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ORIGINAL ARTICLE

Impact of low birthweight on early childhood caries in 6–36 months old infants in Uganda: A cross-sectional study

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Abstract

Objective. Focusing on 6–36 months old infants, this study assessed (1) whether socio-economic status, current anthropometric status, presence of enamel hypoplasia, number of erupted teeth, oral hygiene and consumption of sugared snacks varied between children with normal birthweight (NBW) and low birthweight (LBW) and (2) the association between ECC and birthweight whilst adjusting for covariates of ECC, such as current anthropometric status. Method: A cross-sectional study was conducted in Kampala in 2007, involving 816 child/caretaker pairs. All caretakers completed face-to-face interviews. Children were examined for ECC and enamel defects using WHO (1997) criteria and the developmental defects of enamel (DDE) index. Weight at birth was obtained from hospital records and current anthropometric status was assessed using *z*-scores for weight-for-length (WLZ), length-for-age (LAZ) and weight-for-age (WAZ). ***Results.*** Prevalence of LBW (< 2500 g) and ECC were estimated to 11.5% and 18.1%, respectively. Children with LBW and those with ECC presented with more visible plaque, higher sugar consumption and more current underweight (WAZ < −2) than children with normal birth weight (NBW) and no caries; 26.7% of LBW vs 17.3% ($p < 0.001$) of NBW children presented with ECC. Enamel defects (OR = 2.8, 95% CI = 1.6–4.8) and presence of visible plaque (OR = 2.4, 95% CI = 1.3–4.1), but not LBW, were associated with ECC in multiple variable logistic regression analyses. ***Conclusion.*** Both LBW and ECC were associated with poor oral hygiene, high intake of sugars and current underweight. Enamel defects were associated with ECC. Adjusting for covariates there were no clear association between LBW and ECC. Studies using a prospective study design are needed for further investigation.

Key Words: *early childhood caries, birthweigh, sub-Saharan Africa*

Introduction

Early childhood caries (ECC) is a continuous problem of infants and toddlers globally [1]. Although many risk factors of ECC have been identified, the contributing early life events are poorly understood [2,3]. According to the life course approach, early life events have been linked to later disease, suggesting a gradual accumulation of exposures such as low birth weight (LBW), episodes of illness and adverse environments throughout the life-course [4,5]. Little research exists that describes the influence from early sociobiological factors on the dentition status of child populations in developing countries [6,7].

Birth weight, which can be seen as a function of gestational age and intra-uterine growth rate, is a critical measure involved in the life-course approach [8]. Smoking, nutritional defects, pre-eclampsia and infections during pregnancy may result in intra-uterine growth retardation and infants being small for gestational age [8]. The World Health Organization (WHO) has defined pre-term birth as birth of an infant prior to 37 weeks of gestation [9]. A LBW and very low birth weight are defined as the newborn babies weighing less than 2500- and 1500 g at birth, respectively [9]. Recent statistics suggest that the rate of LBW continues to increase worldwide, occurring disproportionally among poor and deprived

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populations [10]. Low birth weight infant delivery presents a major health problem in developing countries and is the second leading cause of infant death [9]. Whereas poor maternal nutrition has been linked to next generation LBW, early childhood malnutrition has in turn adverse effects on the growth and development of the child [10–14].

Some studies suggest that pre-school children with poor anthropometry and low body mass index present with increased risk of ECC [12–14]. A similar relationship has been reported between LBW and caries in both the primary and permanent dentition [7,15,16]. Other studies have disconfirmed such relationships [17]. Cruvinel et al. [18] observed less caries experience in the primary teeth of premature, compared to full-term children. This was attributed to delayed eruption of primary teeth in pre-term and LBW children. Saraiva et al. [15], using data from the US National Health and Nutritional Examination Survey III, reported on a positive relationship between prematurity and ECC, whereas children small for gestational age and those with fetal growth restriction were less likely to develop ECC. Kay et al. [19] reported on an association between high birth weight and dental caries in children at 5 years of age after controlling for possible confounders. In contrast, Burt and Pai [17] concluded on no significant relationship between LBW and ECC. However, their hypothesis of a positive relationship in the primary as well as the permanent dentition was not rejected and the authors recommended further studies on this subject [17].

Children with LBW can be susceptible to dental caries due to biological and socio-behavioral factors, with enamel hypoplasia being one important biological factor [17]. Seow et al. [20] and other researchers [6,21–24] reported on increased prevalence of enamel hypoplasia in LBW children. Lai et al. [25] found a positive relationship between enamel hypoplasia and ECC in very low birth weight children. In a cohort of infants, Nelson et al. [6] found increased risk of enamel hypoplasia in LBW, compared with NBW children, whereas the incidence of ECC did not vary between the birthweight groups. A positive relationship between LBW and ECC might be attributed to a complex set of pathways, including biological and environmental factors, such as enamel hypoplasia, poor nutrition, eating habits, oral hygiene and socio-economic status [6,17]. Thus, the association between LBW and ECC might co-occur as a result of confounding and mediation effects. Whether covariates of ECC also associate with birthweight status has not yet been studied in child populations of developing countries.

Given the prevalence and the public health problem of LBW and ECC globally and considering the lack of information about the oral health consequences of LBW and the nutritional status of early childhood in sub-Saharan Africa, this study aimed to assess (1) whether socio-economic status, current anthropometric status, presence of enamel hypoplasia, number of erupted teeth, oral hygiene and consumption of sugared snacks vary between normal birth-weight (NBW) and LBW children 3–6 months old and (2) the impact of low birth-weight on ECC after controlling for covariates of ECC, including current anthropometric status.

Methods

A cross-sectional study was conducted in Reproductive and Child Health (RCH) care facilities in Kampala district, Uganda, from June to October 2007. At the time of the survey, Kampala covered an area of 197 km^2 and had a population of 1.2 million,, of whom 18% was under 5 years [26]. Kampala has an overall literacy rate of 75% [26]. It is administratively divided into five divisions, including two of which were study areas: Nakawa (42.5 km^2, population of 300 000 in 2008) and Makindye (40.6 km^2, population of 380 000 in 2008). The districts have drinking water with a fluoride content of 0.3 mg/L. One non-governmental (Kibuli) and one governmental (Naguru) RCH care facility were purposely selected in Makindye and Nakawa, respectively. Both facilities have large catchment areas and include community outreach clinics for the provision of child immunization. The inclusion criteria were caregivers with children aged 6–36 months attending the Kibuli and Naguru clinics for immunization and/or growth monitoring. All caregiver–child pairs who attended the clinics during the study period and who met the inclusion criteria were eligible for participation. Out of 831 caregivers approached, 816 agreed to participate (response rate 98%). This satisfied a pre-calculated sample size, assuming a prevalence of ECC of 30%, a standard error of 3% and a confidence interval of 95%. Another 5% was added to the sample size to account for children who had to be excluded from analysis for being the second eligible child of the same mother/caregiver. For a more detailed description of the sampling procedure, see World Health Organization [26]. Permission to conduct the study was given by The Ethical Committee of Uganda National Council of Science and Technology, Research and Publication Committee at Makerere University. Informed written consent was obtained from participating caregivers. When the caregivers could not read and write verbal consents were obtained [27].

Clinical oral examination

Clinical examinations were carried out by a trained and calibrated dentist, whereas a trained assistant recorded the observations. Calibration exercises were carried out according to the guidelines published by the British Association of the Study of Community

Dentistry (BASCD) [28]. Children were examined in knee-to-knee position using a dental mirror, a probe and natural light. Teeth were cleaned and dried by sterile gauze (after having recoded plaque) and inspected for ECC using disposable dental mirrors. ECC was assessed on fully and partially erupted teeth according to the WHO criteria and recorded in terms of decayed, filled and missed teeth [29]. No radiographs were taken and decay was recorded at the level of cavitation. In the present analysis, decayed teeth (dt) was dichotomized as absent (dt = 0) or (1) present (dt ≥ 1). Visible plaque was recorded as absent or present on tooth level. Enamel defects (i.e. hypoplasia and opacities) were recorded on the labial surfaces of each tooth present according to the criteria described by the Developmental Defects of Enamel (DDE) index proposed by FDI [30]. Experience with enamel defects was recorded absent (DDE = 0) or present (DDE > 0). For the diagnosis of enamel defects, codes were used according to the DDE Index. Enamel hypoplasia was defined as a break in the continuity of the enamel in the form of pits, grooves or missing enamel. Enamel opacities were defined as a change in the translucency of enamel without a break in its continuity. When both hypoplasia and opacities were observed in one tooth, it was recorded as hypoplasia [30].

Birth weight and anthropometric status

The details of date and weight at birth were obtained from hospital records and the personal patient records were obtained. Low birthweight (LBW) was defined as less than 2500 g. Before the children were examined clinically they were undressed and their weight and recumbent length were measured by staff of the RCH clinic and in accordance with the WHO standardized techniques [31]. Standardized 25 kg portable Salter Spring scales measuring to the nearest 0.1 kg were used to assess infants' weight. Recumbent length was measured to the nearest 0.1 cm with specially designed length boards. Anthropometric indices were generated using WHO Anthro 2005 software [32,33]. Four different ratios are commonly used, each denoting a different aspect of malnutrition. Wasting was defined as weight-for-length *z*-scores (WLZ) of less than 2 SD below the median in a reference population for the same age and gender (WLZ < −2), stunting as length-for-age *z*-scores (LAZ) less than 2 SD below the median (LAZ < −2) and underweight as weight-for-age *z*-scores (WAZ) of less than 2 SD below the median (WAZ < −2).

Interview

A structured interview was constructed in English and translated into Luganda, the main language in Uganda. The interview schedule was translated in several steps; from English into local languages by bi-lingual Luganda/English professionals and then translated back to English by independent translators. To evaluate the quality of the translations in terms of comprehensibility, readability and relevance to assess face validity, the interview was piloted among caregivers of primary school children. Subsequently, a slightly modified interview was administered in the field by trained locally recruited research assistants. The interviews were performed face-to-face with primary caretakers before their children underwent oral clinical examination. *Parental socio-demographics* were assessed in terms of age, sex and education. Education was categorized as did not complete primary school or at least primary education. *Consumption of sugared snacks* was assessed by asking 'have you given child (Name) glucose water, sugar water, milk tea with sugar, black tea with sugar, sugared soda, biscuits/cakes, ice-cream and sweets/toffees/chocolate in the past 24 hours?' Responses were given as (0) 'No' and (1) 'Yes'. A sum score was constructed (range = 0–8, median = 4.0) and dichotomized using the median split into 0 = low intake and 1 = high intake.

Data analysis

The present analysis included 6–36 months old infants for whom dental examination was completed and birth certificates were available. Covariate information, taken from interviews with caretakers, included known socio-demographic and behavioral risk indicators of ECC identified in a previous study of the cohort in addition to indicators of child growth and development in terms of anthropometric status, number of teeth erupted and presence of enamel hypoplasia [34]. Risk indicators of ECC were grouped into a hierarchy of categories ranging from distal to proximate ones in the following order, parental socio-economic status and child's birthweight (distal variables), enamel developmental defects and nutritional status (intermediate variables) and child's oral hygiene and oral health-related behaviors (proximate variables). This hierarchical approach, initially suggested by Victora et al. [35], was used in the present study to guide the multivariable analyses. Bivariate analysis was conducted using OneWay ANOVA and Chi square test. Explanatory variables selected for the multivariable models were included if they had a *p*-value in the bivariate analysis of < 0.05. Multiple variable analysis was performed using logistic regression analysis, with variables entered in groups from distal determinants in terms of parental socio-demographics and birth weight status (step 1), through intermediate variables in terms of child's current nutritional status and tooth development (step 2) to proximate variables in terms of child current oral hygiene and sucrose consumption (step

3). The fit of the model was assessed using the Hosmer-Lemeshow test [36]. The best value of this test is 1. Inclusion of the youngest age group of 6–12 months would bias the result towards zero as the erupting teeth were few and had been at a very short time at risk for developing dental caries. Thus, multivariable logistic regression was performed with two age groups, 6–36 months and 25–36 months old.

Results

To check reliability, duplicate examinations, involving 20 child/caregiver pairs, were performed with an interval of 3 weeks. Intra-class correlation coefficient (ICC) for reported sugar intake was 0.80 (95% CI = 0.59–0.91) [37]. Cohen's kappa for ECC and enamel defects ranged from 0.8–1.0.

A total of 11.5% and 18.1% of the children studied presented with LBW and ECC. Decayed teeth and missed teeth constituted the main and only components of the dmft index. The prevalence of WLZ, LAZ and WAZ scores < −2 were 6.1%, 16.8% and 8.6%, respectively. The prevalence of enamel defects was 13.7%. Children with LBW compared to NBW did not differ with respect to age, sex, parental education and place of residence (Table I). Visible plaque was more common among children with LBW (53.5%) compared to children with NBW (36.0%). Corresponding figures for high consumption of sugared snacks were 48.8% among children with LBW and 32.4% among children with NBW. Both sugar intake and presence of plaque were strongly associated with ECC ($p < 0.001$).

Table II depicts anthropometric measures in terms of stunting, underweight and wasting, the total number of erupted teeth and presence of enamel hypoplasia by birthweight and ECC status. There were significant differences between NBW and LBW children in all parameters, except enamel hypoplasia and WLZ scores. Totals of 31.4% LBW vs 15.2% NBW ($p < 0.001$) were stunted. Corresponding figures for underweight were 15.1% vs 8.0% ($p < 0.05$). ECC status varied systematically with WAZ and WLZ scores.

Covariates that were statistically significantly associated with birthweight and ECC in the bivariate analyses were adjusted for age, sex and number of erupted teeth in a series of multivariable logistic regression models. LBW children were 1.8 (95% CI = 1.1–1.2), 2.5 (95% CI = 1.5–4.3), 1.9 (95% CI = 1.0–3.6) and 1.9 (95% CI = 1.0–3.5) times more likely than their NBW counterparts to have high consumption of sugared snacks, low LAZ scores (stunted), low WAZ scores (underweight) and presence of visible plaque. No difference was found between the NBW and LBW groups with respect to mean number of erupted teeth (not shown in table).

Figures 1 and 2 show the tooth-specific pattern of erupted teeth in LBW and NBW children for the total group and stratified by age groups. For the youngest age group of 6–12 months, when expectedly maxillary and mandibular anterior teeth erupt, the proportion of children presenting with erupted teeth were lower in LBW than in NBW children, ranging from 20–50%. For the age group of 13–24 months, when most primary canines and premolars are expected to erupt, the percentage of children having erupted teeth were almost equal in the two birth weight groups, being in the range from 40% to > 90%. For the oldest age group, 25–36 months, 95–100% of children in both

Table I. Socio-behavioral characteristics by birth weight and early childhood caries (ECC) in 6–36 months old infants and toddlers with low birth weight (LBW, < 2500 g) and normal birth weight (NBW, ≥ 2500 g) (n = 816).

	LBW % (n)	NBW % (n)	ECC = 0 % (n)	ECC > 0 % (n)
6–12 months	37.2 (32)	46.7 (310)	54.5 (364)	4.7 (7)
13–24 months	27.9 (24)	30.0 (199)	31.6 (211)	20.9 (31)
25–36 months	34.9 (30)	23.3 (155)	13.9 (93)	74.3 (110)**
Boy	50.0 (43)	50.9 (338)	50.4 (337)	52.0 (77)
Girl	50.1 (43)	49.1 (326)	49.6 (331)	48.0 (71)
Mother's education: lower (at least primary)	26.2 (22)	19.5 (127)	59.8 (393)	58.0 (83)
Mother's education: higher	73.8 (62)	80.5 (523)	40.2 (264)	42.0 (60)
Urban residence	73.3 (63)	75.5 (501)	75.6 (505)	72.3 (107)
Rural residence	26.7 (23)	24.5 (163)	24.4 (163)	27.7 (41)
Presence of plaque	53.5 (46)	36.0 (239)	28.6 (191)	81.1 (120)
Absence of plaque	46.5 (40)	64.0 (425)**	71.4 (477)	18.9 (28)**
High sugar intake	48.8 (42)	32.4 (215)	31.4 (210)	52.7 (78)
Lower sugar intake	51.2 (44)	67.6 (449)**	68.6 (458)	47.3 (70)**

**$p < 0.001$. The total number in the different categories did not add up to 816 due to missing values of the variables.

Table II. Growth and development characteristics by birth weight and ECC in 6–36 months old Ugandan infants (n = 816).

	LBW	NBW	No ECC	ECC
Stunted, % (n) (LAZ < −2 z-scores)	31.4 (27)	15.2 (101)	16.8 (112)	16.9 (25)
Not stunted, % (n)	68.6 (59)	84.8 (563)**	83.2 (556)	83.1 (123)
Underweight, % (n) (WAZ < −2 z-scores)	15.1 (13)	8.0 (53)	7.6 (51)	12.9 (19)
Not underweight, % (n)	84.9 (73)	92.0 (611)*	92.4 (617)	87.2 (129)*
Wasting, % (n) (WLZ < −2 z-scores)	7.0 (6)	6.3 (42)	5.4 (36)	9.5 (14)
Not wasted, % (n)	93.0 (80)	93.7 (622)	94.6 (632)	90.5 (134)*
Total number of erupted teeth in the mouth, Mean (SD)	11.3 (7.8)	9.6 (7.1)*	8.11 (3.6)	17.6 (3.8)**
No enamel hypoplasia, % (n)	88.4 (76)	85.5 (568)	90.7 (606)	66.2 (98)
Enamel hypoplasia, % (n)	11.6 (10)	14.5 (96)	9.3 (62)	33.8 (50)**

**$p < 0.001$, *$p < 0.05$. The total number in the different categories did not add up to 816 due to missing values of the variables.

birth weight groups had erupted canines and premolars.

Among children with NBW at the age of 6–12 months, 2% presented with ECC. Correspondingly, at 13–24 months, 13% presented with ECC and at 25–36 months the proportion was 54%. Corresponding rates among children with LBW were 3%, 17% and 60%. As shown in Table III, 26.7% of the children with LBW (combining all ages) presented with ECC, compared to 17.3% ($p < 0.05$) among children with NBW. Corresponding figures for children with WAZ < 2 SD and > 2 SD were 27.1% and 17.3% ($p < 0.05$), respectively. Covariates that were statistically significantly associated with both ECC and birthweight in the bivariate analysis were entered into a stepwise multivariable logistic regression analysis. Presence of enamel defects, child's age and number of erupted teeth were forced into the analysis

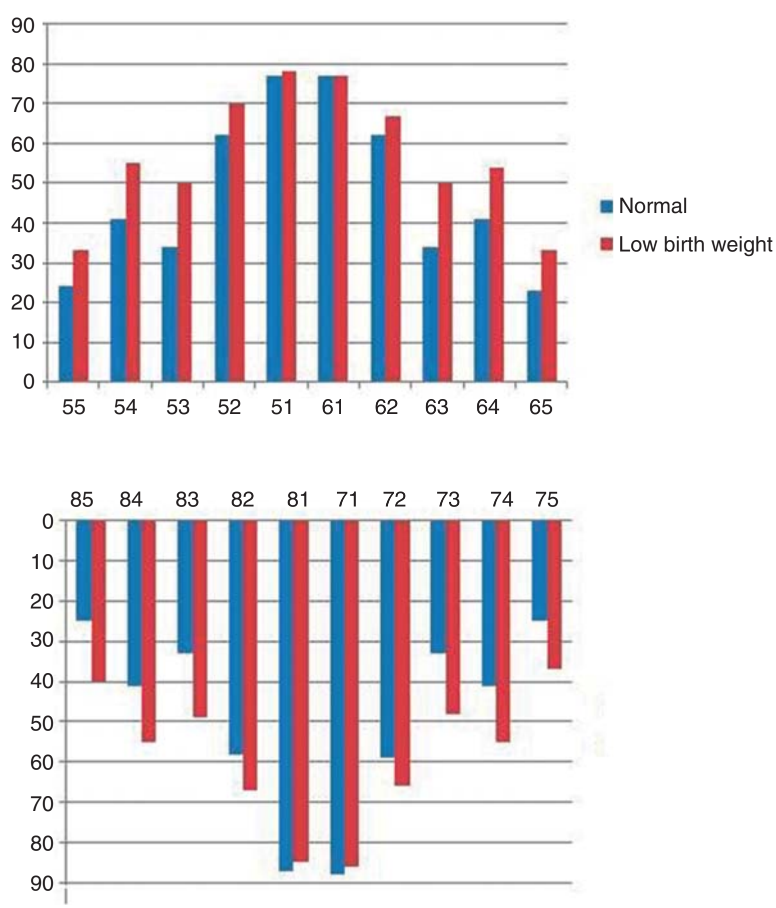

Figure 1. Percentage distribution of erupted deciduous teeth according to birthweight. Upper graph presents maxillary deciduous teeth and lower graph presents mandibular deciduous teeth. Tooth number along the x-axis and percentage of children along the y-axis.

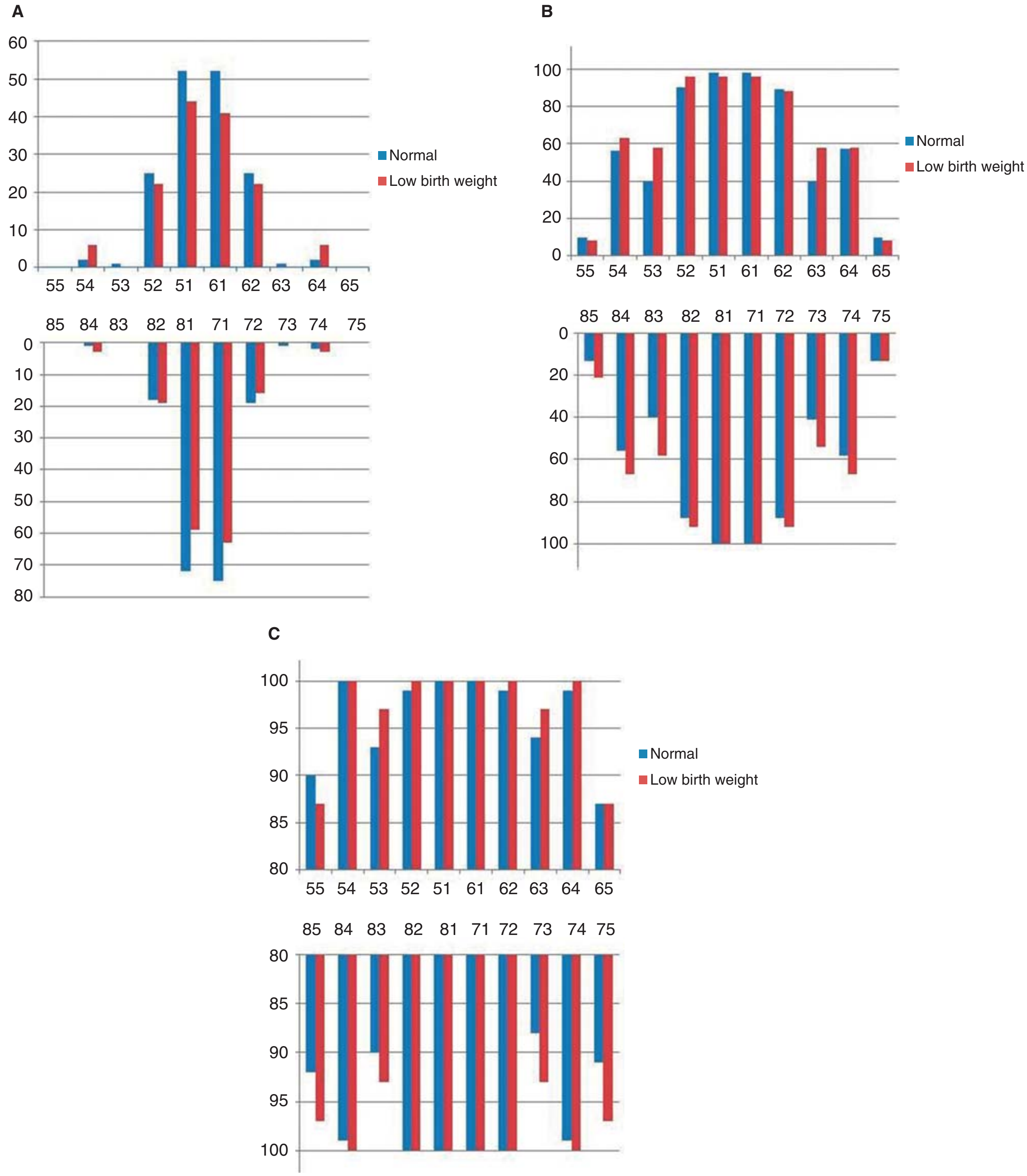

Figure 2. Percentage distribution of erupted deciduous teeth according to birthweight among (A) 6–12, (B) 13–24 and (C) 25–36 months old. Upper graph presents maxillary deciduous teeth and lower graph presents mandibular deciduous teeth. Tooth number along the *x*-axis and percentage along the *y*-axis.

in, respectively, the first and final step of the model. Birthweight entered into the first step of the model followed by WAZ scores and hypoplasia in the second provided a model fit of Nagelkerke's $R^2 = 0.126$, $p < 0.001$, with birthweight (OR = 1.8, 95% CI = 1.1–3.2) and enamel defects (OR = 5.5, 95% CI = 3.4–8.5) being associated with ECC. Entering proximal variables in terms of plaque and sugar consumption in step III improved the model fit to Nagelkerke's $R^2 = 0.319$, $p < 0.001$, with enamel hypoplasia (OR = 3.2, 95% CI = 2.0–5.3), plaque (OR = 7.7, 95% CI = 4.8–12.4) and low sugar consumption (OR = 0.5, 95% CI = 0.3–0.8) being statistically significantly associated with ECC. The final step IV of the model, adjusted for children's age and total number of erupted teeth left enamel defects and plaque the only significant covariates of ECC. Corresponding ORs were 2.8 (95% CI = 1.6–4.8) and 2.4 (1.3–4.1). Analyses limited to the age group 25–36 months left the results essentially unchanged.

Discussion

Consistent with some studies, but contrary to others [6,7,17], the present one revealed a higher burden of caries among the children with LBW compared to children with NBW. However, this relationship did not maintain significance after consideration of covariates in terms of current underweight, presence of enamel defects, poor oral hygiene and high sucrose consumption. In a lifecourse perspective, post-partum environmental and individual factors seem to outweigh birthweight in influencing ECC among the infants investigated [4]. However, the use of a loose definition of caries, a crude measure of fetal growth in terms of birthweight and the inclusion of very young children without a completely erupted primary dentition might have biased the results towards null. Due to the young age of the study group, carious lesions were diagnosed by cavitated lesions. This might have led to under-estimation of the true ECC prevalence, as epidemiological evidence suggests that non-cavitated lesions are most prevalent during the first 18 months of life [38]. Moreover, the difficulties in examining moving and crying infants might have contributed to this under-estimation. Altered eruption timing should be considered when investigating the association between LBW and dental caries [22]. Previous studies have shown that teething age is delayed with significantly fewer teeth observed in 6–11 and 12–17 months old LBW compared with similar-aged NBW children [22]. Nevertheless, this study revealed similar tooth-specific patterns of erupted teeth in both birthweight groups (Figure 1). A prevalence of ECC in the 25–36 months old participants amounting to 53% is approaching what has been reported previously among 3-year- olds in Kampala (45%), suggesting that the background population is mirrored [39].

It seems reasonable to suggest that the association between birthweight and ECC was confounded or mediated by enamel defects, anthropometric status, post- partum exposures to cariogenic sugar containing foods and poor oral hygiene [6,17]. According to the framework described by Victora et al. [35], distal determinants such as low birthweight may influence ECC indirectly through determinants at the intermediate and proximal level of the hierarchy. In accordance with the present finding, increased intake of sugared snacks among LBW children have been reported previously [40]. Sugar is often regarded as a valuable source of energy in sub-Saharan Africa and a major industrialized product in Uganda. Moreover, there is evidence that caregivers of 0–23 month olds add sugar to complementary foods and drinks [41]. Norberg et al. [13] pointed to the risk of establishing eating patterns in underweighted picky eaters that could subsequently endanger their oral health. Lack of breastfeeding or exclusive breastfeeding of short duration previously observed in children with LBW might lead to bottle feeding, use of cow's or goat's milk-based substitutes and solid food items that could potentially expose the infant to greater dietary risk factors for ECC. However, these explanations remain a speculation as there was no observed difference in breastfeeding practices between children with LBW and NBW in this study.

Interestingly, of the children 6–36 months old with LBW, those currently wasted, stunted and underweight were 7%, 31% and 15%, respectively. Except with respect to stunting, this suggests that most children had caught up in growth by the time of the dental examination due to post-natal survival and care. Although current underweight was most common in LBW children, the relationship, indicating higher rates of ECC in underweight children was marginally significant after adjusting for birth weight in the multivariable model (Table III). Norberg et al. [13] found children with low body mass index to present with more caries experience than their counterparts having normal weight. Corresponding results have been reported among Brazilian toddlers [12]. In contrast to strong evidence of an inverse relationship between caries prevalence and socio-economic status in young children [3], the present study could not demonstrate any socio-economic diversity of birth weight and ECC status. However, children with presence of visible plaque were 2.4-times more likely to present with ECC than their counterparts without. Presence of visible plaque may reflect deprivation in general as well as a diet high in sugars. Previous studies of older children have confirmed the assumption that children with LBW have poorer plaque removal capacity, resulting in higher plaque and gingivitis scores [42]. In this study of very young infants, it seems more plausible that increased sensitivity in teeth with ECC and enamel defects might have interfered with caretaker's tooth brushing.

Consistent with previous studies, enamel defects occurred as a major risk indicator for ECC [20,21,23]. Thus, the association of enamel defects, particularly hypoplasia, with ECC suggests a pathway between malnutrition and dental caries. Human studies have indicated low birth weight and prematurity, early childhood malnutrition, fluoride ingestion and childhood diseases as important factors in the etiology of enamel defects, using a variety of study designs [6]. Although an association between LBW and enamel hypoplasia has support in the literature [6,43], this relationship was not confirmed by the present study.

Table III. Models for ECC according to LBW and possible confounding variables among 6–36 months old infants. Non- adjusted and adjusted analyses. Minimum number included in the analysis (n = 750).

	Non-adjusted, % (n)	Step I OR (95% CI) adjusted	Step II OR (95% CI) adjusted	Step III OR (95% CI) adjusted	Step IV* OR (95% CI) adjusted
NBW	17.3 (115)	1	1	1	1
LBW	26.7 (23)*	1.7 (1.1–2.9)	1.8 (1.1–3.2)	1.2 (0.6–2.1)	1.2 (0.6–2.3)
Weight age < 2 SD	27.1 (19)		1	1	1
Weight age > 2 SD	17.3 (129)*		1.7 (0.9–3.1)	1.5(0.8–2.9)	1.5 (0.8–3.2)
Hypoplasia: no	13.9 (98)		1	1	1
Hypoplasia : yes	44.6 (50)**		5.5 (3.4–8.5)	3.2 (2.0–5.3)	2.8 (1.7–4.8)
Plaque: no	5.5 (28)			1	1
Plaque: yes	38.6 (120)			7.7 (4.8–12.4)	2.4 (1.4–4.2)
Sugar diet high	27.1 (78)			1	1
Sugar diet low	13.3 (70)**			0.5 (0.3–0.8)	0.9 (0.5–1.5)

Adjusted for total number of erupted teeth, age and sex.

The equal distribution of hypoplasia observed across the birthweight groups might be attributed to misclassification of enamel defects and the young age of the infants investigated. As dental caries occurs in the linear hypoplasia of the maxillary primary incisors, caries lesions might have masked pre-existing enamel defects and, thus, confused their diagnosis.

In spite of some limitations of this study, such as use of a cross-sectional design, making conclusions about causal relationship difficult and the reversed causality an option, there are several strengths to emphasize. One advantage is the use of a conceptual framework that avoids under-estimations of more distal determinants and, thus, provides more rational policy information. Another advantage is the availability of data on common covariates for birth weight and ECC status and the possibility to identify confounders or mediators of a relationship between birth weight and ECC in very young infants. Data on birth weight was taken from the birth certificates, avoiding recall bias related to parental self-reported information. A further strength is the availability of anthropometric measures representing a historical gold standard for measuring malnutrition in children. This study utilized the growth standards from the WHO Multicenter Reference Study [44].

In summary, ECC was associated with poor oral hygiene, enamel defects, high intake of sugared snacks, total number of erupted teeth and current underweight in 6–36 months old infants. Children with LBW had less favorable oral hygiene, higher consumption of sugared snacks and were more frequently underweight and stunted than their NBW counterparts, which suggests that they are at risk for future oral health problems. However, when adjusting for the other factors there were no significant associations between LBW and ECC. It is possible that post-partum environmental and individual factors mediate the early life course influences of birth weight on ECC. Studies using prospective cohort designs are needed to further investigate the effect of birth weight and malnutrition on ECC in Ugandan infants. Also from an oral health point of view it seems important to strengthen antenatal care to provide protection against LBW.

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