Associations between early childhood caries and malnutrition and anemia: A global perspective

Morenike Folayan (toyinukpong@yahoo.co.uk)
College of Health Sciences https://orcid.org/0000-0002-9008-7730
Maha El Tantawi
Alexandria University
Robert J Schroth
University of Manitoba
Ana Vukovic
University of Belgrade
Authur Kemoli
Africa International University Tony Wilmot Memorial Library
Balgis O Gaffar
Imam Abdulrahman University
Mary Obiyan
Obafemi Awolowo University

Research article

Keywords: early childhood caries, malnutrition, anemia, infants, children

Posted Date: October 31st, 2019

DOI: https://doi.org/10.21203/rs.2.16567/v1

Version of Record: A version of this preprint was published at BMC Nutrition on May 4th, 2020. See the published version at https://doi.org/10.1186/s40795-020-00340-z.

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. The 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 (η^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 (η^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 There were age-related disparities in the relationship between country-level prevalence of ECC, malnutrition and anemia. 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 with the multi-facet impact of malnutrition in children. Food insecurity can lead to undernutrition (i.e., underweight, wasting, stunting, micronutrient deficiencies and low birth weight) in disadvantaged communities, while over consumption of food leads to overweight and obesity in developed and developing communities [1]. Undernutrition 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 occurring in children younger than 6 years old [3]. ECC is a challenging problem faced by preschool children in developed and developing countries [4] with severe forms impacting on children’s growth, development and well-being [5], in addition to the social and economic effects for parents and the 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 interfere with eating and sleeping, and in turn, resulting in the child being underweight [8.9] and stunted [10]. 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 which are associated with higher risk of caries [15–19]. Therefore, the relationship between malnutrition and ECC is complex, bi-directional and with co-morbid relationships [7].

Several recent studies have highlighted the relationship between ECC and malnutrition [20], ECC and micronutrient deficiencies [11, 12, 21–23], and ECC 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, and 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 Nation 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 World Health Organization (WHO) Country Oral Health Profile database and other online databases. Estimates including cavitated lesions were the majority and only these were included. Estimates of non-cavitated lesions were excluded. 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. 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:

- Stunting: below minus two SDs from median height-for-age.
- Wasting: below minus two SDs from median weight-for-height.
- 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.

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

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]. 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 (η^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 factor (VIF) was 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).

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 2 (7.7%) low-income countries, 10 (38.5%) lower middle-income countries, 9 (34.6%) upper middle-income countries, and 5 (19.2%) high-income countries. The 55 countries with complete data on ECC, anemia and malnutrition for 3–5-year-olds included 6 (10.9%) low-income countries, 19 (34.5%) lower middle-income countries, 22 (40%) upper middle-income countries, and 8 (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 for 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 the 0–2-year-olds, 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 the 3–5 year-olds, 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. 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 old, 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 ≤ 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] of 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, therefore, 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 are 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 however caution also that 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 study finding.

One of the strengths of the study was that collated data on malnutrition included those from the Demographic Health Survey with high quality data [59–61]. 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 [62, 63]. 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. 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 gender 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 ≥ 2 years of age [63] whereas we focused on 2-year-olds and younger, and 3 to 5-year-olds [63].

Many of the epidemiological surveys use the World Health Organisation's criteria for assessing caries [64], which does not include assessment for 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 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. Further, our study is cross-sectional and therefore, the direction of the observed relationships can 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 ab le 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 approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Funding: Project was done with no specific support

Availability of data and materials: Study related data and materials are enclosed as supplementary file.

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 they have no competing interests.

References

1. WHO. Action plan to reduce the double burden of malnutrition in the Western Pacific Region. (2015–2020). http://iris.wpro.who.int/handle/10665.1/10892. Published 2015.
2. Rice AL, Sacco L, Hyder A, Black RE. Malnutrition as an underlying cause of childhood deaths associated with infectious diseases in developing countries. Bulletin of the World Health Organization. 2000;78(10):1207-1221.

3. AAPD. Policy on Early Childhood Caries (ECC): Classifications, Consequences, and Preventive Strategies. Pediatr Dent. 39(6):59-61. 2017.
4. Manton DJ. Child Dental Caries – A Global Problem of Inequality. EClinicalMedicine. 2018;1:3-4.
5. Schroth RJ, Harrison RL, Moffatt ME. Oral health of indigenous children and the influence of early childhood caries on childhood health and well-being. Pediatric clinics of North America. 2009;56(6):1481-1499.
6. Jabbarifar SE, Ahmady N, Sahafian SA, Samei F, Soheillipour S. Association of parental stress and early childhood caries. Dental research journal. 2009;6(2):65-70.
7. Dimaisip-Nabuab J, Duijster D, Benzian H, Heinrich-Weltzien R, Homsavath A, Monse B, et al. Nutritional status, dental caries and tooth eruption in children: a longitudinal study in Cambodia, Indonesia and Lao PDR. BMC Pediatrics. 2018;18(1):300.
8. Psoter WJ, Reid BC, Katz RV. Malnutrition and dental caries: a review of the literature. Caries research. 2005;39(6):441-447.
9. So M, Ellenikiotis YA, Husby HM, Paz CL, Seymour B, Sokal-Gutierrez K. Early Childhood Dental Caries, Mouth Pain, and Malnutrition in the Ecuadorian Amazon Region. International journal of environmental research and public health. 2017;14(5).
10. Penafiel D, Termote C, Lachat C, Espinel R, Kolsteren P, Van Damme P. Barriers to Eating Traditional Foods Vary by Age Group in Ecuador With Biodiversity Loss as a Key Issue. Journal of nutrition education and behavior. 2016;48(4):258-268 e251.
11. Schroth R, Jeal N, Kliewer E, Sellers E. The relationship between vitamin D and severe early childhood caries: a pilot study. International Journal for Vitamin and Nutrition Research. 2012;82(1):53-62.
12. Schroth RJ, Levi JA, Sellers EA, Friel J, Kliewer E, Moffatt ME. Vitamin D status of children with severe early childhood caries: a case-control study. BMC Pediatrics. 2013;13:174.
13. Johansson I, Lenander-Lumikari M, Saellstrom AK. Saliva composition in Indian children with chronic protein-energy malnutrition. Journal of dental research. 1994;73(1):11-19.
14. Johansson I, Saellstrom AK, Rajan BP, Parameswaran A. Salivary flow and dental caries in Indian children suffering from chronic malnutrition. Caries research. 1992;26(1):38-43.
15. Agarwal PK, Agarwal KN, Agarwal DK. Biochemical changes in saliva of malnourished children. The American journal of clinical nutrition. 1984;39(2):181-184.
16. Alvarez JO, Lewis CA, Saman C, Caceda J, Montalvo J, Figueroa ML, et al. Chronic malnutrition, dental caries, and tooth exfoliation in Peruvian children aged 3-9 years. The American journal of clinical nutrition. 1988;48(2):368-372.
17. Cleaton-Jones P, Richardson BD, Granath L, Fatti LP, Sinwell R, Walker AR, et al. Nutritional status and dental caries in a large sample of 4- and 5-year-old South African children. South African medical journal = Suid-Afrikaanse tydskrif vir geneeskunde. 2000;90(6):631-635.
18. Li Y, Navia JM, Bian JY. Caries experience in deciduous dentition of rural Chinese children 3-5 years old in relation to the presence or absence of enamel hypoplasia. Caries research. 1996;30(1):8-15.

19. Lingstrom P, Moynihan P. Nutrition, saliva, and oral health. Nutrition. 2003;19(6):567-569.
20. Sokal-Gutierrez K, Turton B, Husby H, Leonor Paz C. Early childhood caries and malnutrition: baseline and two-year follow-up results of a community-based prevention intervention in Rural Ecuador. BMC Nutrition. 2016;2:73.
21. Davidson K, Schroth RJ, Levi JA, Yaffe AB, Mittermuller BA, Sellers EAC. Higher body mass index associated with severe early childhood caries. BMC Pediatrics. 2016;16:137.
22. Schroth RJ, Lavelle C, Tate R, Bruce S, Billings RJ, Moffatt ME. Prenatal vitamin D and dental caries in infants. Pediatrics. 2014;133(5):e1277-1284.
23. Schroth RJ, Levi J, Kliewer E, Friel J, Moffatt ME. Association between iron status, iron deficiency anaemia, and severe early childhood caries: a case–control study. BMC Pediatrics. 2013;13(1):22.
24. Bansal K, Goyal M, Dhingra R. Association of severe early childhood caries with iron deficiency anemia. Journal of the Indian Society of Pedodontics and Preventive Dentistry. 2016;34(1):36-42.
25. UN. Member States. United Nations; [assessed 2018 August 26] http://www.un.org/en/member-states/. Published 2017.
26. El Tantawi M, Folayan MO, Mehaina M, Vukovic A, Castillo JL, Gaffar BO, et al. Prevalence and Data Availability of Early Childhood Caries in 193 United Nations Countries, 2007-2017. American journal of public health. 2018;108(8):1066-1072.
27. United Nations Children’s Fund, World Health Organization, World Bank Group. Levels and trends in child malnutrition: Key findings of the 2018 Edition of the Joint Child Malnutrition Estimates. https://data.unicef.org/wp-content/uploads/2018/05/JME-2018-brochure-web.pdf. Published 2018.
28. UNICEF. Malnutrition in Children - UNICEF DATA. https://data.unicef.org/topic/nutrition/malnutrition/. Published 2018. Updated May 2018. Accessed 16th February, 2019.
29. WHO. The global prevalence of anemia in 2011. https://www.who.int/nutrition/publications/micronutrients/global_prevalence_anaemia_2011/en/. Published 2015. Accessed 16th February, 2019.
30. TheWorldBankGroup. List of economies in 2018. databank.worldbank.org/data/download/site-content/CLASS.xls. Published 2018. Accessed February, 2019.
31. Xavier A, Bastos da Silva R, Arakawa AM, Caldana de Lourdes A, Bastos de Magalhaes JB. Correlation between dental caries and nutritional status: preschool children in a Brazilian municipality. The Revista de Odontologia da UNESP. 2013;42(5):378-383.
32. Li LW, Wong HM, Peng SM, McGrath C. Anthropometric Measurements and Dental Caries in Children: A Systematic Review of Longitudinal Studies. Advances in Nutrition. 2015;6(1):52-63.
33. Seow WK, Clifford H, Battistutta D, Morawska A, Holcombe T. Case-control study of early childhood caries in Australia. Caries research. 2009;43(1):25-35.
34. Werner SL, Phillips C, Koroluk LD. Association between childhood obesity and dental caries. Pediatric dentistry. 2012;34:23-27.

35. Sullivan JM, Bicego GT, Rutstein SO. Assessment of the quality of data used for the direct estimation of infant and child mortality in the Demographic and Health Surveys. An assessment of DHS-I data quality DHS Methodological Reports No 1 Columbia, Maryland: Institute for Resource Development / Macro Systems, Inc.; 1991. p. 113-143.
36. Dye BA, Hsu KL, Afful J. Prevalence and measurement of dental caries in young children. Pediatr Dent. 2015;37:200-216.
37. Angelopoulou MV, Shanti SD, Gonzalez CD, Love A, Chaffin J. Association of food insecurity with early childhood caries. Journal of public health dentistry. 2018.
38. von Braun J. Food insecurity, hunger and malnutrition: necessary policy and technology changes. New biotechnology. 2010;27(5):449-452.
39. Chankanka O, Cavanaugh JE, Levy SM, Marshall TA, Warren JJ, Broffitt B, et al. Longitudinal associations between children's dental caries and risk factors. Journal of public health dentistry. 2011;71(4):289-300.
40. Peltzer K, Mongkolchati A, Satchaiyan G, Rajchagool S, Pimpak T. Sociobehavioral factors associated with caries increment: a longitudinal study from 24 to 36 months old children in Thailand. International journal of environmental research and public health. 2014;11(10):10838-10850.
41. Van de Poel E, Hosseinpoor AR, Speybroeck N, Van Ourti T, Vega J. Socioeconomic inequality in malnutrition in developing countries. Bulletin of the World Health Organization. 2008;86(4):282-291.
42. Chakraborty M, Saha JB, Bhattacharya RN, Roy A, Ram R. Epidemiological correlates of dental caries in an urban slum of West Bengal. Indian journal of public health. 1997;41(2):56-60, 67.
43. Sawaya AL, Dallal G, Solymos G, de Sousa MH, Ventura ML, Roberts SB, et al. Obesity and malnutrition in a Shantytown population in the city of Sao Paulo, Brazil. Obesity research. 1995;3 Suppl 2:107s-115s.
44. Kimani-Murage EW, Kahn K, Pettifor JM, Tollman SM, Dunger DB, Gómez-Olivé XF, et al. The prevalence of stunting, overweight and obesity, and metabolic disease risk in rural South African children. BMC public health. 2010;10:158.
45. Ohsuka K, Chino N, Nakagaki H, Kataoka I, Oshida Y, Ohsawa I, et al. Analysis of risk factors for dental caries in infants: a comparison between urban and rural areas. Environmental health and preventive medicine. 2009;14(2):103-110.
46. Popkin B. The Dynamics of the Dietary Transition in the Developing World. In: Caballero B, Popkin B, editors. The Nutrition Transition: Diet and Disease in the Developing World. London, UK: Academic Press; 2002: 111-128.
47. Poskitt EM. Countries in transition: underweight to obesity non-stop? Annals of tropical paediatrics. 2009;29(1):1-11.
48. Kumar S, Tadakamadla J, Zimmer-Gembeck MJ, Kroon J, Lalloo R, Johnson NW. Parenting practices and children's dental caries experience: A structural equation modelling approach. Community dentistry and oral epidemiology. 2017;45(6):552-558.

49. Chen W, Chen P, Chen SC, Shih WT, Hu HC. Lack of association between obesity and dental caries in three-year-old children. Zhonghua Min Guo Xiao Er Ke Yi Xue Hui Za Zhi. 1998;39(2):109-111.
50. Dye BA, Shenkin JD, Ogden CL, Marshall TA, Levy SM, Kanellis MJ. The relationship between healthful eating practices and dental caries in children aged 2-5 years in the United States, 1988-1994. J Am Dent Assoc. 2004;135(1):55-66.
51. Hong L, Ahmed A, McCunniff M, Overman P, Mathew M. Obesity and dental caries in children aged 2-6 years in the United States: National Health and Nutrition Examination Survey 1999-2002. Journal of public health dentistry. 2008;68(4):227-233.
52. Macek MD, Mitola DJ. Exploring the association between overweight and dental caries among US children. Pediatric dentistry. 2006;28(4):375-380.
53. Saunders C, Abel G. 2014. Ecological studies: use with caution. *Br J Gen Pract*. 64(619): 65-66. doi: 10.3399/bjgp14X676979.
54. Oliveira MA, Osorio MM. [Cow's milk consumption and iron deficiency anemia in children]. Jornal de Pediatria. 2005;81(5):361-367.
55. Parkin PC, DeGroot J, Maguire JL, Birken CS, Zlotkin S. Severe iron-deficiency anaemia and feeding practices in young children. Public health nutrition. 2016;19(4):716-722.
56. Wong C. Iron deficiency anaemia. Paediatrics and Child Health. 2017;27(11):527-529.
57. Müller O, Krawinkel M. Malnutrition and health in developing countries. Canadian Medical Association Journal. 2005;173(3):279-286.
58. Lagerweij MD, van Loveren C. Declining Caries Trends: Are We Satisfied? Current oral health reports. 2015;2(4):212-217.
59. CDC. About Child & Teen BMI. https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html. Published 2018. Updated October 24, 2018. Accessed 8th February, 2019.
60. Mturi AJ, Curtis SL. The determinants of infant and child mortality in Tanzania. Health policy and planning. 1995;10(4):384-394.
61. Rutstein SO. Effects of preceding birth intervals on neonatal, infant and under-five years mortality and nutritional status in developing countries: evidence from the demographic and health surveys. International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics. 2005;89 Suppl 1:S7-24.
62. Desai S, Alva S. Maternal education and child health: is there a strong causal relationship? Demography. 1998;35(1):71-81.
63. Munthali T, Jacobs C, Sitali L, Dambe R, Michelo C. Mortality and morbidity patterns in under-five children with severe acute malnutrition (SAM) in Zambia: a five-year retrospective review of hospital-based records (2009-2013). Archives of public health = Archives belges de sante publique. 2015;73(1):23.

64. World Health Organisation. Oral Health Surveys: basic Methods. Geneva: World Health Organisation; 1997.

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	η2	B (95% CI)	P	η2
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.

η2: partial eta squared

*: statistically significant at P< 0.05

Figures

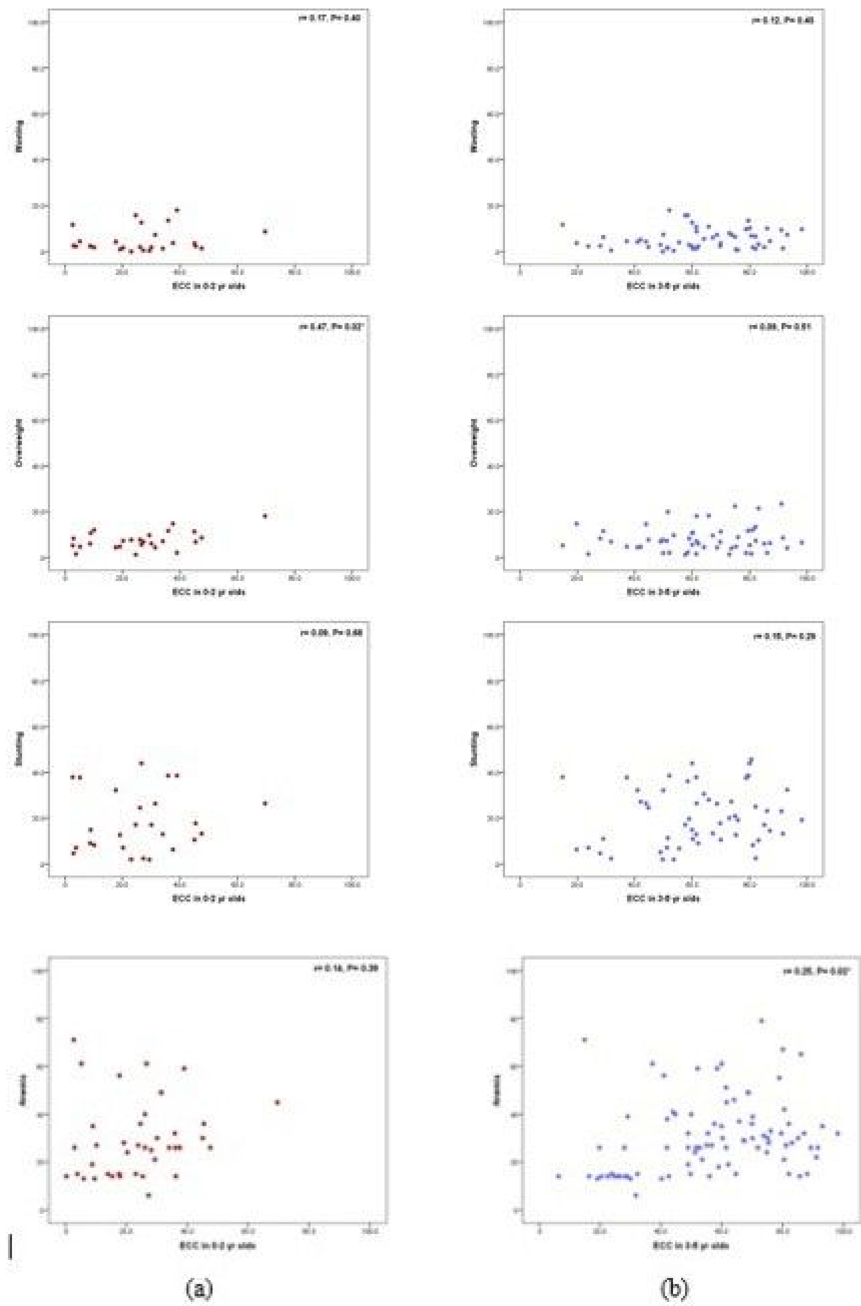

Figure 1

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