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Dental caries and body mass index by socio-economic status in Swedish children

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Abstract – *Objectives:* The aim of the present study was to evaluate the association between dental caries, childhood body mass index (BMI), and socioeconomic status in Swedish children. *Methods:* The study cohort consisted of 2303 10-year-old children with data on socioeconomic status, BMI at 4, 5, 7 and 10 years of age, and caries at 6, 10 and 12 years of age. Anthropometric measures were carried out by trained nurses according to standardized routines. The occurrence of caries was registered from county records, and the children were classified into one of five socioeconomic clusters based on their census registration address. *Results:* Caries prevalence decreased with increasing socioeconomic status at all ages, whereas childhood BMI and proportion of overweight/obese children were unrelated to socioeconomic status. Obese, but not overweight, children had more caries affected teeth than non-obese, and BMI had an independent, though weak, effect on caries variation in multiple regression. Interestingly, overweight/obese 4-year-olds, who had normal body weight at 5, 7 and 10 years of age, had significantly less caries than children who had normal body weight from 4 to 10 years of age. *Conclusions:* Overweight and caries prevalence are significantly associated in Swedish children. However, the association is weak. Nevertheless, the concept that child dental services and child welfare services can benefit from joint programs is supported.

Key words: body mass index; dental caries; socioeconomic status

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Overweight and obesity are increasing public health problems worldwide and in Sweden (1). For example, among Swedish 10-year-olds, 18–25% are overweight and 3–5% are obese (2, 3). Similarly high numbers are reported for many Western countries (4, 5). Overweight and obese children/adolescents are at increased risk for developing psychosocial and medical problems compared with individuals with normal weight (6, 7).

High sugar intake, e.g. sugar-containing snacks and soft drinks, is reported to be more common among overweight and obese children/adolescents than those with normal weight (8). Frequent sugar intake is also a recognized risk factor for dental caries (8–12). Thus, the claimed eating pattern among overweight or obese children may be a risk factor in common for overweight and caries. Although theoretically, overweight and obesity can be associated with dental caries, the documentation of such associations is sparse and seemingly inconsistent (13). Larson et al. (14) reported that dental caries correlates positively with body mass index (BMI) in 15-year-olds living in northern Sweden, whereas Chen et al. (15) found no association with obesity in Taiwanese 3-year-olds, and Tuomi (16) reports that obesity alone is not a good predictor for caries in Finnish 5- to 13-year-olds. Thus, further studies are needed to evaluate the

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impact of age (such as growth phase) and other study population characteristics (such as general nutritional status) on a possible association between overweight and dental caries. Notably, malnutrition (wasting or stunting) is associated with enhanced susceptibility to caries because of impaired saliva secretion and composition (17).

Lifestyle factors (such as dietary habits) and lifestyle-influenced conditions/diseases (such as overweight/obesity and dental caries) are shown to co-vary with socioeconomic status (18, 19). In spite of the fact that socioeconomic status appears to be a confounder when the association between overweight and caries is searched for, we have not found any publication describing associations between relative body weight, socioeconomic status and dental caries. The aim of the present study was to evaluate associations between dental caries and BMI, and socioeconomic status in all children born in 1991 and living in the county of Östergötland, Sweden.

Methods

Study cohort

All children born in 1991 and living in the county of Östergötland, Sweden in 2001 were eligible for the present study. Data on body weight and height at 4, 5 (i.e. 5–5.5), 7, and 10 years of age were extracted from records at the child welfare centres and at the school health service. Out of 5987 eligible children, anthropometric data were available for 5517 (92%) children. Information on dental status at 6, 10 and 12 years of age was retrieved from annual routine epidemiological reports to the county council. Data on caries status in 2001, i.e. when the children were 10 years old, were reported for 4305 children (72%), and of these, caries data were also available at 6 and 12 years for 2303 children (54%). These children were students at 184 elementary schools, and patients of 165 dental care providers. The Regional Ethical Board at the University of Linköping, Sweden, approved the study.

Anthropometric measures

Anthropometric measures were carried out by trained nurses according to standardized routines in the county. Height (recorded to the nearest centimetre) and body weight (to the nearest 0.1 kg) were measured on validated scales when the child wore light clothing but no shoes. Body mass index (BMI; weight/height in kg/m^2) was calculated and compared with the international, gender- and age-adjusted (2–18 years) cut-off points for BMI for overweight (>25 kg/m^2 at 18 years) and obesity (>30 kg/m^2 at 18 years) presented by Cole et al. (20).

Socioeconomic status

Based on their registration address at census, the children were classified into one of five distinct clusters with homogenous socioeconomic characteristics for the area using information on available income, social allowances (e.g. social security allowance, and rent allowance) from the municipality, and educational level (see statistics section), as previously described (21). A total of 781 small areas in the county were classified into one of the five clusters [highest (I) to lowest (V) socioeconomic status].

Dental caries

In the county of Östergötland all children are called for regular dental check ups from age 3 to 20 years. At the check ups the occurrence of dental caries is detected with a mirror and a blunt probe under good operating light. Bitewing X-rays are used on individual indications, as regulated by the Swedish Radiation Protection SSI FS 1990:2 regulation (http://www.ssi.se/forfattning/PDF_Eng/1990-2e.pdf). Data on the history of decayed (manifest caries), extracted (due to caries) or filled teeth and approximal tooth surfaces, respectively, are reported annually to the County Council. The criteria for manifest caries are: the minimal level that can be defined as a visually detectable cavity on smooth surfaces, a catch of the blunt probe under slight pressure for fissures, or an approximal translucency into the dentin on the bitewing. For the study cohort, i.e. children born 1991, caries data for 1997 (6 years of age), 2001 (10 years), and 2003 (12 years) were retrieved from the County Council registers. The following caries scores were used: (i) deft (6 years), sum of decayed (d), extracted (e) and filled (f) deciduous teeth (t); (ii) DFT (10 and 12 years), sum of decayed (D) and filled (F) permanent teeth (T), and DFSa, sum of decayed (D) and filled (F) approximal tooth surfaces (a) of permanent teeth.

Statistical methods

Statistical analyses were performed with SAS (version 9.1; SAS Institute Inc., Cary, NC, USA) and SPSS (version 10.0; SPSS Inc., Chicago, IL,

USA) software. Means with 95% CI and proportions according to defined criteria, e.g. overweight, are presented for description purposes. To adjust for possible socioeconomic cluster and gender differences in oral health and body weight associated behaviour, means were standardized for socioeconomic clusters, and/or gender. Differences between means were tested with one-way ANOVA followed by a multiple mean post hoc test using the glm procedure in SAS. Independent effects of BMI on caries prevalence at various ages were tested using linear multiple regression analysis including gender and socioeconomic cluster as covariates.

Tests for trends of proportions in strata, e.g. percent overweight and obese children in different socioeconomic clusters, were performed using the chi-squared linear trend test. All statistical tests were two-sided, and the significance level was set at $P < 0.05$. Sensitivity (percent truly diseased classified as diseased) and specificity (percent truly healthy classified as healthy) were calculated.

Cluster analysis for socioeconomic classification

Hierarchical cluster analysis using the Ward method was applied to identify distinct clusters with respect to socioeconomic status in the county of Östergötland (21). Briefly, Wards cluster analysis uses an analysis of variance approach to evaluate the distances between clusters, and thereby identify the ideal number of clusters to describe the variation in socioeconomic status among residential areas in the county. Data on (i) available income, (ii) social allowances, and (iii) educational level as obtained from Key-Code areas from Swedish Statistics (http://www.scb.se) were employed in the model.

Besides identifying the optimal number of clusters, cluster means for the independent variables were generated by Ward's cluster analysis. The cluster means were then modelled using the K-means procedure in SPSS, and five socioeconomic clusters of 20–355 small areas in the county were defined. The children were classified into one of these five socioeconomic clusters based on their registration address at census.

Results

Participant characteristics

Caries prevalence was highly skewed in the study cohort at all ages, i.e. 6, 10 and 12 years of age. Thus, 69.0%, 76.9%, and 68.0% were caries free at 6, 10 and 12 years of age, respectively (Table 1). Children with signs of caries had 3.8 (3.6–4.1) [mean (95% CI)] caries affected teeth at 6 years of age, 1.9 (1.8–2.0) affected teeth at 10 years, and 2.1 (2.0–2.2) affected teeth at 12 years (Table 1). The proportion of caries free children were similar for boys and girls at all ages, as was caries prevalence at 6 years of age, whereas at 10 and 12 years of age girls had 0.12 ($P < 0.01$) and 0.16 ($P < 0.05$) more caries affected teeth, respectively, than boys.

At 4 years of age, 87.2% of the children were classified as having normal body weight, 10.8% were classified as overweight, and 2.0% as obese (Table 1). Significantly more girls were overweight/obese than boys at ages 4, 5 and 7 years ($P = 0.01$–0.001), whereas the proportions were similar at 10 years of age. The proportion of

Table 1. Study cohort ($n = 2303$) characteristics[a]

	Dental caries			Body weight			Social group	
Age (years)	Scored	% Caries free[b]	Mean (95% CI) deft/DEFT[c]	Measured	Mean (95% CI) childhood BMI	% Overweight/ obese[d]	Socioeconomic cluster	%
4	–			Yes	16.0 (15.9–16.0)	12.8	I (high)	6.8
5	–			Yes	15.9 (15.8–16.0)	14.2	II	28.6
6	Yes	69.0	3.8 (3.6–4.1)	–			III	32.4
7	–			Yes	16.4 (16.3–16.5)	17.1	IV	26.7
10	Yes	76.9	1.9 (1.8–2.0)	Yes	18.3 (18.2–18.4)	21.8	V (low)	5.5
12	Yes	68.0	2.1 (2.0–2.2)					

[a]53% boys and 47% girls.
[b]deft = 0 (6-year-olds) or DFT = 0 (10- and 12-year-olds).
[c]Mean (95% CI) among children with deft ≥ 1 (6-year-olds) or DFT ≥ 1 (10- and 12-year-olds).
[d]Based on BMI (20).

overweight/obese children increased with age (Table 1). At age 10 years 17.5% were overweight and 4.3% were obese (Table 1).

Caries and childhood BMI by socioeconomic status

First, caries prevalence and proportion of overweight/obese children were compared among groups of children in the five socioeconomic clusters. Caries prevalence (standardized for gender) was highest in the lowest socioeconomic cluster and decreased with increasing socioeconomic status at all ages, as illustrated for 6- and 12-year-olds (Fig. 1a,b, respectively). Thus, at age 6 the mean number of caries affected teeth was three times higher among children in the lowest (V) compared with the highest (I) socioeconomic cluster (deft 2.4 versus 0.8, $P < 0.001$), and at age 12 it was nearly twice as high (DFT 1.1 versus 0.6, $P < 0.002$). Similar results were obtained when boys and girls were analysed separately (data not shown). Neither childhood BMI (gender standardized mean) nor proportion of overweight/obese children differed significantly between the different socioeconomic groups at any age (data not shown).

Associations between individual measures of childhood BMI and caries

Next, the relationship between body weight and caries prevalence at the individual level was evaluated. Obese, but not overweight, children had more caries affected teeth than nonobese. A statistically significant difference was evident when the children were 12 years old. Thus, children who were obese at 4 years of age had 1.1 caries affected teeth when they were 12 years old compared with 0.7 affected teeth ($P = 0.027$) in those who had normal weight at age 4 (gender and socioeconomic status standardized means; Fig. 2). Similar results were seen when comparing children who were not obese at 10 years. Regression analysis, including gender and socioeconomic clusters as covariates, confirmed that childhood BMI, included as a continuous variable, at various ages had an independent, although weak, effect on caries prevalence at 12 years of age (Table 2).

Children who were overweight/obese at 4 years of age but with normal weight at 5, 7 and 10 years of age ($n = 37$) had significantly fewer approximal carious surfaces than children with normal weight from 4 to 10 years of age ($n = 1186$; Fig. 3). In contrast, those children who were overweight/obese at 4 years and remained overweight/obese at 5, 7 and 10 years of age ($n = 101$) had significantly more approximal carious surfaces (DFSa) than children with normal weight at all measure points, i.e. at 4, 5, 7 and 10 years of age (Fig. 3).

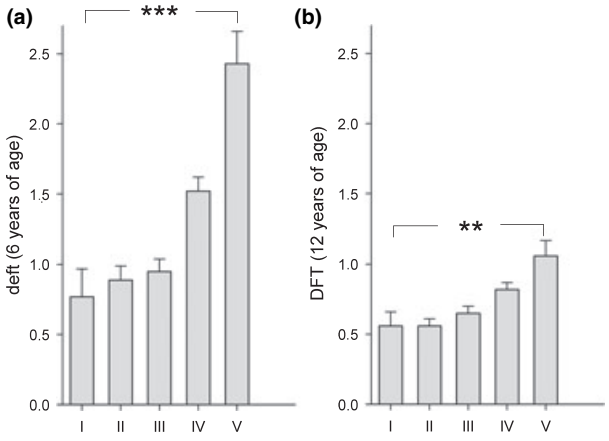

Fig. 1. Number of caries affected teeth at (a) 6 years (deft) and (b) 12 years (DFT) of age by socioeconomic clusters. $^{**}P < 0.01$ and $^{***}P < 0.001$.

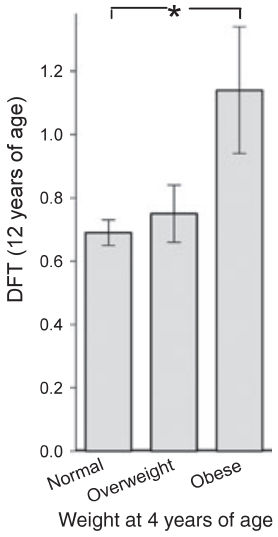

Fig. 2. Caries prevalence at 12 years of age (gender and socioeconomic status standardized mean with 95% CI) by weight status based on childhood BMI at 4 years of age. $^{*}P < 0.05$.

Sensitivity to and specificity of predicting caries by using childhood BMI and overweight/obesity

The specificity of predicting freedom of caries symptoms (DFT = 0) at age 12 by lack of overweight/obesity at age 4 was moderate for both genders (68%), whereas the sensitivity to predicting presence of caries (DFT > 0) was low (34%). Similar levels of specificity and sensitivity were obtained for overweight at other ages.

Table 2. Linear regression analysis of childhood BMI on number of caries affected teeth

Independent variables[a]	Dependent variable (DFT at 12 years of age)[b]		
	β-value	SE	P-value
Childhood BMI at 4 years of age	0.048	0.020	0.021
Childhood BMI at 5 years of age	0.050	0.018	0.007
Childhood BMI at 7 years of age	0.032	0.013	0.017
Childhood BMI at 10 years of age	0.024	0.009	0.010
Gender[c]	−0.130 to −0.169	0.056–0.057	0.022–0.0032
Socioeconomic cluster[c]	0.107–0.120	0.027–0.028	0.0001

[a]Each age was modeled separately including gender and socioeconomic status as co-variates.
[b]Variation of childhood BMI had no independent effect on caries variation at 6 or 10 years of age.
[c]The range of values for gender and socioeconomic group in the various models.

Discussion

Based on the concept that a common dietary pattern contributes to development of dental caries and overweight, dental personnel have been suggested to be one of the corner stones in weight counselling (22). The present study confirmed that caries prevalence is positively associated with obesity in the study population but the association was weak. An interesting finding was that children who were overweight/obese at 4 years but who had normalized their body weight by 5 years of age had even less caries than children who had normal weight from 4 years to 10 years. The rationale for a suggested joint effort by dental and health services in the prevention of overweight is the assumed overconsumption of sucrose and unfavourable meal patterns in overweight individuals. On average, as much as 25% of the daily energy intake originated from cookies, soft drinks, and other sweet products in Swedish 4- to12-year-old children (23). In spite of this high sugar exposure, several recent studies in the western countries have failed to demonstrate a correlation between sugar intake and caries (8, 24, 25), which indirectly supports a weak association between overweight/obesity and dental caries in these countries. The present results do not allow for a conclusion on whether the association between overweight/obesity associated behaviours and dental caries is weak per se, or if confounding factors have attenuated the association. Attenuation may relate to the fact that BMI in children changes substantially with age and the changes do not correlate strictly with body fat (Centers for Disease Control and Prevention, National Health and Nutrition Examination Survey growth charts, http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/datafiles.htm). It may also be hypothesized that the net effect of a possible positive association between overweight/obesity associated behaviour on dental health is weaker in regions with organized caries preventive measures as in Sweden.

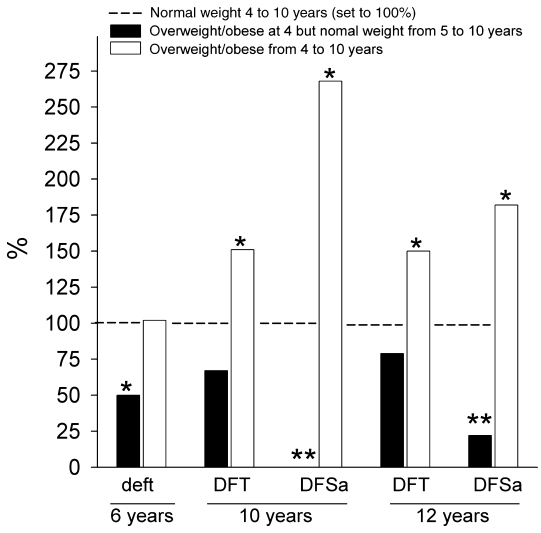

Fig. 3. Caries prevalence in children who were obese at 4 years of age and then either normalized their body weight (black bars) or remained overweight/obese until 10 years of age (white bars). Data (age and gender standardized means) are expressed as percent of caries prevalence in children with normal weight from 4 to 10 years of age (reference group, dashed line). *$P < 0.05$ compared with the reference group.

The present study embraced the entire population of children born in 1991, living in the county of Östergötland, Sweden, in 2001. To achieve this, information was retrieved from data assembled in daily routine activities at the public dental and health clinics in the county. Thus, out of 5987 eligible children, anthropometric data were available for 5517 children and caries data at 6, 10, and 12 years of age for 2303 children. The main reason that caries information was lacking at all three ages was that the child had moved in or out of the county between 6 and 12 years of age, but it was also due to the fact that some children/parents

refused care, and that some clinics failed to report data to the county register. The number of children free of caries, mean DFT, BMI and proportion overweight/obese among the 2303 children in the final study cohort, and those who were excluded because of lack of caries information when the child was 6 or 12 years did not differ significantly. Furthermore, caries prevalence and the proportion of overweight/obese children were similar to data reported from the other parts of Sweden and Scandinavia (5, 26). We therefore suggest that the children in the study cohort are representative of the child population of the county of Östergötland and similar regions in Scandinavia.

The comparably large setting employed to correlate caries with body weight and socioeconomic status is the strength of the present study. The fact that no data on inter- and intra-assay calibration were available is a weakness, which, however, is balanced by adherence to national instructions for anthropometric measures and caries examination. Another common weakness of the present type of register study is that registers may not embrace information on possible confounding factors, and ethical integrity considerations limit the possibility to retrieve additional individual information. An example of this is the lack of data on individual fluoride and diet exposure in the present study. However, it is known that virtually all children in Sweden report daily exposure to fluoridated tooth paste (24), and that there is a positive correlation between total fluoride exposure and caries prevalence reflecting the prophylactic measures directed to individuals at high risk for caries in Sweden (27).

Socioeconomic status was scored using a recently developed area-based classification method. The individual is assigned to one of five socioeconomic classes based on the residence address and a previous classification of addresses in small geographic areas in the county into one of five socioeconomic clusters using population statistics. The use of small areas renders more socially homogeneous groups than larger jurisdictions (28). Therefore, this measure is considered advantageous in population studies where socioeconomic data cannot be retrieved at an individual level, as in the present register study where data at the individual level is restricted for ethical reasons. The measure is increasingly used in planning of health services and research on health inequalities (19), although lack of information at the individual level may increase residual confounding.

Body weight (childhood BMI) had an independent effect on caries levels and obese children had significantly more caries than children with normal weight. However, the associations were not statistically significant until the children reached 12 years of age. Thus, the assumption that overweight/obesity correlates with more caries was confirmed but the association was weak. The weak association between dental caries and childhood BMI may be ascribed, at least partly, to the ages selected for caries status. In the selected age span, transition from primary to permanent teeth occurs, which combined with retardation of disease development from fluoride, may show that a more extended cariogenic exposure time is needed to reveal a wider variation in disease outcome. From this perspective, it should be kept in mind that in Sweden, fluoride-containing toothpaste is used daily for children at all ages and additional professional fluoride treatment is given to children at risk for caries. Therefore, a follow-up of the caries status at later ages might add significant information.

In accordance with numerous other studies, decreasing socioeconomic status was associated with increasing development of caries (29). Results from previous studies on association between socioeconomic status and overweight are not consistent (13, 18, 30, 31). In this study, no association was seen between socioeconomic status and childhood BMI or prevalence of overweight/obesity. Hence, based on the present results, it may be hypothesized that geographic targeting of resources may be used for caries prevention, as stated by Locker (19), whereas, although restricted to one county in Sweden, less support is found for such a strategy for prevention of overweight in this study.

It is concluded that the association between overweight and caries is weak, and it is suggested that the association is obscured by the regular use of fluoride and associated retardation of disease activity, and narrowing of variance in the study cohort. Nevertheless, results support the concept that child dental services and child welfare services can benefit from joint programs. Furthermore, results suggest that these efforts should be launched at an early age. This is based on the finding that children who were obese at 4 years of age had significantly more caries at 12 years of age than those of normal weight at the same age, and also that children who were overweight/obese at 4 years of age, but who had normalized their weight by 5 years of age had

even less caries at 12 years than children who had normal weight throughout the ages studied. However, this notable result is based upon a small number of children, which underlines the need for further studies.

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