

# Associations Between Early Childhood Caries and Malnutrition and Anemia: A Global Perspective

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## Research article

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# Abstract

**Background:** To determine the relationship between country-level prevalence of early childhood caries (ECC), malnutrition and anemia in infants and preschool children. **Methods:** Matched country level ECC, malnutrition and anemia prevalence information were generated from databases covering the period from 2000 to 2017. Multivariate general linear models were developed to assess the relationship between outcome variables (prevalence of stunting, wasting, overweight, and anemia) and the explanatory variable (ECC prevalence) adjusted for Gross National Income per capita. Adjusted regression coefficients (B) and partial eta squared were computed. **Results:** The mean (standard deviation (SD)) ECC prevalence for 0-2 year-olds was 23.8 (14.8)% and 57.3 (22.4)% for 3-5 year-olds. The mean (SD) prevalence of wasting was 6.3 (4.8)%, overweight was 7.2 (4.9)%, stunting was 24.3 (13.5)%, and anemia was 37.8 (18.1)%. For 0-2-year-olds, the strongest and only significant association observed was between the prevalence of ECC and overweight ( $\eta^2 = 0.21$ ): one percent higher ECC prevalence was associated with 0.12% higher prevalence of overweight (B= 0.12, P= 0.03). In 3-5-year-olds, the strongest and only significant association was observed between the prevalence of ECC and anemia ( $\eta^2 = 0.08$ ): one percent higher prevalence of ECC was associated with 0.14% lower prevalence of anemia (B= -0.14, P= 0.048). **Conclusion:** Age-related disparities in the relationship between country-level prevalence of ECC, malnutrition and anemia were observed. The relationship between ECC and overweight may be due to intake of sugars. The relationship between ECC and anemia needs further investigations.

## Background

There are global concerns about the multi-facet impact of malnutrition in children. Malnutrition includes undernutrition (i.e., underweight, wasting, stunting, micronutrient deficiencies and low birth weight) more often seen in disadvantaged communities, and over consumption of food (overweight and obesity) seen in both developed and developing communities [1]. Malnutrition is the main risk factor for most common communicable diseases, resulting in acute deaths in children under five years of age [2]. On the other hand, overweight and obesity increase the risk for non-communicable diseases, poor adulthood health, and premature death [1].

Early childhood caries (ECC) is dental decay affecting the primary dentition in children younger than 6 years of age [3]. ECC is a challenging problem faced by preschool children in developed and developing countries [4]. Severe forms of ECC are known to impact children's growth, development, and well-being [5], and can have negative social and economic effects on parents and society [6]. Malnutrition has many of the same etiological factors as ECC, including poor dietary habits and food intake, and social-economic inequalities [7]. If not addressed, ECC can result in severe destruction of the primary dentition causing oral pain that can interfere with eating and sleeping. This can ultimately result in a child being underweight [8, 9] and stunted [10]. Also, vitamin D, iron, calcium and albumin deficiencies and protein-energy malnutrition may be associated with enamel defects that make the enamel surface rough and prone to plaque accumulation, with subsequent post-eruptive caries [11, 12]. Malnutrition can also cause salivary gland hypo-function, reduced saliva flow rate and buffering capacity [13, 14], in addition to changing the

salivary constituents ratio, particularly amylase, lysozyme, and immunoglobulins. These changes are associated with higher risk of caries [15-19]. Therefore, the relationship between malnutrition and ECC is complex, bi-directional and involves co-morbid relationships [7].

Several recent studies have highlighted the relationship between ECC and malnutrition [20], micronutrient deficiencies [11, 12, 21-23], and anemia (which may or may not result from malnutrition [24]). However, most of the evidence on the relationship between ECC, malnutrition and anemia is still unclear. To the best of our knowledge, the scientific literature lacks macro-level data on the relationship between these three public health issues with shared etiological factors. Understanding these relationships might contribute to designing cost-effective and efficient interventions using the common risk factor approach, and targeting at-risk children in various parts of the world where the problems are most concentrated [20].

The purpose of this study was to determine the association of country-level prevalence of ECC with malnutrition and anemia in infants and preschool children. The null hypothesis of the study was that ECC prevalence in 0 to 2-year-olds, and 3 to 5-year-olds was not associated with malnutrition or anemia.

## Methods

This was an ecologic study. We collected macro-level data about ECC, anemia and nutritional status of children under six years of age. The study data covered the period from January 2007 to October 2017 for a number of the United Nations member States [25].

### Data sources

*Prevalence of ECC.* According to the American Academy of Pediatric Dentistry, children < 72 months of age with one or more decayed, missing due to decay or filled primary tooth surfaces have ECC [3]. The data on ECC prevalence were extracted from the World Health Organization (WHO) Country Oral Health Profile database and other online databases. Majority of the estimates of ECC were based on cavitated lesions only and these were included in the study data. No language filter was applied for the database search. The retrieved data were used to calculate the ECC prevalence for each country by dividing the total number of children affected by ECC by the total number of children examined and multiplying by 100. Most retrieved studies did not provide estimates of ECC severity such as the number of affected teeth/surfaces or the number of teeth/surfaces that were filled or missing. For this reason, we only used data on the prevalence of ECC prevalence. Prevalence was calculated for two separate age groups: 0-2 and 3-5-year-olds. Further details on the computation of country level ECC prevalence were reported in our previous paper [26].

*Nutritional status of children under-5 years:* Information on nutritional status was obtained from country-level data jointly produced by WHO, UNICEF and World Bank in 2018 [27, 28] covering the period 2000 to 2017. The thresholds for defining stunting, wasting and overweight were established through the WHO-UNICEF Technical Advisory Group on Nutrition Monitoring [27] and were developed in relation to standard

deviations (SD) of the normative WHO Child Growth Standards. We used the following definitions applying to children aged 0-5 years old:

1. Stunting: below minus two SDs from median height-for-age.
2. Wasting: below minus two SDs from median weight-for-height.
3. Overweight: above one SD from median weight-for-height.

The prevalence of wasting, stunting and overweight were reported as the percentage of children 0–5 years old who met the definition.

*Anemia status in children under-5 years of age:* We used country-level estimates for anemia prevalence from the WHO [29], where iron-deficiency anemia was defined as blood hemoglobin concentrations <110g/l in children younger than 5 years of age.

## Data Analysis

The data sets (ECC, malnutrition, and anemia indicators) were matched by country. Scatter plots were used to represent the correlation between the prevalence of anemia, malnutrition and ECC in the two age groups (0-2-year-olds and 3-5-year-olds), and correlation coefficients and p values were calculated. Multivariate general linear models were developed to assess the relationship between outcome variables (prevalence of types of malnutrition; and prevalence of anemia) and the explanatory variable (ECC prevalence) for the two age groups. Each model was adjusted for the economic level of the country according to the 2017 Gross National Income per capita calculated using the World Bank Atlas method [30] based on our previous finding of the association between global ECC prevalence and growth in per capita gross national income [26].

The groups were: low income (\$995 or less); lower middle income (\$996–3,895); upper middle income (\$3,896–12,055); and high income (\$12,056 or more). Adjusted regression coefficients (B), confidence intervals (CIs), p values and partial eta squared ( $\eta^2$  as measure of effect size) were computed. Residual plots were assessed for the randomness of residuals' distribution to ensure that model assumptions apply. Variance inflation factors (VIF) were calculated to assess collinearity. Significance level was set at 5%. Statistical analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, N.Y., USA).

## Results

ECC data were available for 39 countries for 0-2-year-olds, and 86 countries for 3-5-year-olds. Data on malnutrition and anemia were available for 128-185 countries depending on malnutrition type. Combined ECC, anemia and malnutrition data were available for 26 countries in the age group 0-2-years-old and 55

countries in the age group 3-5-years-old (See Supplement 1 for list of countries). Thus, the results in this study are based on analyzing data from 26 and 55 countries in the 0-2-year-old group and the 3-5-year-old group, respectively.

The mean (SD) ECC prevalence in 0-2 year-old children was 23.8 (14.8)% and 57.3 (22.4)% in 3-5 year-old children. The overall mean (SD) prevalence of wasting was 6.3 (4.8)%, overweight was 7.2 (4.9)%, stunting was 24.3 (13.5)%, while anemia was 37.8 (18.1)%.

The 26 countries with complete data on ECC, anemia and malnutrition for 0-2-year-olds included two (7.7%) low-income countries, 10 (38.5%) lower middle-income countries, nine (34.6%) upper middle-income countries, and five (19.2%) high-income countries. The 55 countries with complete data on ECC, anemia and malnutrition for 3-5-year-olds included six (10.9%) low-income countries, 19 (34.5%) lower middle-income countries, 22 (40%) upper middle-income countries, and eight (14.5%) high-income countries.

Figure 1(a) shows that ECC prevalence for 0-2-year-olds was positively, weakly and non-significantly correlated with the prevalence of wasting ( $r = 0.17$ ,  $P = 0.40$ ), stunting ( $r = 0.09$ ,  $P = 0.68$ ), and anemia ( $r = 0.14$ ,  $P = 0.39$ ). The prevalence of overweight was positively, moderately and significantly correlated with the prevalence of ECC ( $r = 0.47$ ,  $P = 0.02$ ).

Figure 1(b) reveals that among 3-5-year-olds, ECC prevalence was positively, weakly and non-significantly correlated with the prevalence of wasting ( $r = 0.12$ ,  $P = 0.40$ ), stunting ( $r = 0.15$ ,  $P = 0.29$ ), and overweight ( $r = 0.09$ ,  $P = 0.51$ ). However, the prevalence of anemia was positively, weakly and significantly correlated with the prevalence of ECC ( $r = 0.25$ ,  $P = 0.02$ ).

Results of the multivariate general linear analysis controlling for economic level is reported in Table 1. For children 0-2-years of age, the greatest effect size and only significant association was between the prevalence of ECC and the prevalence of overweight ( $\eta^2 = 0.21$ ); where a one percent higher ECC prevalence was associated with 0.12% higher prevalence of overweight ( $B = 0.12$ ,  $P = 0.03$ ). For children 3-5 years of age, the greatest effect size and only significant association was between the prevalence of ECC and the prevalence of anemia ( $\eta^2 = 0.08$ ); where a one percent higher prevalence of ECC was associated with 0.14% lower prevalence of anemia ( $B = -0.14$ ,  $P = 0.048$ ). No collinearity was observed ( $VIF < 5$ ).

## Discussion

To our knowledge, this study provides the first evidence on the relationship between country-level prevalence of ECC, malnutrition, and anemia. However, not all types of malnutrition were associated with ECC. We demonstrated a positive and significant relationship between country-level prevalence of overweight and ECC in children 0-2-years of age, with higher prevalence of overweight associated with higher ECC prevalence. There was also an inverse relationship between country-level prevalence of anemia and ECC in 3-5-years olds with lower prevalence of anemia in countries with higher prevalence of ECC.

Overweight was associated with ECC only in children  $\leq$  2-years of age. The relationship between ECC, and childhood growth and development is not entirely clear [5, 31]. The existing studies on the relationship between ECC and nutritional status provide conflicting results – some found no association [32-34], others demonstrated a positive relationship, while some provided inconclusive results [31, 35]. Recent Canadian studies reported that preschool children with severe ECC undergoing dental rehabilitation were more likely to have higher BMI z-scores than caries-free controls [11, 12, 21, 23]. The inconsistent findings of the previous studies may be due to differences in the methods used for nutritional assessments, age range cut-offs, and confounders of dental caries, including differences in definition and severity of ECC [33].

The higher prevalence of overweight in countries with higher ECC estimates in 0-2-year-olds may reflect the findings by El Tantawi et al. [26] who reported a higher ECC prevalence in countries with greater economic growth. ECC and overweight/obesity share common risk factors – high frequency and quantity of free sugar consumption [36], food insecurity [37, 38], low socioeconomic status [39-41], residence in urban slums [42, 43] and rural areas [44, 45]. Growing economies are most likely to be undergoing nutrition transitions from traditional diets to low-quality, processed, high-sugar, high-fat, carbohydrate-dense food and beverages poor in micronutrients [46, 47] that predisposes to overweight and high ECC prevalence. Our results might suggest that having ECC and being overweight have shared risk factors that are related to the macro-economic status of the country. A common risk factor approach [20, 48] may be used to address both ECC and overweight problems; with global action to control these health problems giving priority to countries with greater economic growth.

The few studies that assessed the relationship between ECC and nutritional status frequently included age ranges larger than that for ECC. Four studies conducted amongst preschool children, showed no association between ECC and overweight in children 3 years of age [49], 2-5-year-olds [50], and 2-6-year-olds [51, 52]. These findings highlight the need for appropriate age groupings when studying ECC, as the relationship between ECC and nutritional status seems to be modulated by age. However, Davidson et al. [21] found that severe ECC was associated with obesity in 2-5-year-olds thereby highlighting two additional dimensions to determining the association between ECC and overweight – the severity of ECC and the severity of overweight. Interestingly, they found an association between the two extremes of the phenomena studied. This also implies that enrolling those with milder forms of caries and nutritional status may downplay potential relationships [21]. Therefore, we suggest that future studies on ECC and nutritional status not only ensure that ECC is analyzed by age groups 0-2-year-olds and 3-5-year-olds, but also ECC and malnutrition data should include the extremes of the variables, with emphasis placed on studying severe levels of ECC like using the WHO Significant Caries Index. We exercise caution with the correlation we observed may be an artifact as correlational analysis at the macro-level is usually larger than it will otherwise be for individuals [53].

Anemia, a complication of malnutrition and other factors that are not malnutrition related [24, 36], was inversely associated with ECC in older preschool children. Anemia may not necessarily be a direct result of ECC, but may be related to increased milk consumption in early childhood [23]. There is evidence

suggesting that in developed countries where the intake of milk is high, the risk of anemia is also high [54, 55]. Anemia from high milk intakes results from early weaning of the child, and introduction of other foods with low iron bioavailability. Milk also has a negative effect on non-heme and heme iron absorption [56]. Developed countries do not have malnutrition as a major health crisis [57], and have lower prevalence of ECC [58]. Recent Canadian studies reported that preschool children with severe ECC undergoing dental rehabilitation were more likely to have iron deficiency anemia than caries-free controls [11, 12, 21, 23]. Future studies are required to explore this reported finding.

The present findings have implications for parents of young children. Feeding practices leading to malnutrition and/or anemia may be associated with greater risk for ECC. Health education programs to improve parental dietary choices and sponsored healthy meals in kindergartens and similar gatherings may reduce the risk of these diseases. In addition, health providers managing malnutrition, anemia and/or ECC are in a position to provide better and more comprehensive care to children by screening for either of the diseases, and referring to for specialized care. Structuring primary health care services to provide integrated dental and pediatric care may be of benefit in addressing the dual burden of ECC and malnutrition. Dentists caring for patients with severe ECC should be aware that the children may have undiagnosed nutritional disease that might warrant further investigation.

One of the strengths of the study was that collated data on malnutrition included those from the Demographic Health Survey with high quality data [59]. However, there is the risk of over-representing children of living mothers since the anthropometric variables used for nutritional status assessment are only available for those who are alive. The sample may therefore have under-represented the presence of malnutrition in infants and preschool children [60, 61]. We controlled for the gross national income per capita, but were also unable to control for all possible confounders as these remain largely unknown due to lack of data. One of these confounders is sex, which although clearly plays a role in nutrition [62], the clarity of its role as a risk factor for ECC is poor. Controlling for these factors may further attenuate the relationships we established in this study. Our use of the z-scores adjusted for both age and sex to determine nutritional status allowed for more meaningful reporting of means [21]. We did not use the body mass index to assess nutritional status because it is meant to be used in children  $\geq 2$  years of age whereas we focused on 2-year-olds and younger, and 3 to 5-year-olds.

A study limitation was use of the World Health Organization's criteria for assessing caries by many of the epidemiological surveys [63]. This assessment tool does not include non-cavitated lesions: only 15% of ECC surveys reported non-cavitated and/or cavitated as the caries detection level [36]. The ECC prevalence for many countries may therefore be under-reported. Our study analysis was also limited by the fact that only a minor portion of the global ECC prevalence estimates was based on national surveys making the generalizability of our study finding challenging. ECC is under-studied in many parts of the world and true population estimates are often unknown. Also, although we split the data on ECC into two group - two age groups 0-2 and 3-5-year-olds – it was not possible to split these estimates for wasting, stunting and overweight as the data was not available. Further, our study is cross-sectional and therefore, the direction of the observed relationships cannot be ascertained: whether ECC increases the risk of

overweight in 0-2-year-old children, or being overweight increases the risk for caries. However, a carefully designed longitudinal study might be able to answer the questions this study and past studies have raised

## Conclusion

Our results suggest the presence of age-related disparities in the relationship between ECC, malnutrition, and anemia. This emphasizes the need for future analysis of ECC related data for the two distinct age groups as earlier highlighted by El Tantawi et al. [26]. Further, prospective studies are needed to determine how different social, economic and cultural factors characterizing these different age groups impact the co-morbid existence of the three diseases. The small magnitude of the association suggests the possibility for other attenuating factors that modulate the association between ECC, anemia and overweight. Further longitudinal research assessing the relationship between separate age groups, ECC severity and severity of malnutrition is necessary in order to identify the direction of the relationship between ECC, malnutrition, and anemia. Understanding these relationships might contribute to designing cost-effective and efficient global preventive interventions using the common risk factor approach for infants and preschool children.

## Abbreviations

CI	– Confidence Interval
ECC	– Early Childhood Caries
UNICEF	– United Nations Children’s Emergency Funds
SD	- Standard Deviation
WHO	– World Health Organization

## Declarations

**Acknowledgements:** Dr. Schroth holds a Canadian Institute of Health Research Embedded Clinician Researcher position in “improving access to care and oral health service delivery for young children in Manitoba”.

**Authors’ contributions:** MOF conceptualized and designed the study, coordinated the data analysis, drafted the initial manuscript, and critically reviewed and revised the manuscript for important intellectual content. ME conceptualized and designed the study, designed the data collection instruments, collected data, carried out the analyses, and reviewed and revised the manuscript. RS and AV conceptualized and designed the study, made inputs into the data analyses plan, and reviewed and revised drafts of the manuscript. AK, BG and MO made inputs into the data analyses plan, and reviewed and revised drafts of

the manuscript. . All authors agreed to the final version of the manuscript to its submission. All authors read and approved the final manuscript.

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**Ethics approval and consent to participate:** Not applicable. Public accessible data was used for the study

**Consent for publication:** Not applicable.

**Competing interests:** The authors declare that Morenike Oluwatoyin Ukpong and Maha El Tantawi are Sectional and Associate editors with BMC Oral Health, respectively.

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## Table

Table 1: Association between prevalence of ECC in 0 to 2 year olds and 3 to 5 year olds, anaemia and malnutrition

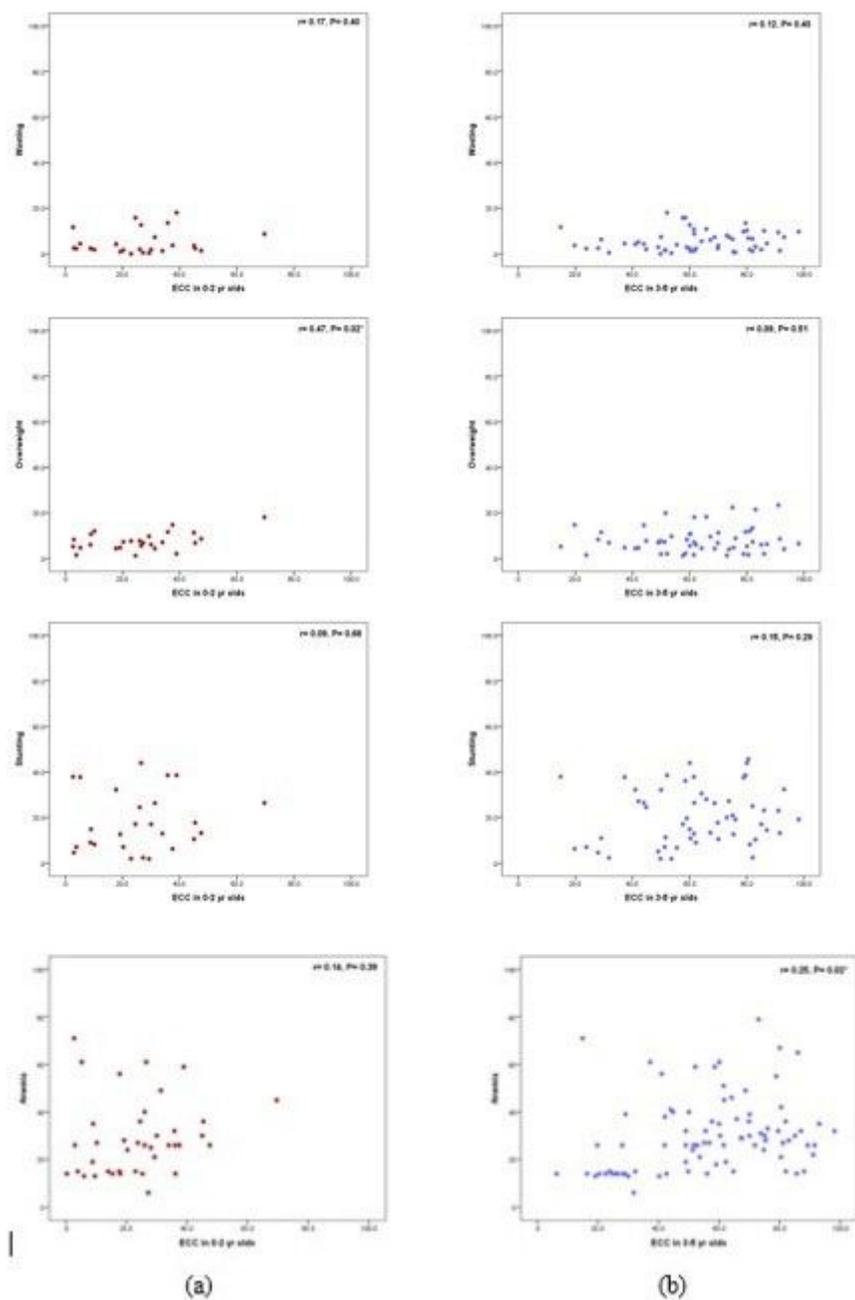
Malnutrition	ECC prevalence in 0-2 year olds			ECC prevalence in 3-5 year olds		
	B (95% CI)	P	$\eta^2$	B (95% CI)	P	$\eta^2$
Wasting	-0.02 (-0.14, 0.11)	0.76	0.004	0.001 (-0.06, 0.06)	0.98	<0.0001
Overweight	0.12 (0.02, 0.23)	0.03*	0.21	0.02 (-0.06, 0.09)	0.65	0.004
Stunting	-0.05 (-0.31, 0.21)	0.68	0.008	-0.01 (-0.14, 0.11)	0.84	0.001
Anemia	-0.15 (-0.48, 0.19)	0.38	0.04	-0.14 (-0.29, -0.001)	0.048*	0.08

Multivariate general linear models were adjusted for income levels. For 0-2 yr olds: p value for income association with dependent variables < 0.05 except with overweight where P= 0.76. For 3—5 yr olds, p value for income association with dependent variables < 0.05 for all.

$\eta^2$ : partial eta squared

\*: statistically significant at P< 0.05

## Figures



**Figure 1**

Scatter plots for the correlation between prevalence of malnutrition indicators, anaemia and ECC in (a) 0-2 year-old children and (b) 3-5 year-old children

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementalECCMalnutritionAnemia.docx](#)