extensively in clinical paediatrics during the years.⁶ Early risk factors such as maternal smoking, maternal nutrition during pregnancy, rapid infant growth, sleeping behaviour, amount of physical activity, TV watching, parental socioeconomic status and parental overweight/obesity,⁷ duration of exclusive breastfeeding and number of siblings⁸ have been associated to the development of obesity in childhood. In some parts of Sweden, prevalence of childhood obesity has been reported to be higher in girls^{2,9} and in rural areas.^{9,10} High parental/family psychological stress, such as serious life events, has been also reported to be related to obesity in infancy.^{5,11}

Cardiovascular disease, as well as mortality in both cardiovascular and non-cardiovascular disease, is associated with overweight and obesity in adulthood.¹² The risk is higher the earlier overweight and obesity debuts in young adults.¹² Obesity affects almost every organ in an adverse manner during adolescence and childhood, and the pattern is similar to adults in many ways.^{13,14} However, the relationship between overweight/obesity in childhood and morbidity and disease in adulthood is weak.¹⁵ Childhood obesity early in life is related to metabolic disorders, hypertension, serum lipid abnormalities and medical conditions including bronchial asthma,¹⁴ orthopaedic problems¹⁶ and psychosocial issues.¹⁷

Overweight and obesity in infants and school children have been related to persistent overweight and obesity during adolescence,^{18–20} as well as future development of obesity and morbidity in adulthood.¹⁵

Lifestyle modification, pharmacotherapy and surgery are the main therapeutic alternatives in obesity.²¹ In Sweden, pharmacotherapy is currently not available for children and obesity surgery in adolescents is only performed in controlled studies.²² The results of multidisciplinary lifestyle modification and diet treatment in children with overweight and obesity between 6 and 11 years of age²³ and adolescents²⁴ is modest at best. Long follow-up in younger children has been reported with better treatment results.^{25,26}

Thus, without efficacious treatment, it is even more important to be able to prevent obesity. Early predictive risk factors have been studied in preschool^{3,4,27,28} and school children,^{29,30} and tracking the development of overweight and obesity in early infancy has now been emphasized.^{19,20} It is important to know more about risk factors promoting infant obesity between preschool and school age as well as factors of success in the management of overweight/obesity in childhood in order to prevent further development of obesity in older children. The hypothesis of this study was that the development of overweight and obesity in children starts as early as 2.5 to 5 years and remain later. Factors that may predict this development, that is, overweight/obesity or normalization of ISO-body mass index (BMI) between 2.5 and 8 years of age in childhood, were assessed.

2 | MATERIAL AND METHODS

All mothers who gave birth to a child between 1 October 1997 and 31 October 1999 in the Southeast of Sweden ($n = 21\,700$) were asked to participate in the prospective study All Babies in Southeast Sweden (ABIS). The main purpose of the study was to prospectively study the aetiology of autoimmune and other diseases. Parents were instructed to answer a questionnaire at birth of the child and further fill in a diary during the child's first year of life regarding perinatal factors, breastfeeding and time of introduction of other foods, dietary habits in the family, infections and so forth. Parents answered a comprehensive questionnaire regarding demographic data, maternal nutrition, psychosocial factors, serious life events, disease in the family or child and dietary habits in the family at birth and in association with a regular check-up for the child at well baby clinics at 1, 2.5 and 5 years of age. At the age of 8, two questionnaires, one to a parent and one to the child, were sent home to the family and returned through mail. Maternal and paternal height and weight were collected at the 1-year assessment, and the BMI of the children was validated between Child Health Clinic chart and ABIS questionnaires. The weight and height development of the children in this cohort up to 5 years of age has been presented previously.³

2.1 | Samples at 2.5, 5 and 8 years

Parents of 17,055 (78.6%) newborn children accepted to participate in ABIS. This study focusses on those children who participated in all three follow-ups at 2.5 years, 5 years and at 8 years—a cohort of $N = 2245$ children, 52.1% boys ($n = 1170$) and 47.9% girls ($n = 1075$). Complete data regarding length and weight at all three follow-up time points were available in 1783 children and were the basis for the analysis of BMI tracking between 2.5 and 8 years of age. The prevalence of overweight and obesity in the children at 5 and 8 years and other demographic, perinatal and nutritional factors have been reported previously.³¹ This subsample of the ABIS cohort was found to be representative of the main cohort.

2.2 | Definitions

2.2.1 | Underweight, overweight and obesity

The weight categories were defined as underweight (ISO-BMI < 18.5), normal weight (ISO-BMI = 18.5–24.9), overweight (ISO-BMI = 25–29.9) and obesity (ISO-BMI > 30) in accordance with international standard for children.^{32,33} According to the Public Health Agency of Sweden, 99.2% to 99.5% of the children born in this period were registered at the Health Child Clinics in Sweden, where, among other things, weight and height were measured at 1, 2.5 and 5 years with instruments regularly calibrated. The next time Swedish children are measured was during the first/second grade in school. Parents reported measured weights and heights taken at 2.5, 5 and 8 years of

age. Age and sex-specific BMI was calculated and used to group the children into four weight categories: children with underweight, normal weight, overweight or with obesity.

2.2.2 | Demographic, perinatal, nutritional and social factors

Demographic factors (e.g., maternal and paternal education, household income after taxation, living area at birth and gender of the child) and perinatal factors (e.g., maternal age at delivery, gestational age, birth weight, maternal nutrition and maternal smoking during pregnancy) related to the development of overweight/obesity in this group have been previously reported.³¹ Other social data, such as single motherhood at child's birth and reported serious life events in the family before 5 and 8 years age of the child, were also obtained in the questionnaires. For the purpose of this paper, a 4-grade index of the families' early psychosocial vulnerability was used.³⁴

2.3 | Physical activity, TV watching and computer/game activity

Parents reported the level of daily physical activity, defined as hours running, jumping and playing outside, of the child at 5 and 8 years. The number of hours the child spent on TV watching or computer/game activity at home in general daily was also assessed. The levels were defined as low activity (<30 min), medium activity (>30 min–4 h) and high activity (>4 h a day) for all three variables.

2.4 | Statistical analysis

Two distinct research questions were addressed with respect to predictors of change in weight status. In Table 1, polychotomous logistic regression was used to evaluate the association between weight status at age 2.5 and 5 years with weight status at 8 years of age. In these models, normal weight was utilized as the logical reference category, and hence, odds ratios should be interpreted as for being either with underweight, overweight or with obesity rather than normal weight. In Table 2, unconditional logistic regression was used to identify predictors (other than prior weight status) of weight normalization (from overweight or obesity) to normal weight between 5 and 8 years. In these models, individuals who were found to be underweight at the earlier age were omitted from the analysis (*n* = 102, Figure 2). Findings are reported as odds ratios with 95% confidence interval and two-tailed *p* values. Due to missing values, model estimation was undertaken using multiple imputation with five imputation samples. Identification of independent predictors of weight normalization used a forward stepwise algorithm. A multivariate analysis was performed to identify predictor related to the resolution from overweight/obesity to the normal weight category between 5 and 8 years.

TABLE 1 Predictors of weight status at 8 years of age based on weight status at ages 2.5 and 5 years using polychotomous logistic regression

Predictors at age 2.5 years				
	Odds ratio	Lower	Upper	<i>p</i> value
Underweight at age 8 years				
Underweight	6.17	4.17	9.12	<0.0001
Overweight	0.25	0.08	0.79	0.02
Obesity	<0.01	<0.01	ne	0.98
Children with normal weight at age 8 years (reference category)				
Children with overweight at age 8 years				
Underweight	0.28	0.09	0.88	0.03
Overweight	4.34	3.09	6.10	<0.0001
Obesity	7.95	3.56	17.76	<0.0001
Children with obesity at age 8 years				
Underweight	0.92	0.12	7.10	0.94
Overweight	12.86	6.35	26.04	<0.0001
Obesity	46.72	16.20	134.74	<0.0001
Predictors at age 5 years				
	Odds ratio	Lower	Upper	<i>p</i> -value
Children with underweight at age 8 years				
Underweight	9.98	6.65	14.97	<0.0001
Overweight	0.10	0.01	0.75	0.02
Obesity	<0.01	<0.01	ne	0.99
Children with normal weight at age 8 years (reference category)				
Children with overweight at age 8 years				
Underweight	0.22	0.03	1.57	0.13
Overweight	13.64	9.82	18.94	<0.0001
Obesity	116.82	45.18	302.08	<0.0001
Children with obesity at age 8 years				
Underweight	<0.01	<0.01	ne	0.98
Overweight	46.12	15.06	141.19	<0.0001
Obesity	2086.24	532.70	8170.43	<0.0001

Note. The reference category is normal weight. Odds ratios represent the relative odds of being in each weight category at 8 years of age (rather than normal) based on weight category at ages 2.5 and 5 years. Due to small numbers in the obesity category, some odds ratios are large and, if too large to be interpreted meaningfully, have been reported as 'ne' in the table.

The ABIS study has ethical approvals from the Research Ethics Committees of the Faculty of Health Science at Linköping University, Sweden, Ref. 1997/96287 and 2003/03-092, and Medical Faculty of Lund university, Sweden (Dnr 99227, Dnr 99321), covering this study. All parents of the children in the ABIS study gave their informed consent after careful oral and written information in addition to video film presentation.

3 | RESULTS

The prevalence of underweight between 2.5 and 8 years of age was between 6%–9%. For normal weight, the prevalence varied between

TABLE 2 Factors related to development of overweight and obesity in childhood and the resolution of weight class from overweight/obesity to normal between 5 and 8 years of age

Predictor of resolution	Odds ratio ^a	95% confidence interval	p value
<i>Univariate analysis</i>			
Maternal smoking during pregnancy			>0.9
No	1.0		
Yes	1.04	0.44, 2.48	>0.9
Activity level at age 5			0.13
Low (<30 min)	1.0		
Medium (>30 min–4 h)	1.01	0.49, 2.07	>0.9
High (<5 h)	1.63	0.83, 3.28	0.2
Activity level at age 8			0.3
Low (<30 min)	1.0		
Medium (>30 min–4 h)	1.39	0.86, 2.25	0.2
High (<5 h)	0.64	0.16, 2.60	0.5
TV watching at age 5			0.7
Low	1.0		
Medium	0.89	0.35, 2.30	0.8
High	0.70	0.25, 1.97	0.5
TV watching at age 8			0.01
Low	1.0		
Medium	1.28	0.63, 2.57	0.5
High	0.60	0.29, 1.24	0.2
Fish index of child at age 1			0.7
Seldom	1.0		
1–2 per week	1.04	0.61, 1.75	0.9
3–5 per week/almost daily	0.64	0.21, 2.00	0.4
Mother nutritional index			0.5
Low quality	1.0		
Partly lower quality	0.94	0.42, 2.14	0.9
Partly higher quality	0.73	0.31, 1.67	0.5
Higher quality	0.48	0.14, 1.68	0.3
Education of mother at birth			0.1
College/university	1.0		
Secondary school	0.77	0.27, 2.23	0.6
Primary school	0.76	0.27, 2.14	0.6
Serious life event: mother			0.1
No	1.0		
Yes	2.01	0.88, 4.62	0.1
Paternal BMI at children age 5	0.94	0.88, 1.01	0.08
Maternal BMI at children age 5	0.90	0.84, 0.97	0.004
Paternal BMI at children age 8	0.91	0.85, 0.97	0.007
Maternal BMI at children age 8	0.91	0.85, 0.97	0.002
Birth weight of the children	1.00	0.99, 1.01	0.6
Birth height of the children	0.99	0.90, 1.09	0.8
<i>Multivariable analysis</i>			
TV watching at age 8			0.04
Low	1.0		

TABLE 2 (Continued)

Predictor of resolution	Odds ratio ^a	95% confidence interval	p value
Medium	1.26	0.62, 2.55	0.5
High	0.65	0.31, 1.35	0.2
Maternal BMI at children age 5	0.91	0.85, 0.98	0.01

Abbreviation: BMI, body mass index.

^aUnconditional logistic regression.

76%–80%; for overweight, 11%–12%; and for obesity, 2%–3% (Figure 1).

3.1 | Transition across weight categories between 2.5 and 8 years of age

When considering the normalization of weight, that is, the transition between weight categories across age, the data indicate a change among individuals. All children (*n* = 141) in the underweight category at 2.5 years remained in the underweight (40/141, 28%) or normal (101/141, 72%) weight categories at 5 years, and none of the children in the underweight group at 2.5 or 5 years transitioned to the overweight or obesity category at 8 years of age (Figure 2).

Children in the normal weight category remained in the normal weight category over the first years of life: 1209/1398 (87%) of the children between 2.5 to 5 years and 1224/1425 (86%) of the children between 5 and 8 years. Among the children in the normal weight category at 2.5 years of age, 128/1398 (9%) transitioned to the overweight/obesity categories until 5 years of age. From the age of 5, 96/1425 (7%) of children in the normal weight category transitioned to overweight/obesity categories at 8 years of age (Figure 2).

Among children in the overweight category at 2.5 years of age, 107/213 (50%) normalized their weight, 82/213 (39%) remained in the overweight category and 23/213 (11%) transitioned to the obesity category at 5 years of age (Figure 2). From the age of 5, 99/202 (49%)

of children in the overweight category normalized their weight, whereas 103/202 (51%) transitioned to overweight/obesity categories at 8 years of age (Figure 2). The probability of normalizing ISO-BMI for children with overweight was similar between 2.5 to 5 years than 5 to 8 years, 50% versus 49%.

Among children in the obesity category at 2.5 years of age, 8/31 (26%) normalized their weight, whereas 23/31 (74%) remained in the overweight category or transitioned to the obesity category at 5 years of age (Figure 2). From the age of 5, 3/53 (6%) of children in the overweight category normalized their weight, whereas 51/54 (94%) transitioned to overweight/obesity categories at 8 years of age (Figure 2). The probability of normalizing ISO-BMI for children with obesity was higher between 2.5 to 5 years than 5 to 8 years (26% vs. 6%), although the numbers were quite small. None of the children with obesity early in life became underweight until 8 years of age.

3.2 | Relation between weight categories between 2.5 and 8 years of age

Changes from 2.5 to 8 years were as follows: Underweight at age 8 was positively predicted by underweight at age 2.5 (*p* < 0.0001) and negatively by overweight at age 2.5 (*p* = 0.02). Overweight at 8 years was negatively predicted by underweight at age 2.5 (*p* = 0.03) and positively predicted by both overweight and obesity at age 2.5 (*p* < 0.0001 for both). Finally, obesity at age 8 was positively predicted by both overweight and obesity at age 2.5 (*p* < 0.0001 for both). All comparisons were made in relation to normal weight (Figure 3A and Table 1).

Changes from 5 to 8 years were as follows: Underweight at age 8 was positively predicted by underweight at age 5 (*p* < 0.0001) and negatively by overweight at age 5 (*p* = 0.02). Overweight at 8 years was predicted by both overweight and obesity at age 5 (*p* < 0.0001 for both). Obesity at age 8 was positively predicted by both overweight and obesity at age 5 (*p* < 0.0001 for both). All comparisons were made relative to normal weight (Figure 3B and Table 1).

As the focus of this paper was to predict factors influencing the development of overweight and obesity in the children, children in the underweight group were excluded from further analysis. In a univariate analysis, known factors related to obesity in children as paternal and maternal BMI as well as TV watching at 8 years were significantly (*p* = 0.01 to 0.002) related to the transition between overweight/obesity to a normal ISO-BMI in the children between 5 and 8 years of age (Table 2). Neither social factors such as maternal education and severe life events, nor maternal smoking, other

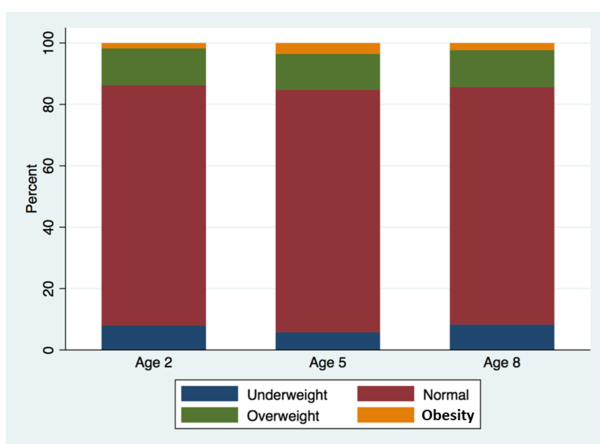


FIGURE 1 The prevalence of underweight, normal weight, overweight and obesity at 2.5, 5 and 8 years of age in 2245 Swedish children born in 1997–1999

Complete cases at all ages (n=1783)

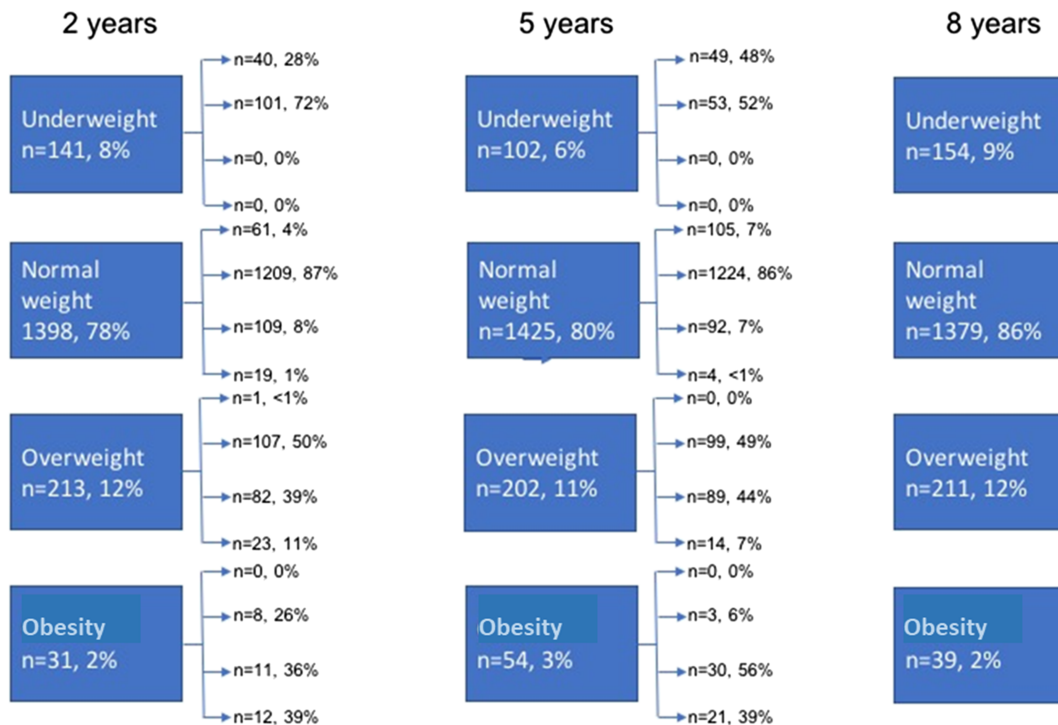


FIGURE 2 The transition of children between the different weight categories between 2.5, 5 and 8 years of age. The arrows emanating from each box indicate number and percent transitioning from that state to underweight, normal, overweight and obesity (from top to bottom)

measures of physical activity or nutritional factors were related to this transition (Table 2). In a multivariate analysis, besides a high level of TV watching at 8 years of age, only maternal BMI when the child was 5 years of age was related to lower probability to a normalization of ISO-BMI in the children from 5 to 8 years of age (Table 2).

4 | DISCUSSION

This study found that children tend to follow their ISO-BMI acquired already at 2.5 up to 8 years of age. Children with underweight remain underweight or become normal weight. Over 90% of the children with underweight or normal weight remain underweight or normal weight over the ages. Children with overweight tend to gain to obesity and children with obesity tend to remain in this group. The odds ratio for children to be affected by obesity at 8 years was considerably higher between 5 and 8 than 2.5 and 8 years of age. There were children who normalized ISO-BMI between ages, particularly those with overweight, 50% between 2.5 and 5 and 49% between 5 and 8 years of age. High level of TV watching at 8 years of age and maternal BMI when the child was 5 years were related to lower probability to a normalization of ISO-BMI between 5 and 8 years of age.

Our findings corroborate previous studies.^{19,20} In one of these studies, the BMI of 532 adolescents was categorized in weight classes according to the International Obesity Taskforce (IOTF) international cut-off values and the association between BMI categories at

15–17 years was related to BMI at 2–4 and 7–5 years of age. Similar to our results, the older the child, that is, between 5–7 years as compared with 2–4 years, the more persistent combined overweight/obesity at 15–17 years.¹⁹ In a recent large registry study,²⁰ BMI of 55 505 German adolescents between 15 to 18 years was classified to weight classes thin, normal, overweight and obesity according to SD scores based on a German population. A yearly BMI weight class assessment between birth and 14 years showed that thin/normal adolescents seem to be stable from early life, in contrast to adolescents with overweight or obesity. Adolescents with obesity seemed to start their tracking into obesity already before the age of 4,²⁰ which is in accordance with our prospective data.

The results of multidisciplinary lifestyle modification and diet treatment in children with overweight and obesity between 6 to 17 years of age^{23,24} are not as promising as expected, but the results are better in children between 5 and 9 years of age.^{25,26} Parents and clinicians have been concerned of inducing eating disorders later in childhood if the weight of the child is addressed to early.³⁵ However, this has not been corroborated.³⁶ Thus, in clinical practice, it has been discussed among paediatricians at what age overweight/obesity should be addressed as an issue when advising parents at the Child Health Centers. This study cannot confirm that maternal nutrition, maternal smoking during pregnancy nor maternal education explain the change in overweight/obesity in the children between 5 and 8 years. However, besides parental overweight/obesity, the amount of physical activity and TV watching early in life⁷ seem to be

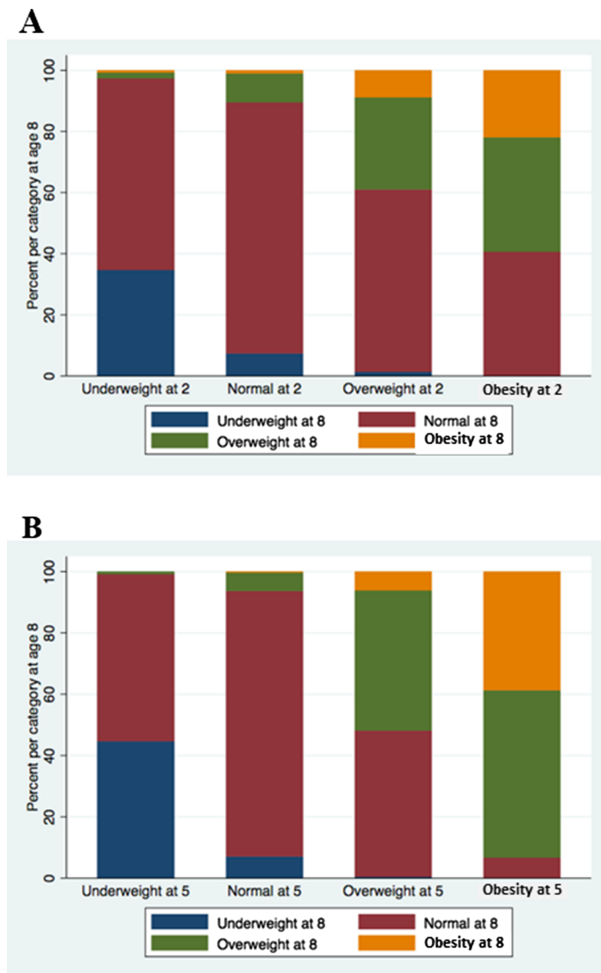


FIGURE 3 Weight class distribution in Swedish children at age 8: risk from previous ages. (A) Weight class at age 2.5 as predictor and (B) Weight class at age 5 as predictor for weight at 8 years of age

important. Particularly, maternal BMI, when the children were 5 and 8 years, as well as the children developing higher frequency of TV watching habits at 8 years of age seem to be important risk factors for persistent overweight/obesity in early childhood.

Our results suggest that an effort to prevent further increase of weight in children should be initiated as early as between 2 and 5 years of age. As maternal overweight and obesity are not only genetic predictors but also a mixture of psychosocial factors in an 'obesogenic' environment,³⁷ changing the family lifestyle, particularly in families with high maternal BMI, should be in focus and not only the infant/child. The family and the physical and social environment tend to influence children's obesity risk through an influence on children's nutrition and physical activity.³⁸

The strengths and limitations of this study are related to its design. It was a prospective, observational study following a large cohort of children from birth to 8 years of age. The weight and height of the children were reported by the parents, but the questionnaires were timed with measurements of weight and height of the children in the general child health care system and are reliable. Recall bias may have influenced the results of the questionnaires in general.

Including only children who participated in all the three follow-ups may jeopardize the representability of the population as families with obesity may be prone to discontinue. Similar assumptions can, however, be made about otherwise healthy families. Nonetheless, the relatively large number of participants with complete data suggests that the results are reliable and that significantly small differences between small groups could be identified. TV watching when the participants in this cohort were children is not the same nowadays. The variety of electronic gaming devices is larger but reflects the same phenomenon: physical inactivity.

In conclusion, children follow their ISO-BMI acquired already from 2.5 up to 8 years of age. Most of the children with normal ISO-BMI for age remain normal weight. Many children with overweight tend to become obese, and children with obesity tend to remain with obesity between 5 and 8 years of age. High level of TV watching at 8 years of age and high maternal BMI when the child was 5 years were related to lower probability to a normalization of ISO-BMI between at 8 years of age. Lifestyle changes in the family very early in life must be promoted in the treatment and prevention of overweight and obesity in childhood.

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CONFLICT OF INTEREST

The authors do not have any conflicts of interest to report.

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