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Article

High Birth Weight Is a Risk Factor of Dental Caries Increment during Adolescence in Sweden

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Abstract: This study aimed to assess whether birth weight is associated with dental caries during the teenage period. In this register-based cohort study, all children of 13 years of age (n = 18,142) who resided in the county of Stockholm, Sweden, in 2000, were included. The cohort was followed until individuals were 19 years of age. Information regarding dental caries was collected from the Public Health Care Administration in Stockholm. Data concerning prenatal and perinatal factors and parental socio-demographic determinants were collected from the Swedish Medical Birth Register and National Registers at Statistics Sweden. The final logistic regression model showed that birth weight ≥4000 g, adjusted for potential confounders, was significantly associated with caries increment (DMFT ≥ 1 (D = decayed, M = missing, F = filled, T = teeth)) between 13 and 19 age (OR, 1.22; 95% CI = 1.09–1.36). The relatively enhanced risk OR was further increased from 1.22 to 1.43 in subjects with birth weight ≥4600 g. On the contrary, subjects with birth weight <2500 g exhibited a significantly lower risk (OR, 0.67; 95% CI = 0.50–0.89) for exhibiting caries experience (DMFT ≥ 4) at 19 years of age. In conclusion, high birth weight can be regarded as a predictor for dental caries, and especially, birth weight ≥4500 g is a risk factor for caries increment during adolescence.

Keywords: adolescents; birth weight; cohort study; dental caries; longitudinal study; predictor; risk assessment; risk factor

1. Introduction

Birth weight in children has increased during the last two decades in many developed countries [1–4] despite an increased number of preterm births [5,6]. One explanation is an increasing proportion of infants born with high birth weight [6,7]. In approximately 10% of deliveries, the fetus exhibits a birth weight higher than 4000 grams [8].

Fetal growth is initially autonomous, but later, more dependent on the flow of nutrients across the placenta. Viral infections, as well as various maternal diseases, such as diabetes and hypertension, and maternal life style factors, including smoking, have an impact on fetus growth, thereby affecting the birth weight of the child [9–11]. In clinical studies, several maternal anthropometric characteristics have been demonstrated to be positively associated with increased fetal growth, such as a maternal body mass index (BMI) and excessive weight gain during pregnancy [11,12].

In recent years, the relationship between birth weight of the child and the risk for development of chronic diseases as adults has been frequently discussed. It has been shown that infants born with low birth weight (<2500 g) have a higher risk later in life of developing diabetes [13–15] or coronary heart diseases [16]. In addition, children with a high birth weight (≥4000 g) are reported to exhibit a higher prevalence of being overweight during adolescence [17], as well as an increased risk of developing obesity [18,19], diabetes [13,14] or cancer [20–22] later in life.

The relationship between birth weight and oral conditions has mostly been addressed in infants with low birth weight. There are several clinical studies demonstrating the enhanced frequency of molar-incisor hypomineralization (MIH), gingival inflammation and behavioral management problems [23–27] in children with low birth weight. Most of the studies state that there is no relationship between low birth weight and the development of dental caries [28–31], although conflicting results are available [32,33]. There is only one study, to the knowledge of the authors, which focused on children with high birth weight. In that study the authors reported a weak association between dental caries and high birth weight in five-year-old children [34]. Furthermore, the parameter Apgar score, which reflects not only labor and delivery, but also the condition during prenatal life, is reported to be associated with dental caries in five-year-old children [35].

In a cohort of teenagers, this study recently identified being overweight in the first trimester as a risk factor for caries increment in their offspring between 13 and 19 years of age [36]. Overweight mothers and mothers with high gestational weight gain are at risk of delivering infants with high birth weight [4,10] who exhibit a higher risk for developing obesity during childhood [17,18]. In a cross-sectional study, we previously reported a close relationship between obesity and the occurrence of dental caries in adolescence [37]. The link between obesity and dental caries might be caused by the lower salivary flow rate (mL/min) demonstrated in the obese subjects compared with normal weight subjects [37]. In light of these findings, it was hypothesized that birth weight might be associated with dental caries later in life.

Therefore, the current register-based cohort study of 13 and 19-year-old adolescents was undertaken to address whether their birth weight is associated with dental caries later in life.

2. Results

Of the final cohort (n = 13,808), 4.5% (n = 621) were born with a birth weight less than 2500 grams and 15.4% (n = 2,131) exhibited a birth weight of 4000 grams or more. In Table 1, the mean value and standard deviation of caries experience at 13 years of age, total caries increment between 13 and 19 years of age and caries experience at 19 years of age are described in relation to subgroups of birth weight. The lowest mean values of caries experience (DMFT (D = decayed, M = missing, F = filled, T = teeth)) at both 13 and 19 years of age were seen among subjects born with a birth weight of less than 1500 grams, and the highest mean values were seen among subjects born with a birth weight of 4500 grams or more (Table 1).

Table 1. Dental caries at 13 and19 years of age in relation to birth weight.

Birth weight	DMFT 13 y Mean ± SD	DMFT-increment 13–19 y Mean ± SD	DMFT 19 y Mean ± SD
<1500 g; n = 86	0.71 ± 1.23	2.06 ± 2.94	2.77 ± 3.25
1500–1999 g; n = 127	0.91 ± 1.60	2.13 ± 2.82	3.05 ± 3.51
2000–2499 g; n = 408	1.32 ± 1.84	2.10 ± 2.77	3.42 ± 3.41
2500–2999 g; n = 1606	1.24 ± 1.82	2.14 ± 2.97	3.38 ± 3.60
3000–3499 g; n = 4768	1.26 ± 1.81	2.00 ± 2.88	3.19 ± 3.44
3500–3999 g; n = 4682	1.20 ± 1.77	2.09 ± 2.88	3.22 ± 3.43
4000–4499 g; n = 1768	1.28 ± 1.78	2.03 ± 2.85	3.31 ± 3.43
≥4500 g; n = 363	1.54 ± 2.13	2.21 ± 2.78	3.75 ± 3.69

Notes: DMFT: D = decayed, M = missing, F = filled, T = teeth; SD = standard deviation; g = gram.

2.1. Univariate Analysis

In the univariate logistic regression analysis, the key exposure "birth weight" was analyzed as a continuous variable and all covariates as categorical variables. The analyses were performed with caries experience (DMFT ≥ 1) at 19 years of age as a dependent variable and showed that "birth weight", as a continuous variable, was significantly associated with the outcome ($p = 0.013$), (Table 2). In addition, the following potential confounders were also significantly associated with the outcome: parity, maternal age, country of birth, marital status, smoking during early pregnancy, BMI in early pregnancy, BMI at delivery, gestational weight-gain, educational level, income and receiving social welfare allowance (Table 2).

2.2. Multivariate Analysis

In a multivariate logistic regression analysis, the association between high birth weight (≥4000 g) and the total caries increment (DMFT ≥ 1) between 13 and 19 years of age was tested. At the start, all variables in Table 2 were included in the model. In the final model, only significant covariates persisted. The results showed that "high birth weight" was significantly associated with the outcome (OR, 1.29; 95% CI = 1.13–1.48). Remaining significant variables in the final model, except for "high birth weight", were parity, country of birth, smoked during early pregnancy, BMI in early pregnancy, gestational weight-gain, marital status, maternal educational level and family receiving social welfare allowance (Table 3).

Table 2. Univariate logistic regression analysis with pre-, peri-natal and sociodemographic factors, such as exposure and caries experience (DMFT ≥ 1) at 19 years of age, as the outcome.

Variables	Subject with DMFT ≥ 1 (n = 11,605)/total number of participants (n = 15,538)	Odds ratio, 95% CI	*p*-value
Child characteristics			
Gender			
Female	5,757/7,728	1.00	
Male	5,762/7,810	0.96, 0.90–1.04	0.298
Gestational weeks			
>36 weeks	9,624/14,747	1.00	
≤36 weeks	584/791	0.98, 0.84–1.16	0.842
*Birth weight**			
317–5,760 g	11,605/15,538		0.013
Congenital malformation			
No	9,959/15,145	1.00	
Yes	291/393	0.99, 0.79–1.25	0.967
Parity			
1–2	8,112/12,877	1.00	
≥3	2,138/2,661	1.54, 1.39–1.71	<0.001
Maternal characteristics			
Age			
≥29 y	5,024/8,356	1.00	
<29 y	5,226/7,182	0.86, 0.80–0.93	<0.001
Country of birth			
Sweden	8,164/11,526	1.00	
Born abroad	3,227/4,012	1.54, 1.41–1.68	<0.001
Marital status 2005			
Married	6,992/9,572	1.00	
Not married	4,613/5,966	1.26, 1.17–1.36	<0.001
Smoked in early pregnancy			
No	6,515/12,277	1.00	
Yes	2,604/3,261	1.55, 1.40–1.71	<0.001
BMI in early pregnancy			
0–24.99	5,606/14,413	1.00	
≥25.00	883/1,125	1.39, 1.20–1.62	<0.001
BMI at delivery			
0–24.99	1,873/8,740	1.00	
≥25.00	5,063/6,798	1.21, 1.10–1.34	<0.001

Table 2. *Cont.*

Variables	Subject with DMFT ≥ 1 (n = 11,605)/total number of participants (n = 15,538)	Odds ratio, 95% CI	*p*-value
Maternal characteristics			
Gestational weight gain			
0–20.0 kg	6,241/14,119	1.00	
>20.0 kg	1,094/1,419	1.27, 1.11–1.45	<0.001
Educational level 2005			
>12 y	4,694/6,677	1.00	
10–12 y	5,087/6,705	1.33, 1.23–1.43	<0.001
≤9 y	1,824/2,156	2.32, 2.04–2.64	<0.001
Income 2005			
High income range (>25%)	9,043/12,338	1.00	
Low income range (≤25%)	2,562/3,200	1.46, 1.33–1.61	<0.001
Social welfare allowance 2005			
No	10,775/14,568	1.00	
Yes	830/970	2.09, 1.74–2.51	<0.001

Note: * = continuous variable.

Table 3. Final multivariate logistic regression analysis with total caries increment (DMFT ≥ 1) between 13 and 19 years of age as the outcome and high birth weight (≥4000 g) as the key exposure.

Variables	B	Wald	Sign	Exp(B)	95% CI for Exp(B) Lower Upper
Key variable					
High birth weight					
3150–3815 g (n = 4318)				1.00	
≥4000 g (n = 1391)	0.257	13.979	<0.001	1.29	1.13 1.48
Adjusted for					
Child characteristics					
Parity					
1–2				1.00	
≥3	0.176	5.280	0.022	1.19	1.03 1.39
Maternal characteristics					
Country of birth					
Sweden				1.00	
Born abroad	0.160	4.284	0.038	1.17	1.01 1.37
Smoked in early pregnancy					
No				1.00	
Yes	0.257	13.171	<0.001	1.29	1.13 1.49
BMI in early pregnancy					
0–24.99				1.00	
≥25.00	0.209	5.853	0.016	1.23	1.04 1.46

Table 3. *Cont.*

Variables	B	Wald	Sign	Exp(B)	95% CI for Exp(B) Lower Upper
Maternal characteristics					
Marital status 2005					
Married				1.00	
Not married	0.125	4.365	0.037	1.13	1.01 1.27
Educational level 2005					
>12 y		24.841	<0.001	1.00	
10–12 y	0.187	9.497	0.002	1.21	1.07 1.36
≤ 9 y	0.496	22.023	<0.001	1.64	1.34 2.02
Social welfare allowance 2005					
No				1.00	
Yes	0.490	7.896	0.003	1.63	1.16 2.30

2.3. Dental Caries in Relation to the Magnitude of Low Birth Weight

In this statistical analysis, the total caries increment between 13 and 19 years of age, as well as caries experience at 19 years of age in relation to the magnitude of low birth weight was studied. All analyses were adjusted for possible confounders presented in Table 2. After adjustments, the results showed that children born with a birth weight less than 2000 grams exhibited a statistically-significant negative association with caries experience (DMFT ≥ 1) at 19 years of age (OR, 0.69; 95% CI = 0.49–0.96) (Table 4). When the birth weight was less than 1600 grams, the variable "low birth weight" was no longer significant in the model. Further, when low birth weight was analyzed in relation to caries experience (DMFT ≥ 4), a statistically-significant negative association was found in subjects born with a birth weight less than 2500 grams (OR, 0.67; 95% CI = 0.50–0.89). The strongest negative association was seen at low birth weight less than 2100 grams (OR, 0.50; 95% CI = 0.30–0.81), (Table 4). However, when the birth weight was less than 1800 grams, the variable "low birth weight" was no longer significant in the model. Concerning total caries increment, no significant associations with low birth weight were found.

2.4. Dental Caries in Relation to the Magnitude of High Birth Weight

In Table 5, the total caries increment between 13 and 19 years of age, as well as the caries experience at 19 years of age was analyzed in relation to the magnitude of high birth weight. All analyses were adjusted for possible confounders presented in Table 2. After adjustments, the results showed that children born with a high birth weight more than or equal to 4000 grams exhibited a statistically-significant positive association with caries experience (DMFT ≥ 1) at 19 years of age (OR, 1.24; 95% CI = 1.09–1.40), (Table 5). When high birth weight was analyzed at various cut-off levels, ≥4200 g, ≥4400 g, ≥4500 g and ≥4600 g, the positive risk of exhibiting caries experience (DMFT ≥ 1) at 19 years of age was still significant. Further, the excess risk across the various cut-off levels increased up to a high birth weight more than or equal to 4600 g (OR, 1.50; 95% CI = 1.05–2.13), (Table 5). However, when the birth weight was more or equal to 4700 grams, the variable "high birth weight" was no longer significant in the model. High birth weight was also analyzed in relation to caries experience (DMFT ≥ 4). In this analysis, the excess risk of exhibiting caries was lower compared to the association between high birth weight and caries experience (DMFT ≥ 1) (Table 5). In the next multivariate model, high birth weight was tested with the total caries increment as the outcome. The results showed that high birth weight was significantly positive when associated with the outcome across all tested cut-off levels of high birth weight. Further, the excess risk was enhanced as the cut-off levels of high birth weight increased.

Table 4. Logistic regression analysis with the magnitude of low birth weight as the exposure and caries experience at 19 years of age and total caries increment between 13 and 19 y as an outcome.

Caries indices	**Birth weight <2500 g OR 95% CI**	**Birth weight <2100 g OR 95% CI**	**Birth weight <2000 g OR 95% CI**	**Birth weight <1800 g OR 95% CI**	**Birth weight <1700 g OR 95% CI**
Caries experience					
(DMFT ≥ 1)	n = 455	n = 180	n = 148	n = 97	n = 76
Unadjusted	0.97 0.80–1.17	0.88 0.67–1.17	0.80 0.60–1.08	0.76 0.53–1.09	0.75 0.50–1.11
Adjusted	0.84 0.68–1.03	0.75 0.55–1.03	0.69 0.49–0.96	0.63 0.42–0.94	0.60 0.38–0.93
(DMFT ≥ 4)	n = 232	n = 83	n = 69	n = 48	n = 36
Unadjusted	0.98 0.82–1.16	0.80 0.62–1.05	0.79 0.59–1.05	0.84 0.59–1.19	0.78 0.52–1.16
Adjusted	0.67 0.50–0.89	0.50 0.30–0.81	0.51 0.30–0.89	0.71 0.38–1.32	0.71 0.34–1.46
Caries increment					
(DMFT ≥ 1)	n = 398	n = 161	n = 135	n = 90	n = 69
Unadjusted	1.09 0.92–1.29	1.08 0.83–1.40	1.05 0.79–1.40	1.05 0.75–1.49	0.98 0.67–1.43
Adjusted	0.97 0.81–1.17	1.03 0.77–1.37	0.98 0.72–1.35	0.91 0.62–1.34	0.83 0.54–1.26

Note: Adjusted for prenatal and perinatal factors (gender, gestational weeks, congenital malformation, parity, maternal age, maternal smoking during early pregnancy, BMI in early pregnancy, BMI at delivery and weight-gain during pregnancy) and maternal sociodemographic factors (civil status, maternal country of birth, maternal educational level, maternal income level and mother receiving social welfare allowance).

Table 5. Logistic regression analysis with the magnitude of high birth weight as the exposure and caries experience at 19 years of age and caries increment between 13 and 19 years of age as an outcome.

Caries indices	**Birth weight ≥4000 g OR 95% CI**	**Birth weight ≥4200 g OR 95% CI**	**Birth weight ≥4400 g OR 95% CI**	**Birth weight ≥4500 g OR 95% CI**	**Birth weight ≥4600 g OR 95% CI**
Caries experience					
(DMFT ≥ 1)	n = 1634	n = 867	n = 416	n = 286	n = 192
Unadjusted	1.16 1.04–1.30	1.20 1.03–1.39	1.22 0.99–1.51	1.31 1.01–1.70	1.54 1.11–2.15
Adjusted	1.24 1.09–1.40	1.24 1.06–1.46	1.28 1.02–1.60	1.35 1.03–1.79	1.50 1.05–2.13
(DMFT ≥4)	n = 842	n = 458	n = 220	n = 154	n = 103
Unadjusted	1.07 0.97–1.18	1.13 0.99–1.28	1.14 0.95–1.36	1.21 0.98–1.50	1.27 0.98–1.65
Adjusted	1.13 1.01–1.26	1.17 1.02–1.35	1.20 0.99–1.46	1.27 1.01–1.60	1.34 1.01–1.77

Table 5. *Cont.*

Caries indices	Birth weight ≥4000 g OR 95% CI	Birth weight ≥4200 g OR 95% CI	Birth weight ≥4400 g OR 95% CI	Birth weight ≥4500 g OR 95% CI	Birth weight ≥4600 g OR 95% CI
Caries increment					
(DMFT ≥ 1)	n = 1391	n = 743	n = 362	n = 248	n = 166
Unadjusted	1.14 1.03–1.27	1.19 1.04–1.36	1.27 1.05–1.53	1.31 1.05–1.65	1.44 1.09–1.92
Adjusted	1.22 1.09–1.36	1.23 1.07–1.42	1.32 1.08–1.61	1.36 1.07–1.74	1.43 1.06–1.94

Note: Adjusted for prenatal and perinatal factors (gender, gestational weeks, congenital malformation, parity, maternal age, maternal smoking during early pregnancy, BMI in early pregnancy, BMI at delivery and weight-gain during pregnancy) and maternal sociodemographic factors (marital status, maternal country of birth, maternal educational level, maternal income level and mother receiving social welfare allowance).

3. Discussion

This novel finding demonstrates that birth weight (≥4000 g) is associated with caries development later in life during adolescence. The risk of caries increment (DMFT > 1) for infants born with a birth weight of 4000 grams or higher was 1.22 (OR) and increased positively with the magnitude of birth weight, adjusted for potential confounders, like maternal and child characteristics, including socioeconomic factors. Regarding infants with birth weight <2500 g, we did not demonstrate any enhanced risk for dental caries development. However, low birth weight infants reveal a relatively lower risk for exhibiting one or more DMFT at 19 years of age compared with normal weight infants.

There is a great advantage of using population-based registers compared with common dental health surveys when identifying various risk factors for dental caries. In this study, we used the Medical Birth Register (MBR) register as our source of information. An advantage of using MBR is that it covers ~97%–99% of deliveries in Sweden [38]. The quality of MBR has been evaluated with the conclusion that it is a valuable source of information for reproduction epidemiology [38,39]. The validity of information on prenatal factors used in the statistical analyses is probably accurate, since the information was collected prospectively before birth. Furthermore, all information regarding the family was collected independently of the study outcome, which reduced problems with recall and interviewer bias. However, we were not able to include information on the weight of the subjects during the study period, when the adolescents were between 13 and 19 years of age. Consequently, it was not possible to adjust for the confounder "weight of the subject" in the multivariate model with caries increment as the outcome.

Dental data were collected at 13 and 19 years of age from the Public Health Care Administration in the county of Stockholm and have been used in other register-based studies with valid results [36,40]. In register-based studies, there is a risk of random errors, because the diagnosis of manifest caries can sometimes be under-reported or over-reported due to several examiners. However, random errors are affected by increasing the size of the study and will be reduced to zero if a study becomes infinitely large [41]. In this study, the final study cohort consisted of 13,808 children, and the risk of random error is, therefore, of minor importance.

We decided on a cut-off point of high caries experience (DMFT ≥ 4) for both statistical and theoretical reasons. The population in the highest tertile of frequency distribution is those who attended dental services with more treatment need [42]. On the other hand, a child with DMFT equal to one may be considered as acceptable, because dental caries is almost impossible to eradicate.

In a multivariate model, the association between birth weight and dental caries was controlled for various confounders, like maternal characteristics in terms of age, country of birth, marital status, smoking habits, BMI early in pregnancy and at delivery, gestational weight gain, social welfare allowance, family income and educational level, as well as the child characteristics, like gestational weeks, congenital malformation and parity.

For the first time, this study demonstrates that birth weight (≥4000 g) is a risk factor for dental caries development later in life. This finding is interesting in light of previous discussions where dental caries experience might be biologically programmed *in utero* or early life [32], like other chronic diseases [43]. The mechanism behind the link between birth weight (≥4000 g) and dental caries development is unclear, although there might be some factors of importance for predisposing such an association. One explanation is that infants born with high birth weight have an increased risk for becoming overweight or developing obesity during childhood [17,18]. Together with our previous finding of an association between obesity and dental caries in adolescents [37], the link between birth weight and dental caries found in our study might be confounded by an overrepresentation of adolescents that are overweight or obese within the group of infants with birth weight ≥4000 g. As previously pointed out, there was no information regarding the weight of the adolescents during the study period. Therefore, it was not possible to evaluate whether the weight of the subject was a confounder or not when analyzing the relationship between birth weight and caries increment in the multivariate model. Taking into account previous findings that obese subjects might exhibit more dental caries compared to normal weight subjects [37], it is important in future clinical studies to control for the weight of the adolescents.

A potential mechanism explaining the link between obesity and dental caries might be the reduction of the salivary flow rate seen among obese subjects compared with normal weight adolescents [37]. The mechanism(s) behind the association between obesity and dental caries subjects might also be mediated by an alteration of the oral microflora during obesity. Due to decreased salivary flow in obese subjects, the oral biofilm might change in quality and/or quantity, which contributes to an alteration in the balance between the demineralization and remineralization activity on the tooth surface. In a recent paper, we demonstrated that the subgingival microflora differs in obese teenagers compared with normal weight subjects [44]. We found approximately three-fold higher levels of the Phylum Firmicutes, whereas *Streptococcus mutans* was two-fold higher in obese adolescents compared with normal weight adolescents.

One has to consider that we did not have any information regarding dietary habits or prevention measures given to the subjects. We can therefore not eliminate that the birth weight, as a risk factor for dental caries, can be biased, to some extent, by decreased prevention procedures, insufficient dietary habits or poorer oral hygiene among subjects with a high birth weight.

There might also be biological factors that partly can influence a fetus's immune response, like maternal lifestyle factors [36], which, in the long-term, influence the oral colonization of caries-related microorganisms [28] and, thereby, increasing the risk for caries development.

Another interesting finding in this study was the negative association between low birth weight and caries experience at 19 years of age after taking into account potential confounding factors. Our finding, that low birth weight infants run a lower risk of developing caries compared to normal birth weight infants, is in line with previous studies indicating that caries prevalence in primary teeth was lower among premature and very low birth weight infants compared to term and normal weight infants [45,46]. It is unclear what might be causing the decreased caries experience (DMFT ≥ 4) in adolescents with birth weight <2500 g. One explanation could be closer monitoring of low birth weight children, since infants born both short and thin have been found to be at greater risk for mortality and hospitalizations [47,48]. In addition, it has been shown that very low birth weight infants at 14 years had significantly more functional limitations and received more coordinated care than the term adolescents [26]. In addition, caregivers were providing brushing assistance/supervision for the very low birth weight group for a significantly longer period than for normal birth weight infants [26].

Another possible explanation for the negative association between low birth weight and caries experience at 19 years of age is more frequent antibiotic use in our low birth weight group, due to the many health problems among premature and very low birth weight children. The frequent use of antibiotics has been indicated as inhibiting the colonization of cariogenic bacteria [49], which may possibly explain the reduced caries experience in our very low birth weight group. Unfortunately, information regarding antibiotic use was not available and is therefore a limitation of this study.

4. Experimental Section

4.1. Study Design

The present study was designed as a retrospective longitudinal register-based cohort study and was based on information collected from data sources at the Public Health Care Administration in Stockholm, as well as from the National Registers at the National Board of Health and Welfare and at the Central Bureau of Statistics Sweden (SCB). The study was approved by the Regional Ethical Board in Stockholm, Sweden, and the study protocol was approved by the Swedish Data Inspection Board, a Swedish federal agency that serves as an institutional review board for database linkages. Data were collected on dental caries, prenatal and perinatal factors, as well as on socio-demographic determinants.

4.2. Subjects

All 13-year-old adolescents (n = 18,142) who resided in the county of Stockholm, Sweden, in the year 2000 were included in the study. This cohort was followed until the individuals were 19 years of age. During this period, the subjects received regular dental check-ups, either from the Public Dental Health Service, private practitioners or at the Division of Pediatric Dentistry, Department of Dental Medicine, at the Karolinska Institute, Stockholm. A total of 15,538 adolescents (7810 boys and 7728 girls) had clinical, as well as radiographic dental examinations at both 13 and 19 years of age. The sample attrition rate was 14%, and the most common reason for sample attrition was that the individual had moved out of the area. Of the examined subjects (n = 15,538), information about birth weight was collected in 13,808 and, thus, constituted the final study cohort.

4.3. Population-Based Registries

The registers' usefulness in epidemiological research is facilitated by the personal identification number (PIN), which is a 10-digit number unique to all residents and recorded in all health and census registers [50]. The PIN permits the linkage of each individual between different registries. In the present study, information from the Medical Birth Register (MBR), the Total Population Register (TPR), the Total Enumeration Income Register and the Education Register were used. Information about the registers and register linkages have previously been described [36].

4.3.1. The Medical Birth Register (MBR)

Mothers-to-be are followed from their first visit at the public maternity healthcare clinic (usually between 8 and 10 weeks of gestation), throughout their pregnancy to delivery and 8–12 weeks post-delivery. The register's quality has been evaluated three times: in 1976, 1988 and in 2001 [38,39]. The following variables were collected from the MBR: gender, gestational weeks, birth weight, congenital malformations, parity, maternal age, smoking habits during early pregnancy and the mother's height and weight at the first visit to the public maternity healthcare clinic, as well as at delivery. The Body Mass Index (BMI) was calculated and analyzed according to whether the mother was overweight (BMI ≥ 25.00) or not (BMI < 24.99). On the basis of the mother's weight in early pregnancy and at delivery, the variable "gestational weight gain" was calculated and further dichotomized and analyzed in two groups, ≤20 kg and >20.0 kg. The variable "birth weight" was categorized into eight subgroups according to 500-gram intervals. Children with a birth weight more than or equal to 5000 grams (n = 43) were added to the subgroup of "≥4500g". Each subgroup was then analyzed in relation to caries experience at 13 and 19 years of age, as well as total caries increment between 13 and 19 years, presented in Table 1. In the logistic regression analyses, low birth weight (<2500 grams) and high birth weight (≥4000 grams) were analyzed separately. A reference group "normal birth weight" was calculated based on the distribution of birth weight. The range for normal birth weight was estimated to be between 25% and 75% of the subjects. Based on this, the normal birth weight range was found to be between 3150 and 3815 grams. Remaining variables collected from the MBR were dichotomized in the statistical analyses; see Table 2.

4.3.2. The Register of the Total Population

This register is kept by Statistics Sweden. From the Register of the Total Population, the following variables were collected: maternal country of birth and marital status in 2005. In the statistical analysis, both variables were dichotomized (Table 2).

4.3.3. The Total Enumeration Income Register

Data on individuals' annual income tax, founded on income tax returns and tax-authority decisions, is collected by the National Swedish Tax Board. The Board then sends summary statistics to Statistics Sweden. From this register, information regarding the family's income and receipt of social-welfare allowance in 2005 was collected. Both variables were dichotomized and family income expressed as low income (less than or equal to 25% of the lowest income range) or high income (more than 25% of the lowest income range) in the statistical analysis (Table 2).

4.3.4. The Education Register

Data on education were obtained from the Education Register. In the statistical analysis, the variable "educational level" was divided according to years of schooling as: low (≤ 9 years), intermediate (10–12 years) and high (> 12 years) (Table 2).

4.4. Data Collection Concerning Dental Caries

In Stockholm, data on manifest caries lesions (based on clinical and radiographic examination) in children and adolescents were sent from the Public Dental Health Service, private practitioners and the Division of Pediatric Dentistry, Department of Dental Medicine at the Karolinska Institute, to the Public Health Care Administration and are analyzed at ages 3, 7, 13 and 19 years of age. Since the year 2000, all of these data have been linked to the PIN. The registration sheets of 13 and 19-year-old children consist of the following caries counts: DT = decayed teeth, MT = missing teeth, FT = filled teeth, DSa = decayed surfaces approximal and FSa = filled surfaces approximal. Manifest caries were recorded on smooth surfaces as the minimal level that can be verified as a cavity and detectable by probing and in fissures by a catch of the probe under slight pressure. Approximal caries on the radiographs were recorded as manifest caries when the lesion clearly extended into the dentin. For this study, the caries experience at 19 years of age and total caries increment between 13 and 19 years of age, using the DFT-indices, was used as the outcome in the statistical analyses.

The dental caries file of the study cohort was sent from the Public Health Care Administration to the SCB, where the data file was linked with the registers from Statistics Sweden and Swedish National Health and Welfare. The key to identify individuals was kept within the SCB and was not disclosed to the investigators.

4.5. Statistical Analysis

Data analyses were carried out using the Statistical Package for the Social Sciences (SPSS, version 21.0) [51]. For analyzing the data, frequency tables, cross tables and logistic regression were used. The odds ratios (OR) with 95% CI were used as estimates of the effects.

Total caries increment (DMFT ≥ 1) between 13 and 19 years of age and caries experience (DMFT ≥ 1, DMFT ≥ 4) at 19 years of age were used as the outcomes in the logistic regression analyses.

In a univariate analysis, the key exposure "birth weight" was analyzed as the continuous variable and potential confounders as categorical variables. In a multivariate analysis, "high birth weight" (≥4000 g) was analyzed with "normal birth weight" (3150–3815 g) as a reference and total caries increment (DMFT ≥ 1) as the outcome. To analyze "high birth weight" as a potential risk factor for total caries increment between 13 and 19 years of age, the variable was adjusted for confounders. The confounders for inclusion in the models were selected using a combination of methods, *i.e.*, based on their association with the outcome, as well as based on their association with the exposure and subsequently their influence on the outcome. All of the variables were classified (as shown in Table 2) and then entered into the multivariate analyses as independent variables. The final logistic regression analysis began with a full model, and the model was then reduced by removing, one by one, insignificant covariates, until only significant covariates persisted (Table 3).

The key exposure "birth weight" was also analyzed as either "low birth weight" (<2500 g) or "high birth weight" (≥4000 g) according to the magnitude, with "normal birth weight" (3150–3815 g) as the reference (Tables 4 and 5). Each cut-off level was analyzed separately in a multivariate logistic regression analysis with total caries increment (DMFT ≥ 1), caries experience (DMFT ≥ 1) and caries experience (DMFT ≥ 4) as the outcomes. In these analyses, the key exposure was adjusted for potential confounders (as shown in Table 2).

5. Conclusions

In conclusion, birth weight extremes (less than 2000 g or more than 4500 g) are correlated with caries risk. Low birth weight is associated with lower risk and high birth weight with increased risk. These differences are of note by age 13 and maintained into adolescence, with the exception that high birth weight children (more than 4500 g) continue to have a higher rate of caries incidence during adolescent years. Based on our results, high birth weight can be regarded as a predictor for dental caries and should be taken into consideration in the risk assessment. Furthermore, this study indicates that low birth weight infants do not run a higher risk of developing caries than other children in the permanent dentition.

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Author Contributions

Ulrika Molund and Emma Drevsäter worked with the data set and wrote parts of the manuscript; Annika Julihn and Thomas Modéer designed and performed the study and wrote the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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