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REVIEW

Association of early childhood caries and nutritional status: a scoping review

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Abstract

The most widespread non-communicable disease in the world is dental caries. Early childhood caries (ECC) is the presence of one or more decayed, missing or filled tooth surfaces in any primary tooth in children between birth and 71 months. The disease has been linked to failure to thrive, impaired speech and reduce food consumption due to pain and discomfort. Nutritional status of a child may also be affected by caries. Thus, we conducted a scoping review to review the association between ECC and nutritional status. A total of 492 articles published until December 2022 from three databases were obtained. 20 relevant articles meeting the inclusion criteria were included. From the included articles, dmft index was the most common dental assessment used, while all articles used anthropometric measurements for nutritional assessment except for two articles that used laboratory methods. Based on the results obtained, majority of the articles stated that there was an association between ECC in children with poor nutritional status, while only one study reported an association between ECC and overweight or obese children. Four papers showed no association. A more standardised and consistent study methodology, sample population and protocol in articles selected may help yield more reliable results.

Keywords

Growth and development; Anthropometric measurements; Early childhood caries; Newcastle-Ottawa scale

1. Introduction

Early Childhood Caries (ECC) is one of the most prevalent diseases among children worldwide affecting about 1.76 billion children with deciduous teeth [1, 2]. Early childhood caries is defined as the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a preschool child between birth and 71 months of age [3]. Severe ECC is a more serious and alarming condition defined based on age and number of teeth affected [4]. Caries can be assessed through various indices such as decayed, missing or filled primary teeth/surfaces (dmft/dmfs index), observation of decayed teeth (dt) and International Caries Detection and Assessment System (ICDAS scoring) [5]. Dental caries formation is an active pathological process that requires three main components to be present, which are the cariogenic bacteria, the fermentable carbohydrates, and the susceptible tooth surface/host [6]. In addition to those components, there are other various associated factors that lead to the formation of dental caries as it is a multifactorial disease [7]. Risk factors of ECC broadly include microbiological, dietary, environmental, and host factors [8].

Dietary habits and intake play a crucial role in the development of ECC [9, 10]. The caries formation process begins when carbohydrates are ingested and fermented by bacteria, thus leading to enamel demineralisation [11]. There will also be a rapid fall in potential of hydrogen (pH) from 7.0 to 5.0 and below. The increased frequency of the fermentable carbohydrate intake in between meals causes continuous acid production, which subsequently leads to a continuous cycle of enamel demineralisation [11]. Diet does not only play an important role in caries formation but also affects the nutritional status and child development. [10].

Nutritional status is defined as the meeting of human body needs for nutritive and protective substances and the reflection of these in physical, physiological, and biochemical characteristics, functional capability as well as health status [12]. Nutritional assessment is used to garner information regarding nutritional status. There are five main approaches to nutritional assessment that are described as "ABCDE" that stands for Anthropometric, Biochemical, Clinical, Dietary, and Environmental or Psychosocial [13]. Anthropometry measurement includes children's height, weight, body mass index (BMI), growth pattern indices, mid upper arm circumference, skinfold thickness [14]. This measurement is widely accepted as the most useful tool for assessing the nutritional status of children due to its low cost, simplicity, and strong correlation to a child's growth and development [15]. Biochemical as-

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sessment, also known as laboratory assessment, monitors the concentration of nutrient or metabolites such as folates, iron, and vitamins using whole blood or serum [14]. A clinical examination involves a complete medical history with physical examinations to help detect nutritional deficiency, while a dietary intake assessment detects an inadequate nutrition intake that can cause nutrient deficiency or excess [14, 16]. Finally, environmental and psychosocial assessment is rarely used for children as it evaluates factors such as economic conditions, social status, job status, and living conditions [16]. According to the World Health Organization (WHO), malnutrition is defined as deficiencies, excesses, or imbalances in a person's intake of energy and/or nutrients. Malnutrition is generally divided into three broad groups of condition, which are undernutrition that includes wasting, stunting and underweight; micronutrient-related malnutrition, which includes micronutrient deficiencies or excess; and overweight, which includes obesity and diet-related noncommunicable diseases [17].

Obesity has also been proven to affect ECC as a result of poor nutritional status by reducing the flow rate of stimulated whole saliva [18]. A reduced salivary flow favours biofilm formation and leads to a high risk of caries formation [19]. Obesity has also been linked to a diet intake consisting of high sugar consumption, which is a risk factor for caries [20, 21]. Dental caries may negatively affect children's nutritional status as pain and infection from teeth may cause an insufficient intake of food and nutrients to meet the children's physical needs for growth and consequently lead to malnutrition [22]. Besides that, severe ECC is a risk marker for iron-deficiency anaemia that can affect growth and development of a child [23].

Multiple studies have reported the association between ECC and nutritional status, while others stated otherwise. Studies have shown that dental caries is commonly seen in malnourished children [24]. There are also studies that relate the high caries prevalence with overweight and obese children [25]. However, a study showed that weight-for-age z-score (WAZ), height-for-age z-score (HAZ), and BMI-for-age z-score (BAZ) were not associated with the number of decayed primary teeth [26]. Another study also reported no association between ECC with stunting and underweight [27]. The association between ECC and nutritional status has been continuously and thoroughly researched. However, a well-established direction is yet to be obtained. Thus, this scoping review aims to assess the association between ECC and nutritional status.

2. Methods

2.1 Search strategy

The study methodology of this scoping review was based on the six-stage methodological framework outlined by Arksey and O'Malley that consisted of "identifying the research question, identifying relevant studies, study selection, charting the data, collating, summarizing, reporting results and consultation (optional)" with consideration of the scoping framework suggested by Levac *et al*. [28, 29]. The research question for this scoping review is as follows: "What is the association between ECC and nutritional status?". A search of published literature until December 2022 was performed on PubMed, Scopus, and Web of Science databases using the following search terms ("Early Childhood Caries*" OR "Dental caries*" OR "Caries*") AND ("Nutritional status*" OR "Nutrition status*" OR "Nutritional assessment*") AND ("Growth*" OR "Growth and Development*" OR "Development*") and the search was restricted to articles in English.

2.2 Criteria for study selection

The inclusion criteria for the selection of articles were defined according to participants, concept, and context domains (PCC): Participants (P): Children aged 71 months and below regardless of gender/race; Concept (C): Children assessed for both ECC and nutritional status (anthropometric measurement, biochemical status such as vitamin D, clinical assessment, based on dietary, or environmental/psychosocial data); Context (C): Dental assessment, nutritional assessment, other factors and the association outcome. From the search results obtained, review and systematic review articles were excluded. Articles involving animal studies, sample population of children aged more than 71 months old, and articles not in English language were excluded.

2.3 Data extraction

The initial search yielded 492 articles. Screening of titles and abstracts was conducted by two independent reviewers (LDT and FY). A total of 56 duplicate articles and 226 irrelevant articles were removed using an online platform called Rayyan (`https://www.rayyan.ai/`). In case of disagreement between reviewers, a discussion was conducted until a consensus was reached. A total of 210 potentially eligible full articles were considered for full text evaluation. However, 190 articles were excluded based on the inclusion and exclusion criteria. The excluded articles consisted of 122 unrelated articles, 59 articles with wrong population of children (aged above 71 months), and nine systematic review or review articles. A total of 20 articles were included in this scoping review. A flowchart of the selection process according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is shown in Fig. 1. Data from the 20 shortlisted articles were extracted and tabulated in Microsoft Excel 365 according to the author, year, sample population, dental assessment, dental outcome, nutritional assessment, other factors, and association outcomes, as presented in Table 1. The quality assessment of the included articles was appraised using the adapted version of Newcastle-Ottawa Scale (NOS), as presented in Table 2 [30].

3. Results

3.1 Type of study, sample population and quality assessment

As shown in Table 1, there were five types of studies among the shortlisted articles. Out of the 20 studies, thirteen studies were cross-sectional studies [22–24, 26, 31–39], one retrospective study [40], one subcohort cluster randomised controlled trial [27], one case control study [41], two cohort study [25, 44], one

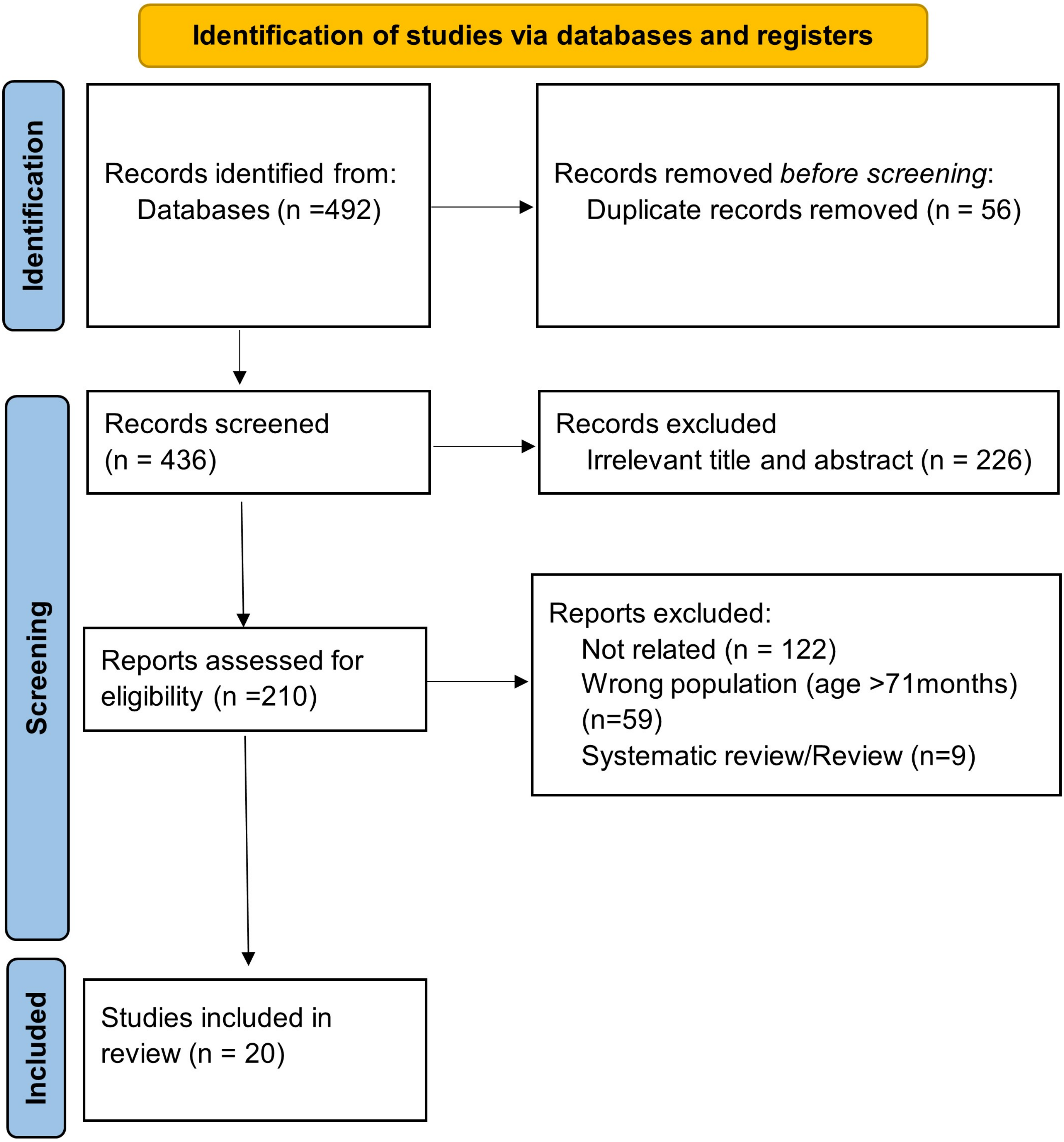

FIGURE 1. Flowchart according to the PRISMA checklist showing the flow of articles arising from the main search.

longitudinal twin study [43], and one longitudinal study [42]. The subcohort cluster randomised controlled trial study by Muhoozi *et al*. [27] involved 203 children in the intervention group who received education intervention on oral hygiene practice and dietary advice, while the other 198 children in the control group did not. However, there was no data regarding caries in relation with nutritional status [27]. All the studies had study populations that included healthy children aged 71 months and below, as defined by the American Association of Paediatric Dentistry (AAPD) for children diagnosed with ECC [3]. There was a great variation in respect to sample population used in the studies ranging from as low as 46 children to as high as 27,333 children [23, 40].

In terms of quality assessment, nine studies [22, 25–27, 32, 34, 38, 41, 44] were considered high quality, and the remaining eleven studies [23, 24, 31, 33, 35–37, 39, 40, 42, 43] were considered moderate quality due to insufficient descriptions on the sample size calculation and methods for controlling confounding factors such as socioeconomic status, diet, and oral hygiene practice. Detailed information regarding quality assessment is tabulated in Table 2.

TABLE 1. Summary of the extracted information from included studies.

Author, Year	Type of Study	Sample Population	Dental Assessment/Dental Outcome	Nutritional Assessment	Other Factors	Outcome/Findings
Li *et al*. (1996) [31]	Cross-sectional study	3–5 years old children (1344 healthy children)	dmfs index dmft index Caries prevalence 82.3% Median dmfs index: 7 Mean dmft index: 5.6	Height-for-age, Weight-for-height	Sociodemographic, socioeconomic status, maternal pregnancy and labour status, infant's medical history, frequency of dental care services, oral health behaviour	There was an association between low height for age and caries.
Petti *et al*. (1999) [32]	Cross-sectional study	3–5 years old children (1494 healthy children)	dft index dt Caries prevalence: 27.3% Mean dft: 3.3 (SD 1.7) Mean dt: 2.5 (SD 1.8)	Weight, Height, BMI-for-age	Sociodemographic, socioeconomic, fluoride and oral hygiene practice, breastfeeding, bottle feeding and pacifier history, microbacterial testing	Malnutrition significantly increased the Rampant Early Childhood Dental Decay probability.
Karvonen *et al*. (2002) [33]	Cross-sectional study	Below 5 years old children (151 healthy children)	dmft index Mean dmft index 6.5	Weight-for-age, Height-for-age, Weight-for-height	Food consumption (24 h recall). Eating frequency, breastfeeding practices, oral hygiene practice, vitamin D supplementation	There was no evidence of any association between ECC and nutritional status.
Oliveira *et al*. (2008) [34]	Cross-sectional study	12–59 months old children (1018 healthy children)	dmfs index Caries prevalence 23.4%	Weight-for-age z-score Height-for-age z-score BMI-for-age z-score	Sociodemographic status and socioeconomic status	There was an association between underweight children and caries.
Clarke *et al*. (2005) [23]	Cross-sectional study	2–6 years old children (46 healthy children)	dt Dental outcome: not reported	Weight-for-height, Body mass index, Arm muscle circumference, Haemoglobin, Mean corpuscular volume, Serum ferritin, Serum albumin	-	Severe ECC was associated with undernutrition.
Norberg *et al*. (2012) [24]	Cross-sectional study	5 years old children (920 healthy children)	deft index dtMean number of deft: 0.79 (2.15) and dt: 0.51 (1.66)	BMI	Sociodemographic status and socioeconomic status	Children with low BMI had statistically significant higher deft and dt values compared to normal BMI.

TABLE 1. Continued.

Author, Year	Type of Study	Sample Population	Dental Assessment/Dental Outcome	Nutritional Assessment	Other Factors	Outcome/Findings
Sood *et al.* (2014) [35]	Cross-sectional study	3−6 years old children (280 healthy children)	dft index Caries prevalence 33.9% Mean number of dft 1.45 ± 2.96	Body weight-for-age	Sociodemographic status and plaque index	A definitive correlation was observed between the oral health status and BMI.
Janakiram *et al.* (2018) [36]	Cross-sectional study	8−60 months old children (550 healthy children)	deft index Mean (SD) deft scores normal nutritional status: 0.93 (1.73), Borderline undernutrition: 2.22 (2.92) and Undernutrition: 3.40 (3.23)	Weight-for-age	Questionnaire on sociodemographic, socioeconomic status of parents, prenatal history, drug history of mother, feeding practices and milestones of development	Undernutrition was associated with ECC.
Shim *et al.* (2018) [37]	Cross-sectional study	4−6 years old children (1910 healthy children)	dft index Caries prevalence of active caries in primary dentition: 28.2%, Prevalence of dental caries experienced in primary dentition: 56.4% Mean number of dft: 2.60	Body weight-for-age, Height-for-age, BMI-for-age	Sociodemographic and socioeconomic status as well as dietary intake assessment (1 day 24-hour recall)	Dental caries was significantly associated with weight-for-age but not with height-for-age or BMI for age. This study indicated that dental caries was associated with nutritional status.
Lee *et al.* (2020) [26]	Cross-sectional study	3−6 years old children (396 healthy children)	dt Caries prevalence (at least one) decayed tooth in primary teeth: 63.4% Mean (SD) dt score: 3.56 (4.57)	Weight-for-age z-score Height-for-age z-score BMI-for-age z-score	Sociodemographic, second-hand smoke exposure and 3-day food record	WAZ, HAZ. and BAZ (nutritional status) were not associated with untreated caries in primary teeth.
Ndekero *et al.* (2021) [22]	Cross-sectional study	3−5 years old children (831 healthy children)	dmft index Caries prevalence: 44.8% dmft index: 2.51	Weight-for-age z-score Height-for-age z-score Weight-for-height z-score	Sociodemographic status, socioeconomic status oral hygiene, and sugar exposure	There was a significantly negative relationship between ECC and children's anthropometric measures indicated by WAZ.

TABLE 1. Continued.

Author, Year	Type of Study	Sample Population	Dental Assessment/Dental Outcome	Nutritional Assessment	Other Factors	Outcome/Findings
Olatosi *et al.* (2022) [38]	Cross-sectional study	1–6 years old children (273 healthy children)	dmft index Mean dmft (SD): 3.04 (2.28)	Weight-for-age z-score Height-for-age z-score BMI-for-age z-score Weight-for-height z-score	Sociodemographic status, socioeconomic status, and feeding methods during first 6 months of life.	There was an increase in severity of caries among the preschool children who were severely wasted or wasted compared to those of normal weight or overweight.
Cuong *et al.* (2022) [39]	Cross-sectional study	2–5 years old children (690 healthy children)	ICDAS score Mean dental caries rate: 71.3 %	Height-for-age Weight-for-age BMI-for-age	Socioeconomic status, oral hygiene practices as well as amount and timing of dietary consumption	There was an association between malnutrition status and dental caries. The stunting group had a higher ratio of dental caries compared to the other groups.
Aung *et al.* (2021) [40]	Retrospective study	5-year-old children (27,333 healthy children)	dmft index Caries prevalence: 23.2% Mean dmft score: 1.85	BMI-for-age	Sociodemographic information, community water fluoridation status	Early childhood caries was associated with higher BMI children.
Schroth *et al.* (2013) [41]	Case control study	Mean age: 40.8 ± 14.1 months old children (266 healthy children)	dmft index Dental outcome: not reported	Vitamin D levels	Sociodemographic status, socioeconomic status, dietary intakes, use of supplements, sun exposure and skin pigmentation and oral hygiene behaviours	Children with severe ECC appeared to have relatively poor nutritional health.
Alvarez *et al.* (1993) [42]	Longitudinal study	6–11 months old children recruited followed till 4 years of age (209 healthy children)	deft index Dental outcome: not reported	Height-for-age Weight-for-height	History of malnutrition	There was an association between early malnutrition and dental caries.
Silva *et al.* (2020) [43]	Longitudinal twin study	18 months–6 years (twins) (344 twin children)	ICDAS score Caries prevalence: 32.3% (with caries) and 24.1% (with advanced caries)	BMI	Age, sex, sugar consumption, toothbrushing frequency, socioeconomic status, and community water fluoridation	There was no association between BMI and dental caries.

TABLE 1. Continued.

Author, Year	Type of Study	Sample Population	Dental Assessment/Dental Outcome	Nutritional Assessment	Other Factors	Outcome/Findings
Ribeiro *et al.* (2017) [25]	Cohort study	24–71 months children (388 healthy children)	Total number of caries (including cavitated, active non-cavitated, missing and filled cavities) Caries prevalence: 33.8%	BMI-for-age z-score	Sociodemographic status, socioeconomic status (income), birthweight, nutritional status at twelve months and frequency of sugar consumption.	Being overweight or obese or being thin or very thin were associated with ECC, independent of socioeconomic variables and high frequency of sugar.
Renggli *et al.* (2021) [44]	Longitudinal cohort study	<24 months of age children (1307 healthy children)	dmft index Mean dmft (SD): 5.1 (3.6)	Height-for-age z-score	Sociodemographic status and feeding practices	Severe caries experience was associated with poorer childhood growth, which could be a contributor to stunting.
Muhoozi *et al.* (2018) [27]	Subcohort of Cluster Randomised Controlled Trial Intervention group (203 children): Education intervention oral hygiene practice and dietary advice Control group (198 children)	36 months old children (399 healthy children)	Decayed anterior teeth (Photographs) Caries prevalence intervention group: 27.8% and control group: 18.2%	Weight-for-age z-score Height-for-age z-score Weight-for-height z-score	Questionnaire on oral health, feeding practices, and water fluoridation	There was no evidence of any effect of ECC on the nutritional status of the children.

dmft: decayed, missing, and filled primary teeth; dt: decayed teeth; SD: standard deviation; ECC: Early Childhood Caries; BMI: body mass index; WAZ: Weight-for-age z-score; HAZ: Height-for-age z-score; BAZ: BMI-for-age z-score; ICDAS: International Caries Detection and Assessment System.

TABLE 2. Adapted Newcastle-Ottawa Scale (NOS) for assessing the quality of the selected studies.

	Selection				Comparability	Outcome		Quality of Study
Studies	Representativeness of the sample	Sample Size	Non-respondent	Ascertainment of exposure	Comparability of subjects in different outcome groups on the basis of design or analysis. Confounding factors controlled.	Assessment of outcome	Statistical test	
Li *et al.* [31] (1996)	*	-	-	**	-	**	*	Moderate quality
Petti *et al.* [32] (1999)	*	*	-	**	-	**	*	High quality
Karvonen *et al.* [33] (2002)	*	-	-	**	-	**	*	Moderate quality
Oliveira *et al.* [34] (2008)	*	*	*	**	-	**	*	High quality
Clarke *et al.* [23] (2005)	-	-	-	**	-	**	*	Moderate quality
Norberg *et al.* [24] (2012)	*	-	-	**	-	**	*	Moderate quality
Sood *et al.* [35] (2014)	-	-	-	**	-	**	*	Moderate quality
Janakiram *et al.* [36] (2018)	-	-	-	**	-	**	*	Moderate quality
Shim *et al.* [37] (2018)	*	-	-	**	-	**	*	Moderate quality
Lee *et al.* [26] (2020)	-	*	*	**	-	**	*	High quality
Ndekero *et al.* [22] (2021)	*	*	*	**	-	**	*	High quality
Olatosi *et al.* [38] (2022)	*	*	*	**	-	**	*	High quality
Cuong *et al.* [39] (2022)	*	-	-	**	-	**	*	Moderate quality
Aung *et al.* [40] (2021)	*	-	-	**	-	**	*	Moderate quality
Schroth *et al.* [41] (2013)	-	*	*	**	-	**	*	High quality

TABLE 2. Continued.

	Selection				Comparability	Outcome		Quality of Study
Alvarez *et al*. [42] (1993)	*	-	-	**	-	**	*	Moderate quality
Silva *et al*. [43] (2020)	*	-	-	**	**	**	*	Moderate quality
Ribeiro *et al*. [25] (2017)	*	*	*	**	-	**	*	High quality
Renggli *et al*. [44] (2021)	*	*	*	**	-	**	*	High quality
Muhoozi *et al*. [27] (2018)	*	-	-	**	-	**	*	High quality

*Asterisks indicate the star rating according to Newcastle-Ottawa scale. High quality: * in the Representativeness of the sample, Sample size, Non-respondent, and Statistical test AND ** in the Ascertainment of exposure, Comparability of subjects and Assessment of outcome. Moderate quality: * in the Ascertainment of exposure, Comparability of subjects and Assessment of outcome. Poor quality: '-' in the Representativeness of the sample, Sample size, Non-respondent, Ascertainment of exposure, Comparability of subjects, Assessment of outcome and Statistical test.*

3.2 Dental assessment and dental outcome

A total of eleven studies used dmft or deft index [22, 24, 25, 31, 33, 36, 38, 40–42, 44] as their dental assessment for ECC. Two studies used dmfs index [31, 34] while three studies used dft index [32, 35, 37] as their dental assessment index where "d" represents decayed teeth, restored teeth with secondary caries or caries on another surface while "f" represents teeth with restorations but no secondary caries as it gives a good understanding of the tooth decay status [35]. Missing teeth were not included as there was no definitive aetiology of whether the teeth underwent early extraction or did not exist [35]. Next, ICDAS scoring was used by two studies [39, 43]. Silva *et al*. [43] used the ICDAS scoring to categorise their samples into "any" or "advanced" caries, while Cuong *et al*. [39] used the scoring method to diagnose the presence of caries. Decayed teeth (dt) assessment [23, 24, 26, 32] was used in four studies, while another study used close-up intraoral photographs of upper front teeth of the children to analyse the presence of carious lesions [27]. Only obvious cavitated lesions into the dentine were considered carious [27].

Dental outcomes reported in the studies consisted of indexes such as dmft index and caries prevalence. Caries prevalence was reported in twelve studies with 82.3% being the highest [31]. Out of those studies, two studies with high caries prevalence [31, 39] and seven studies with low caries prevalence [22, 25, 32, 34, 35, 37, 40] showed a positive association between ECC and nutritional status, while three studies [26, 27, 43] showed no association. All the studies reported dental outcomes based on the indices used, as shown in Table 1, except for three studies [23, 41, 42].

3.3 Nutritional assessment

Nutritional assessment was carried out in all the selected studies. Anthropometric measurements were used in all studies except for two studies that used biochemical assessments such as vitamin D, haemoglobin, mean corpuscular volume, serum ferritin, and serum albumin levels [23, 41]. The anthropometric measurements obtained for weight, height, and calculated BMI were converted using the WHO Anthroplus software (Version 1. 0. 4, WHO, Geneva, Switzerland) to categorise the children into categories of stunted, underweight, normal, overweight, and obese respectively. Undernutrition children with HAZ and WAZ less than −2SD were classified as stunted and underweight accordingly while WHZ of less than −2SD indicated wasting. Severely undernutrition children were scored less than 3SD below the median [45]. As for BAZ, overweight and obese were classified in children aged 60 months and below with BAZ above +2SD and for children aged above 60 months with BAZ $\geq$ +1SD [45, 46]. SD stands for standard deviation. To assess blood biomarkers, venipunctures were conducted for collection of blood samples [41].

3.4 Other factors

The selected studies showed variations in the additional data collected, besides dental and nutritional outcomes. These parameters have the potential to affect the association between ECC and nutritional status. The data regarding sociodemographic factors and socioeconomic factors were collected using questionnaire in thirteen studies [22, 24–26, 31, 32, 34, 36–38, 40, 41, 44] and twelve studies [22, 24, 25, 31, 32, 34, 36–39, 41, 43], respectively. Dietary intake assessment, sugar intake, as well as cariogenic food frequency and exposure were conducted in eight studies through diet recalls [22, 25, 26, 33, 37, 39, 41, 43]. Three studies also further attained information regarding dietary habits by observing feeding practices [27, 36, 38]. A small proportion of the studies obtained the data regarding community water fluoridation through sampling of water at the study area [27] or obtained the available data from the local government [40, 43]. Oral health status and practice were evaluated in five studies through questionnaires based on the frequency of brushing, assistance during brushing [22, 32, 39, 41, 43], and through examination of visible plaque [35]. Other factors that were also present in the selected studies were prenatal history, drug history of mother, developmental milestones [36], second hand smoke exposure [26], use of supplements [33], sun exposure and skin pigmentation [41].

3.5 Outcome/findings

The outcome of the selected studies showed that ten studies reported an association between ECC and poor nutritional status children who were stunted or underweight [22–24, 31, 34, 36, 38, 39, 41, 44]. A general association between ECC with both undernutrition and overweight or obese children was reported in five studies [25, 32, 35, 37, 42]. One study reported an association between ECC and higher BMI children who were overweight or obese [40]. No association between ECC and nutritional status was reported in four studies [26, 27, 33, 43].

4. Discussion

4.1 Dental assessment

There were various dental assessments used in the studies included in this scoping review, namely dmft, deft, dft, dmfs, ICDAS scoring and photographs of anterior teeth. Based on the WHO diagnostic criteria for the diagnosis of dental caries, dmft is defined as the sum of the number of decayed, missing due to caries and filled primary teeth [47]. Majority of studies used the dmft index as a dental assessment and an outcome measurement for dental caries as this index is one of the simplest ones to use [48]. However, since dmft includes both untreated decay and filled tooth/teeth due to caries, population with high rate of untreated decay and population with high rate of filled tooth will have similar high dmft values [38]. The severity and chronic nature of the decayed teeth may be masked when the dmft index is used to determine the present and past caries experience [26]. Thus, Lee *et al*. [26] suggested the number of decayed teeth (dt) as a better or stronger determinant than dmft [49]. Based on the WHO oral health survey, dt index is a criteria to score dental caries, besides dmft, but WHO does not state the superiority of one over the other [5]. The diagnostic criteria of dt includes a lesion in pit, fissure, or on a smooth tooth surface a detectably softened floor or wall, undermined enamel, filled tooth with decay, or an obvious cavity [26]. The number of untreated caries in the oral cavity is indicated by the number of decayed teeth [50].

Besides that, another form of dental assessment used was close-up intraoral photographs of upper front teeth where obvious cavitated lesions into the dentine were considered as presence of caries [27]. The study by Ardenghi *et al.* [51] showed that the development of caries in the maxillary anterior teeth of primary teeth was associated with the development of caries in posterior teeth. This can also be used as a good predictor of caries in permanent dentition. However, compared to dmft, photographs of upper front teeth may not represent the condition of the entire dentition and may lead to underdiagnosis [27].

4.2 Nutritional assessment

According to Norberg *et al.* [24], to better understand the relationship between dental caries and body weight, dental caries should be studied in relation to the whole span of weight or BMI. There are many factors that affect BMI, such as carbohydrate consumption, socioeconomic status, dietary pattern, oral hygiene practice, and alterations due to genetic aspects [52, 53]. Body mass index for age has been proven to be a sensitive indicator of body fatness in children [54]. Majority of the articles in this scoping review used the classification by WHO Child Growth Standards for children aged 60 months and below and WHO Growth Reference for children 60 months above that uses the HAZ, WAZ, and BAZ to categorise the children's nutrition status [45, 46]. The WHO Growth Standards describes the growth of a healthy child who is fed according to the WHO feeding recommendations. Any deviation of a child's growth from the standard indicates abnormal growth [55]. As for the WHO Growth Reference, it describes "the growth of a sample individuals and provides basis for comparing populations without making inferences about the meaning of observed difference". This is used as a reference but not a standard [55].

Other than that, HAZ, WAZ, and BAZ are z-scores that describe "the number of standard deviations (SD) of the actual height, weight or BMI of a child respectively, from the median value of his/her age as determined from the reference population" [56]. The z-score is recognised as the best system for analysis and display of data compared to other methods because it is quantified based on the distribution of reference population. Thus, the score reflects the reference distribution and standardised quantities allowing it to be comparable across age, sex, and anthropometric measures [57, 58]. However, there may be differences between study population and the reference population used in the calculation of z-scores [38].

Laboratory methods such as measurement of vitamin D, serum ferritin, and serum albumin levels can be used to determine nutritional status [23, 41]. Vitamin D plays an important role in the formation of enamel and dentin, as well as maintenance of good oral health and craniofacial development [41]. Vitamin D is also an important component in bone mineral metabolism and skeletal growth and development [59]. Vitamin D supplementation has been associated with reduced caries risk and prevention of caries [60]. According to the study by Schroth *et al.* [41], caries-free children were twice as likely to have an optimal vitamin D concentration, while those with severe ECC have nearly three times the odds of having deficient levels. In addition to low vitamin D levels, unsatisfactory levels of albumin, haemoglobin, serum ferritin, calcium and parathyroid hormones are indicators of nutritional deficiency or malnutrition [23, 41]. In the relationship between ECC and nutritional status, the chronic dental infection may cause effects to the systemic body response which may include low vitamin D levels that affect growth [61]. Low levels of ferritin and haemoglobin cause iron-deficiency anaemia that can affect children's brain development, body function, and growth [62]. A study by Clark and team showed that severe ECC may be a risk marker for iron-deficiency anaemia [23]. Laboratory methods, however, poses a disadvantage during phlebotomy procedure on children. The procedure is an invasive investigation and time-consuming, unlike the anthropometric measurements, which are low cost and simple to conduct [15].

4.3 Other confounding factors

Factors that may relate to the relationship between nutritional status and ECC are the socioeconomic status and sociodemographic status such as gender, household income, and parental education level [53, 63]. Lee *et al.* [26] reported that males in general had a higher number of decayed teeth compared to females due to psychological factors such as noncompliance, faster eruption, and retentive primary teeth. On the other hand, two studies showed no differences between males and females [24, 52]. Various studies showed that the presence of caries was higher in children with a low socioeconomic status [53, 64]. The study by Renggli *et al.* [43] showed that children, predominantly those in the rural provinces, had below par baseline anthropometric measurements, dietary findings, and caries experience compared to the urban provinces. This may impact the formation of teeth by causing dental defects such as brittle and poorly mineralised dental enamel, which is a risk factor for caries. On the other hand, due to the high and excessive sugar consumption among the urban children, their caries experience worsened over time and may confound any potential causal relationships between caries and nutritional status [44]. In addition to that, underweight children in low- and middle-income countries and overweight children in high income countries were reported to have high levels of dental caries [63, 65].

Poor oral hygiene, together with other risk factors for caries, has been associated with caries formation [66]. One of the studies used presence of visible plaque to help explain the lack in oral hygiene practice and parents support in toothbrushing [22]. The start of toothbrushing behaviour before the age of two years old has been related to being caries-free at four years old [67]. Based on AAPD, brushing with fluoridated toothpaste twice daily is recommended for all children for prevention of caries [68].

The study by Lee *et al.* [26], highlighted the positive association between second-hand smoke exposure on the formation of dental caries. Children had a 1.72 times higher risk of having caries in their primary teeth if they were exposed to second hand smoke during infancy [69]. The second-hand smoke increases the *Streptococcus mutans* levels and decreases the mineralisation of tooth and rate of salivary flow, thus leading to an increased risk of caries formation [70].

4.4 Effect of early childhood caries on nutritional status

ECC can have a direct impact on children's nutritional status, growth, and development as the disease causes a reduced intake of food and nutrients due to the pain and discomfort when eating [26, 71]. The insufficient food consumption to cater for the metabolic needs of children will affect their growth [22, 36]. ECC can have detrimental effects to children's immediate and long-term quality of life [72, 73]. The effects of caries on children have been linked to failure to thrive, impaired speech development, and odontogenic infection with premature loss of primary teeth that may affect the development of permanent dentition [27, 72]. Children with severe dental caries have been shown to have double the risk of developing chronic malnutrition [44]. Weight gain and catch up growth were seen in underweight children after dental treatment of caries, revealing that caries can hinder growth and development [74]. Pain and discomfort from toothache may cause disturbed sleep, which may affect glucosteroid production and growth [75]. Metabolic pathways involving cytokines may also be affected by the presence of chronic inflammation due to pulpitis and dental abscess [36].

4.5 Effect of nutritional status on early childhood caries

Nutritional status either underweight, normal, or overweight is related with dietary intake. This depends on the total amount of calories consumed especially from calories that derive from sugar consumption [25]. The amount of sugar consumption can lead to overweight and obesity, while the frequency of sugar consumption is a risk factor for caries formation [76]. Many previous studies have supported this positive association where high frequency of both liquid and solid sugar intakes leads to a high caries risk [22, 26]. This association is supported by Stephan's curve which shows that a fall in pH below 5.5 (critical level) will cause demineralisation of enamel [77]. Consumption of fermentable carbohydrates or sugar reduces the salivary pH beyond the critical pH value. Gradual return of pH takes 30–40 minutes before remineralisation can take place [78, 79]. Prolonged low pH due to repeated intakes of carbohydrates does not allow remineralisation to happen [77]. Thus, a high frequency of sugar consumption increases the episodes of drop in pH values, which then increases the risk for caries formation [26]. Frequent night feeds lead to formation of dental caries due to the physiological reduced salivary flow whilst asleep [27]. Bottle feeding among preschool children has also been proven to be significantly associated with ECC [80].

In terms of the aetiology of obesity, besides genetic factors and frequent consumption of high calorie and sugary food, children's food preference also plays a very important role [24, 44, 81]. Children are generally picky eaters when they have a strong food preference, inadequate variety of food groups intake, reluctance to try new food and eating lesser amount of food [82]. In addition, children may have undernutrition issues and dental caries as the nutritious food and drinks that are needed for growth have been replaced by consumption of sugary foods and drinks [44]. According to Dubois *et al*. [83], picky eaters were twice as likely to be underweight at the age 4.5 years compared to the non-picky eaters.

Obesity may lead to increased susceptibility to caries as obesity is related to the salivary flow and immune response [40]. A correlation was discovered by Gerdin *et al*. [64], who found that obese preschool children may have a risk of developing dental caries at a later age. However, the inability to eat adequately due to caries or the presence of undernutrition due to wasting may also affect salivary composition and flow, thus leading to more caries [38].

4.6 Association between early childhood caries and nutritional status

There is vast literature on the relationship between caries and nutritional status [44]. The differences in the literature may be due to the complex relationship between caries and nutritional status, which may be affected by many factors such as socioeconomic status, child age, oral hygiene practice, and county or location (urban vs. rural) [44, 53, 84]. According to the systematic review by Chen *et al*. [65], there is a high occurrence of caries among overweight and obese children in high-income countries, but not for children from low- or middle-income countries. Besides that, the association between ECC and overweight or obese children is also supported by Ribeiro *et al*. [25]. However, there are also studies that reported no association between overweight/obesity and dental caries [24, 85]. The children with low BMI were found to have more caries than children with normal weight, and this was proven to be statistically significant [24]. This statement is also supported by various other researchers [25, 38, 86]. Other than that, previous studies also showed no relationship between ECC and nutritional status [26, 43, 52]. This may be due to the chronic nature of both ECC and nutritional deficiency such as obesity or stunting, that may take several years to develop. Thus, the effects of these diseases may be more obvious in older children with permanent dentition [26, 87]. This may eventually cause inconsistency in the association [52, 88].

In terms of the effects of low and high caries prevalence population on the association of ECC and nutritional status, there were conflicting results between the shortlisted studies. High caries prevalence population can affect the association between ECC and nutritional status. In two studies with high caries prevalence population, the association was seen between ECC and stunted children [31, 39]. High caries prevalence population showed that the caries occurrences disturbed the children's ability to eat, thus causing a poor dietary intake that affected the growth and development [31]. On the other hand, the association between ECC and nutritional status was found in seven studies involving low caries prevalence populations. Majority of the studies had a general association between malnutrition and ECC, while one study associated ECC with underweight and another study associated ECC with higher BMI [22, 40]. This variation did not show a clear effect of low caries prevalence population on the association of ECC and nutritional status. This may be due to other confounding factors that may have affected the association, such as socioeconomic factors including family income and parent's education [34]. Therefore, there were differences in the association between ECC and nutritional status in high and low caries populations.

4.7 Strength and limitations

The strength of this review was the inclusion of methodological quality assessment by using the Newcastle-Ottawa quality scale to provide information regarding the strength of the included studies [89]. The high-quality studies included data regarding justification of sample size calculation, assessment outcome, and supporting statistical tests with sufficient statistical power, where moderate-quality studies lacked these criteria [22, 25, 38, 41, 44]. The type of study was also a limitation, as majority of the studies included were cross-sectional studies. A cause and effect relationship cannot be determined by a cross-sectional study [52]. A cohort study may be more suitable when establishing relationships between factors [26]. One interventional study compared groups with and without oral hygiene and dietary advice but did not include information regarding caries in different groups of nutritional status such as undernutrition, normal, and overnutrition [27]. Hence, the cause-and-effect relationship between ECC and nutritional status cannot be determined.

Besides that, the confounding factors in the shortlisted studies, such as sociodemographic profiles and socioeconomic factors were not controlled except in one study by Silva *et al.* [43], which involved participation of twins. A longitudinal twin study may have advantages as it removes the bias resulting from confounding factors as twins have similar genetic variation, and this allows adjustment of known and unknown potential shared confounders [43]. Confounders have also been found to modify the outcome of the association between ECC and nutritional status [90]. There was also heterogeneity of the dental and nutritional assessments used. The dental assessments consisted of dmft, deft, dft, dmfs, ICDAS scoring, and photographs of anterior teeth, while nutritional assessments consisted of weight, height, HAZ, WAZ, BAZ, and BMI. Thus, there was a lack of homogeneity among the studies included. These differences and lack of consistency in the studies were the limitations of this review and may influence the analysis of the results. This review also presented the results in a descriptive manner, unlike a systematic review that may be more analytical. Therefore, further well-designed studies are needed with similar sample population and consistent methodology to allow comparability to yield more valid conclusion.

5. Conclusions

Most articles reported an association between ECC and poor nutritional status, while only one study reported an association between ECC and overweight or obese children. A general association between ECC and nutritional status was reported in five articles, while four articles reported no association.

ABBREVIATIONS

ECC: Early Childhood Caries; dmft: decayed, missing, and filled primary teeth; dmfs: decayed, missing, and filled teeth surfaces; deft index: decayed, extracted, or filled primary teeth; dt: decayed teeth; BMI: body mass index; WHO: World Health Organization; WAZ: Weight-for-age z-score; HAZ: Height-for-age z-score; BAZ: BMI-for-age z-score; SD: standard deviation; WHZ: weight-for-height z-score.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

DTL and FY—has designed the research study and performed literature search, data analysis. DTL—wrote the original manuscript. FY—help advice on the write up and critically revised the work. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Human Research Ethics Committee, Centre for Research and Instrumentation Management, UKM. Reference number UKM PPI/111/8/JEP-2021-681.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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