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SYSTEMATIC REVIEW

A systematic review of the association between food insecurity and behaviours related to caries development in adults and children in high-income countries

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Abstract

Objectives: To synthesize and appraise the evidence regarding the relationship between food insecurity and behaviours associated with dental caries development in adults and children in high-income countries.

Methods: A systematic review including observational studies assessing the association between food insecurity and selected dietary (free sugar consumption) and non-dietary factors (tooth brushing frequency; use of fluoridated toothpaste; dental visiting; oral hygiene aids; type of toothbrush used; interdental cleaning frequency and mouthwash use) related to dental caries development in adults and children in high-income countries. Studies specifically looking at food insecurity during the COVID-19 pandemic were excluded. Searches were performed in MEDLINE, Embase, Global Health and Scopus from inception to 25 May 2023. Two authors screened the search results, extracted data and appraised the studies independently and in duplicate. Study quality was assessed using the Newcastle–Ottawa Scale (with modifications for cross-sectional studies). Vote counting and harvest plots provided the basis for evidence synthesis.

Results: Searches identified 880 references, which led to the inclusion of 71 studies with a total of 526 860 participants. The majority were cross-sectional studies, conducted in the USA and reported free sugar consumption. Evidence for the association between food insecurity and free sugar intake from 4 cohort studies and 61 cross-sectional studies including 336 585 participants was equivocal, particularly in the sugar-sweetened beverage (SSB) consumption post-hoc subgroup, where 20 out of 46 studies reported higher SSB consumption in food insecure individuals. There was consistent, but limited, evidence for reduced dental visiting in adults experiencing food insecurity compared to food secure adults from 3 cross-sectional studies including 52 173 participants. The relationship between food insecurity and dental visiting in children was less clear (3 cross-sectional studies, 138 102 participants). A single cross-sectional study of 3275 children reported an association between food insecurity and reported failure to toothbrush the previous day.

Conclusions: This review did not identify clear associations between food insecurity and behaviours commonly implicated in the development of dental caries that would explain why individuals experiencing food insecurity are more likely to have dental caries than those who have food security. There was some evidence of decreased dental visiting in adults experiencing food insecurity. Common methodological weaknesses across the evidence base related to the selection of participants or control of potentially confounding variables. Consequently, the quality of evidence for all outcomes was downgraded to very low. More research is needed to explore access to oral hygiene products and household environments conducive to habitual oral self-care in food insecure populations.

KEYWORDS
adult, child, dental care, dental caries, dental caries susceptibility, food insecurity, high-income countries, humans, income, Oral health, sugar, systematic review, toothbrushing

1 | INTRODUCTION

Food insecurity, the "lack of regular access to enough safe and nutritious food for normal growth and development and an active and healthy life" is a public health problem.[1,2] In 2019, an estimated 750 million people worldwide, or 10% of the global population, were considered to be severely food insecure.[1]

Whilst food insecurity is mostly associated with the developing world, moderate or severe food insecurity also exists in high-income countries. Approximately 8% of the population in North America and northern Europe, around 88 million people, were food insecure in 2017–19.[1] Food security is a dynamic phenomenon, varying within a given month, and across seasons.[3,4] Other short-term shocks, such as changes in employment, conflict, and the COVID-19 pandemic, also influence the likelihood of food insecurity.[5,6]

Higher rates of food insecurity are more prevalent in households of lower socio-economic position and in deprived communities.[7] Households experiencing food insecurity are more likely to include children, single parents, grandparents with grandchildren or a disabled person.[8,9] In general, women are more likely to be affected by moderate or severe food insecurity than men.[1] Food insecurity is also more prevalent among indigenous peoples compared to non-indigenous peoples.[10]

Although household food insecurity is associated with socioeconomic status, around half of food-insecure children live in households with incomes above the poverty line.[11] The construct of food insecurity may therefore enable better understanding of the relationship between poverty and its many impacts, beyond what is described by socioeconomic variables, such as household income and employment status. Furthermore, food insecurity may be a more sensitive measure of acute material deprivation experienced by low-income families, than other measures of deprivation.[12,13]

Food insecurity is linked to a broad spectrum of negative health outcomes, including hypertension, hyperlipidemia, malnutrition, obesity, depression, and diabetes.[14] It also impacts on the ability to manage chronic conditions.[15] Food insecurity also has adverse effects on children's health and wellbeing, including cognitive and socio-emotional development, and school achievement.[1,8,11]

Systematic reviews have identified that food insecurity is associated with increased caries incidence in children and adults, even after adjusting for socioeconomic status.[16–18] Food insecurity is also associated with poorer oral health outcomes in adults, such as dental pain, poorer oral health quality of life, and not having a functional dentition.[19,20] Adults with low food security are also more likely to have unmet dental care needs compared to food-secure peers.[19,21]

The two principal modifiable risk factors for the development of dental caries are diet, consuming too much free sugar too often, and lack of optimal fluoride.[22,23] The dietary quality of food purchased by food insecure households is thought to be lower than that of food secure households, as healthier diets are often associated with higher costs.[24] There is a consistent inverse association between food insecurity and intake of nutrient-rich foods such as fruit and vegetables.[25] Similarly, consumption of energy dense foods such as high-fat dairy products, salty snacks, and sugar-sweetened beverages (SSBs) is reported to be higher among food insecure households.[26,27]

If households are experiencing acute financial pressures they may also be unable to purchase oral hygiene aids. This concept has been described as "hygiene poverty" and may play a role in explaining the association between food insecurity and higher rates of dental caries. Individuals experiencing hygiene poverty may ration how often they brush their teeth.[28] Since daily use of a fluoridated toothpaste has been demonstrated to reduce the incidence of dental caries, the increased risk of caries in food insecure individuals may be due to reduced exposure to fluoride-based oral hygiene regimes.[29]

There is also evidence that individuals experiencing food insecurity are less likely to have visited a dentist in the last 3-years and

more likely to consult only in response to an oral health problem.[19] Since dental consultations represent a key opportunity for the delivery of behaviour support interventions and professionally-applied preventive treatments, lack of access to dental care, or inability to pay for care, may further exacerbate pre-existing oral health inequalities.

There is evidence from Ecuador (an upper-middle income World Bank economy) that the association between household food insecurity and poor child oral health is partially mediated by dietary factors, such as the consumption of fermentable carbohydrates, and also non-dietary factors, like tooth brushing frequency.[30] However, since the food infrastructure, and therefore the likely sociocultural implications of food insecurity may differ between countries, it is unclear whether the same factors mediate the relationship between food insecurity and oral health in high-income economies. Previous systematic reviews examining the association between food insecurity and dental caries have not fully examined the evidence for the potential mediators of this relationship. The purpose of this systematic review is therefore to appraise and synthesize the current evidence regarding the association between food insecurity and behaviours associated with the development of dental caries in high-income countries. The aim is to clarify the likely associations between food insecurity and selected dietary and non-dietary behaviours implicated in the development of dental caries, in order to identify potential targets for oral health improvement interventions and make recommendations for further research.

2 | METHODS

2.1 | Research question and development of the review protocol

What are the associations between food insecurity and behaviours associated with the development of dental caries in adults and children in high-income countries?

The protocol for this review was registered with PROSPERO (CRD42022382362) prior to searches. The systematic review was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Data S1).[31]

2.2 | Information sources

Searches were performed in MEDLINE, Embase, Global Health and Scopus from inception to 25th May 2023 (Data S1 for search strategies). There were no restrictions on the year of publication or language. The reference lists of all included studies were checked to identify any further sources. If potentially eligible studies were not accessible via electronic databases, authors were contacted.

2.3 | Eligibility criteria and study selection

Two reviewers independently assessed the titles and abstracts (where available) of the references identified by the search strategy and made decisions regarding eligibility. Full-text versions of all articles being considered for inclusion were obtained, as were those with insufficient information in the title or abstract to make a clear decision. Any disagreements were resolved by discussion. Full-text studies found not to meet the inclusion criteria were recorded together with a reason.

Studies eligible for inclusion were observational studies (cross-sectional, cohort and case–control) from commercially published and grey literature sources. Systematic reviews were not included but their reference lists were screened for primary studies. Ecological studies were excluded. Studies specifically looking at food insecurity during the COVID-19 pandemic were also excluded.

Participants were adults or children in World Bank high-income countries.[32]

Studies were included if they reported a measure of individual or household food security (exposure) and at least one behaviour relating to the development of dental caries (outcome). The primary outcome measures were: free sugar consumption (defined as 'all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and unsweetened fruit juices[33]'); toothbrushing frequency; use of fluoridated toothpaste; and dental visiting. Secondary outcome measures were: access to oral hygiene aids; type of toothbrush used; interdental cleaning frequency and mouthwash use. More detailed inclusion criteria are given in Data S1.

2.4 | Data extraction

Two reviewers independently extracted the data from the included studies using a piloted Microsoft Form (available on request from authors). A full list of the data points extracted is in Data S1. The reviewers discussed the results and resolved any disagreements by discussion. Study authors were not contacted to provide further information.

2.5 | Quality appraisal

The methodological quality of the included studies was independently assessed by the two reviewers using the Newcastle–Ottawa Scale (NOS) for assessing the quality of cohort and case-controlled studies,[34] and an adapted NOS for cross-sectional studies.[35] The NOS assessed the methodological quality of the study in three categories: selection of the study groups (maximum four stars for cohort/case-controlled studies or five stars for cross-sectional studies), the

comparability of the groups (maximum two stars) and the ascertainment exposure criteria (maximum three stars).

The quality of evidence for each outcome was rated using the evidence grading system developed by the GRADE collaboration.[36] One author (ALC) applied the GRADE system and discussed the quality of the evidence ratings with the second author (IGC). The final decision was reached via discussion and consensus. Since the review only include observational studies, evidence was downgraded from low quality if there were serious limitations in relation to risk of bias, inconsistency of results, indirectness of evidence, imprecision of results or evidence of publication bias. Similarly, evidence could be upgraded by one or two levels if there was a large magnitude of effect with no plausible confounders; a dose–response gradient, or if all plausible residual confounding would further support inferences regarding treatment effect.

2.6 | Data synthesis

Evidence was organized by study design, population and grouped according to outcome measures.

Data for children and adults were separated since there is evidence that children are often shielded from the full effects of food insecurity.[37] In cases where studies reported outcomes for a heterogeneous population of children and adults, the mean age of participants determined how the study was grouped.

Due to the large number of studies reporting outcomes related to free sugar consumption these were assigned to four post-hoc subgroups: total free sugars; SSBs; fruit juice and foods high in free sugars (Data S1). No sensitivity analyses were undertaken.

Due to methodological heterogeneity between studies, it was not appropriate to synthesize data using meta-analysis. This was primarily because of disparity in the measurement and reporting of outcomes. Evidence synthesis was instead conducted using a vote counting method that is suited to data from a heterogeneous group of studies and used previously in a systematic review of sugar intake and dental caries development.[23,38] The vote counting approach weighed the evidence (number of studies) showing a positive relationship between exposure and outcome against those showing a null and negative association. In studies reporting multiple eligible measures of association for a single outcome, all of these were assessed.

Data were formulated into harvest plots to summarize study characteristics, including study type, population, quality, and the weight of evidence (number of studies showing positive, partly positive, no, partly negative or negative direction of effect) in relation to specific outcomes.[39] This approach was supplemented with a narrative synthesis of findings.

3 | RESULTS

3.1 | Results of the search

After de-duplication, the electronic searches yielded 813 references. A further 67 references were identified from the reference lists of selected studies. After examination of the titles, and abstracts (where available), 704 references were excluded from further analysis. Full-text copies of the remaining 185 references were obtained. At this stage a further 112 were excluded, leaving 73 reports relating to 71 studies for data extraction and analysis (Figure 1).

3.2 | Included studies

In total, 4 cohort studies and 67 cross-sectional studies were included and provided evidence for the relationship between food insecurity and behaviours related to caries development (Table 1). The majority of the studies were conducted in the USA ($n=52$) with the remainder from Canada ($n=7$), United Kingdom ($n=3$), South Korea ($n=2$), Taiwan ($n=2$), Trinidad and Tobago ($n=2$), Australia ($n=1$), France ($n=1$) and New Zealand ($n=1$). The data in the included studies were collected between 1988 and 2021. References cited are for the first publication from the study. A list of references from each study is provided in Data S1.

Thirty-three studies related to adults only, of which nine solely included higher education students. Twenty-six studies provided evidence relating to children only. The remaining 12 studies reported outcomes for adults and children (either separately or combined), commonly recruited as parent–child dyads.

The majority of included studies ($n=47$) used a validated tool to measure food insecurity, most commonly the United States Department of Agriculture (USDA) US Household Food Security Survey Module (6-, 10- or 18-item versions) ($n=37$),[40] or the 2-item Hunger Vital Sign™ ($n=7$).[41] The remaining studies used non-validated tools, often modifications of previously validated tools.

Sixty-five studies provided evidence relating to the relationship between food insecurity and free sugar consumption. Of these, 23 reported outcomes relating to total free sugar consumption; 46 SSB consumption; 22 fruit juice consumption and 19 high sugar foods intake (this is not equal to 65 as some studies reported more than one outcome relating to free sugar). Of the remaining three primary outcomes, six studies provided evidence relating to dental visiting, one study provided evidence on toothbrushing and there were no studies identified which provided evidence of the relationship between food insecurity and fluoridated toothpaste use. None of the included studies provided evidence for the secondary outcomes.

3.3 | Evidence for the association between food insecurity and free sugar consumption

In total four cohort studies and 61 cross-sectional studies provided evidence of the relationship between food insecurity and free sugar consumption. These included a total of 336 585 participants. A total of 49 studies were conducted in the USA and 16 elsewhere in the world (Canada ($n=5$), UK ($n=3$), South Korea ($n=2$), Taiwan ($n=2$), Trinidad and Tobago ($n=2$), Australia ($n=1$) and France ($n=1$)). Data

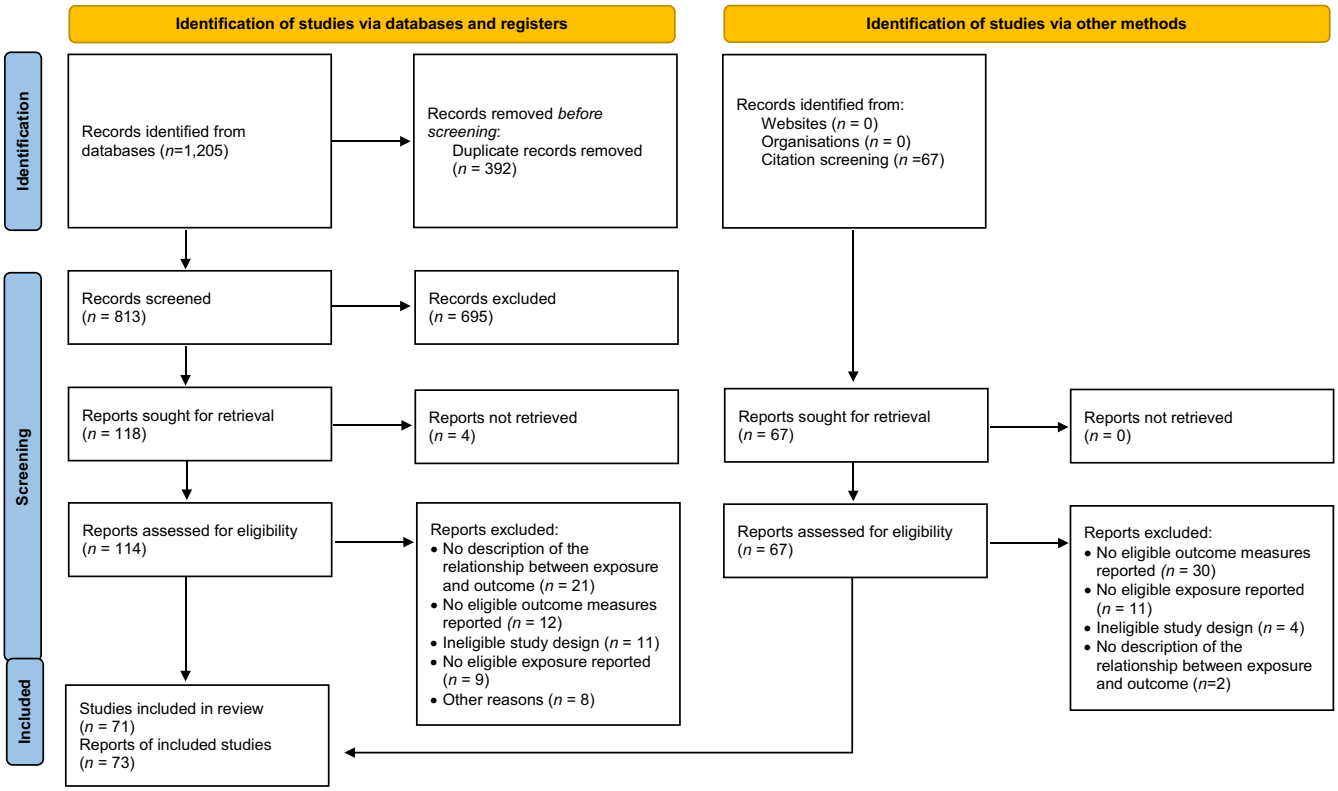

FIGURE 1 PRISMA flow diagram.

were collected between 1988 and 2021. A total of 34 studies reported outcomes related to children and 38 studies reported outcomes related to adults.

The majority ($n=18$) of studies related to children reported no association between food insecurity and free sugar consumption. However, a sizeable minority ($n=16$) reported some degree of higher free sugar consumption in food insecure children (Figure 2A). Similarly in adults, the majority of studies ($n=21$), reported no association between food insecurity and free sugar consumption. Again however, a minority of studies ($n=16$) reported higher free sugar consumption in food insecure adults (Figure 2B).

Many of the studies reporting free sugar consumption had methodological weaknesses, most commonly relating to the selection of participants in a way that minimized selection bias ($n=33$ studies scored ≤2 stars in this domain) or failure to adequately control for potential confounders ($n=20$ scored ≤1 star in this domain). Since over half studies were assessed as at risk of bias, the body of evidence was downgraded to very low quality.

3.4 | Total free sugar consumption

Twenty cross-sectional studies and three cohort studies provided evidence of the relationship between food insecurity and total free sugar consumption. This was most commonly reported as added sugar consumption (a component of free sugars). Data were collected between 1996 and 2020. Thirteen studies reported outcomes for adults and eleven studies reported outcomes relating to children.

The majority of studies reported no association between food insecurity and total added sugar consumption in children (Figure 2C) and adults (Figure 2D). However, there were a minority of studies for both populations which reported a positive association between food insecurity and total added sugar consumption in some or all outcomes.

3.5 | Sugar-sweetened beverage consumption

Forty three cross-sectional studies and three cohort studies provided evidence of the relationship between food insecurity and SSB consumption. Data were collected between 1999 and 2021. Twenty-nine studies reported outcomes relating to adults and twenty-five for children.

For both adults and children there were roughly equal numbers of studies reporting higher SSB consumption associated with food insecurity and studies reporting no association (Figure 2E,F).

3.6 | Fruit juice consumption

Twenty cross-sectional studies and two cohort studies provided evidence of the relationship between food insecurity and fruit juice consumption. Data were collected between 1993 and 2019.

TABLE 1 Summary of included studies.

First author; year	Country	Year(s) of data collection	*n*	Population (description)	Setting	Measurement of food insecurity (validation status)
Cohort studies						
Bruening 2018	USA	2015–2016	1138 (baseline)	Adults (higher education students)	College freshmen, Arizona	USDA 6-item tool (v)
Larson 2020	USA	2009–10 and 2017–18	1568	Young adults	Urban public high schools, Minnesota	USDA 6-item tool modified (nv)
Wu 2019	Taiwan	2009, 2011, 2013	1326	Children (economically disadvantaged)	Taiwan Fund for Children and Families	4-item tool (nv)
Yang 2018	UK	2008–2012	1102 children; 962 adults	Children and adults	Hospital, Bradford	USDA 18-item tool (v)
Cross-sectional studies						
Acciai 2021	USA	2009–2010 and 2015–2016	4772	Children (0–19 years)[c]	NHANES	USDA 18-item tool (v)
Ahmadi 2014	Canada	2012	950	Children (5th–8th grade)	Vancouver public schools	5-item tool (nv)
Au 2019	USA	2013–2015	5138	Children (Health Communities Study communities)	Health Communities Study communities	HVS (v)
Bauer 2012	USA	2005 and 2006	432	Children (Native Americans)	American Indian reservations	USDA 6-item tool (v)
Bhargava 2007	USA	1996–1997	913 households	Households (food stamp participants)[d]	National sample of food stamp participants	5-item tool (nv)
Bhaumik 2023	USA	2011–2017	842 children; 842 adults	Children (2 years) and adults (mother–child dyads)	Pregnant white women, northern Appalachian region	HVS (nv)
Bleich 2013	USA	2003–2010	17 198	Adults	NHANES	USDA 18-item tool (v)
Bocquier 2015	France	2005 and 2007	1918	Adults	Individual and National Dietary Survey (INCA2)	US Department of Agriculture's Food Sufficiency Indicator (nv)
Bruening 2012	USA	2009–2010	2095	Adults (parents of adolescents)	Public housing sites, Arizona	USDA 6-item tool (v)
Bruening 2017	USA	2014	55 children; 55 adults	Children and adults (adult–child dyads)	Project F-EAT (Families and Eating and Activity Among Teens), Minnesota	USDA 6-item tool (v)
Calloway 2016	USA	2014–2015	1268 children; 1402 adults	Children (12–17 years) and adults (adult-child dyads)	Family Life, Activity, Sun, Health, and Eating (FLASHE) study	HVS (v)
Casey 2001	USA	1994–1996	5669	Children (0–17 years)	Continuing Survey of Food Intakes	1-item tool (nv)
Chaparro 2007	USA	2006	395	Adults (higher education students)	Families who received WIC benefits, California	USDA 10/18-item (v)
Chaparro 2022	USA	2014 and 2017	9929	Children (<5 years in receipt of WIC benefits)	Non-freshman students, Hawai'i	USDA 6-item tool (v)
Cheng 2022	USA	2016–2017	858	Adults (pregnant women)	Community health centres, Massachusetts	HVS (v)
Cunningham 2012	USA	2006–2008	1522	Children (2 years)	Oregon Pregnancy Risk Assessment Monitoring System follow-back survey (Oregon PRAMS-2)	1-item tool (nv)
Dave 2009	USA	2006/7	184	Children (1st–5th grade)	Elementary schools, Texas	2-item tool (v)

Prevalence of exposure in population	Comparisons	Outcome measurement tool (s)	Summary of findings[a]	Quality appraisal score (maximum)		
				Selection (4/5[b])	Comparability (2)	Outcome (3)
28%–36%	Free sugar (total; SSBs)	NCI DSQ	0 (total); 0 (SSBs)	***	**	*
23.3%	Free sugar (SSBs; juice)	FFQs	+ (SSBs); 0 (juice)	**	**	**
69.90%	Free sugar (total; SSBs)	1-week FFQ	+ (total); 0 (SSBs)	**	**	*
9%	Free sugar (SSBs; juice; HSFs)	FFQs	0/+ (SSBs, children); 0 (SSBs, adults); 0 (juice, children); 0 (juice, adults); 0 (HSF, children); 0 (HSF, adults)	***	*	**
43.9%	Free sugar (SSBs)	1–2×24-h recall (AMPM)	0	***	**	**
15·8%	Free sugar (SSBs)	30-day FFQ	0	***	*	**
44.6%	Free sugar (total; SSBs)	NCI DSQ	0 (total); + (SSBs)	****	**	**
40%	Free sugar (SSBs)	1-month FFQ	0	****	–	**
28.4%	Free sugar (total)	1-week food use record; 2× computer-assisted personal interview	0	*	**	**
14.1%	Free sugar (SSBs; juice; HSFs)	1-week FFQ	+ (SSBs, children); + (SSBs, adults); 0 (juice, children); 0 (juice, adults)+(HSF, children); 0 (HSF, adults)	***	**	**
11%	Free sugar (SSBs)	1-2×24-h recall (AMPM)	+	***	**	*
12.2%	Free sugar (total)	7-day food record	+	**	–	*
38.9%	Free sugar (SSBs; juice)	Parent-completed survey on eating patterns and home food environment	+ (SSB); 0 (juice)	**	*	**
64.5 (mothers); 43.6% (adolescents)	Free sugar (SSBs)	1-week FFQ	0 (children and adults)	**	–	**
37%	Free sugar (SSBs; HSFs)	Online dietary screener	+ (SSBs, children); 0 (SSBs, adults); 0 (HSF, children); 0 (HSF, adults)	***	**	**
2.2%	Free sugar (total)	24-h dietary recall (AMPM)	+	**	–	**
21%	Free sugar (HSFs)	Self-completion questionnaire on dietary intake	+	****	–	*
27.4%	Free sugar (SSBs; juice; HSFs)	Computer assisted telephone interviewing system	+ (SSBs); + (juice); + (HSF)	***	**	**
21%	Free sugar (SSBs)	Self-completion questionnaire	0	***	**	**
11.7%	Free sugar (SSBs; juice; HSFs)	Mailed/telephone surveys	+ (SSBs); 0 (juice); 0 (HSF)	**	**	**
33.2%	Free sugar (juice)	Self-completion questionnaire	0	**	–	**

(Continues)

TABLE 1 (Continued)

First author; year	Country	Year(s) of data collection	*n*	Population (description)	Setting	Measurement of food insecurity (validation status)
Davy 2015	USA	Not stated	930	Adults (rural dwelling)	Rural Dan River Region, Virginia	USDA 6-item tool (v)
Dixon 2001	USA	1988–1994	10165	Adults	NHANES	1-item tool (nv)
Drieling 2014	USA	2009–2010	207	Adults (at risk of CHD)	Community health clinic, California	USDA 6-item tool (v)
Duke 2018	USA	2016	126868	Children (8th–11th grade)	Public schools, Minnesota	1-item tool (nv)
Duke 2021	USA	2019	125375	Children (8th–11th grade)	Public schools, Minnesota	1-item tool (nv)
Eicher-Miller 2020	USA	2007–2008, 2009–2010, 2011–2012, and 2013–2014	8123	Children (6–17 years)	NHANES	USDA 18-item tool (v)
El Zein 2020	USA	2017	683	Adults (higher education students)	Universities	USDA 10-item tool (v)
Farahbakhsh 2017	Canada	2013–2014	58	Adults (higher education students)	Campus Food Bank, Alberta	USDA 10-item tool (v)
Fernández 2020	USA	2017	394 mothers; 281 infants	Children (<5 years) and adults (mother–child dyads in receipt of WIC benefits)	First 1000 Days Study, New York	HVS (v)
Gamba 2019	USA	1999–2006	1154	Adults (pregnant women)	NHANES	USDA 18-item tool (v)
Giannoni 2022	Canada	2013–2014	51079	Adults	CCHS	USDA 18-item tool (nv)
Gross 2012	USA	2009–2010	75	Children (4–6 months WIC)	Urban medical center, New York	2-item tool (nv)
Gulliford 2003	Trinidad and Tobago	Not stated	531	Adults	Households, north central Trinidad	USDA 6-item tool (v)
Gulliford 2005	Trinidad and Tobago	Not stated	1903	Children	Secondary schools, Trinidad	USDA 6-item tool (v)
Huet 2012	Canada	2007–2008	1901	Adults (Inuit)	Inuvialuit Settlement Region, Nunavut, and Nunatsiavut	USDA 18-item tool modified (nv)
Jackson 2015	USA	2014	95	Children (rural dwelling)	Generating Rural Options for Weight (GROW) Healthy Kids and Communities, Oregon	HVS (v)
Jain 2022	USA	2019–2020	320	Adults (SNAP participants)	Food pantry, Texas	USDA 10-item tool (v)
Jamieson 2006	New Zealand	2002	3275	Children (5–14 years)	National Children's Nutrition Survey (CNS02)	8-item tool (nv)
Kendall 1996	USA	1993	193	Adults (women 20–39 years)	Health Census, New York	Radimer–Cornell scale (v)
Kent 2022	Australia	2021	48	Young adults (15–25 years)[f]	Youth mental health service, Tasmania	1-item tool (nv)
Kim 2015	South Korea	2012	7118	Adults	KNHANES	USDA 18-item (v)
Lee 2019	USA	2011–2012 and 2014–2017	218	Children (high BMI)	Communities, Minnesota	USDA 6-item (v)
Leung 2014	USA	1999–2008	8129	Adults (low income)	University of Michigan	USDA 18-item (v)
Leung 2019	USA	2018	754	Adults (higher education students)	NHANES	USDA 10-item (v)
Liu 2020	USA	1999–2000 to 2015–2016	27906	Children and adults (2–19 years)[e]	NHANES	USDA 18-item tool (v)
Lunan 2020	USA	2019	222	Adults (higher education students)	Appalachia State University	USDA 10-item tool modified (nv)

Prevalence of exposure in population	Comparisons	Outcome measurement tool (s)	Summary of findings[a]	Quality appraisal score (maximum)		
				Selection (4/5[b])	Comparability (2)	Outcome (3)
36%	Free sugar (SSBs)	BEVQ-15	+	***	**	**
7.2% (younger adults); 3.6% (older adults)	Free sugar (HSFs)	24-h dietary recall; 1-month FFQ	0/+	**	**	**
51.2%	Free sugar (SSBs)	Block FFQ	0	**	**	**
4.6%	Dental visiting	Self-completion questionnaires	–	***	**	**
4.5%	Free sugar (SSBs)	Online self-complete questionnaire	+	**	**	**
10%	Free sugar (total; SSBs; HSFs)	24-h dietary recall (AMPM)	0 (total); + (SSBs); 0/– (HSF)	***	–	*
25.4%	Free sugar (total; SSBs)	NCI DSQ	+ (total); + (SSBs)	**	–	**
89.60%	Free sugar (total)	NCI DSQ	0	**	–	**
63% (mothers); 29% (pregnant women)	Free sugar (SSBs)	BEVQ-15	+ (children); + (adults)	***	*	**
10.7%	Free sugar (SSBs)	1–2 × 24-h dietary recalls (AMPM)	0	***	–	**
6%	Dental visiting	CCHS annual component	–	**	**	**
35%	Free sugar (juice)	Questionnaire	0	**	*	**
25%	Free sugar (HSFs)	FFQ	0	***	*	**
22%	Free sugar (HSFs)	FFQ	0/+	***	*	**
62.6%	Free sugar (SSBs; HSF)	24-h dietary recall; FFQ	0 (SSBs); + (HSFs)	**	*	**
28.0%	Free sugar (total)	BKFS	0	***	*	**
38.40%	Free sugar (total)	NCI DSQ	0	**	**	**
15.2%–44.9% depending on question	Toothbrushing; dental visiting	Multiple-pass 24-h dietary recall; FFQ	(toothbrushing); 0/– (dental visiting)	****	–	*
25%	Free sugar (juice)	24-h recall	0	****	–	**
40%	Free sugar (SSBs)	Self-completion online questionnaire	0	*	–	**
11.3%	Free sugar (SSBs; juice)	Dietician-administered interview	• (SSBs); – (juice)	***	*	**
25%	Free sugar (SSBs; juice)	Multiple-pass 24-h dietary recall	0/+ (SSBs); 0 (juice)	**	*	**
39.1%	Free sugar (SSBs; juice; HSFs)	1-2 × 24-h recall (AMPM)	+ (SSBs); 0 (juice); – (HSFs)	***	**	**
31.1%	Free sugar (total; SSBs)	NCI DSQ	0/+ (total); 0/+ (SSBs)	***	**	**
37.8%	Free sugar (total; SSBs; juice)	1-2 × 24-h recall (AMPM)	0 (total); 0/– (SSBs); 0 (juice)	****	–	**
46.3%	Free sugar (HSFs)	Self-completion online questionnaire	0	**	–	*

(Continues)

TABLE 1 (Continued)

First author; year	Country	Year(s) of data collection	*n*	Population (description)	Setting	Measurement of food insecurity (validation status)
Mark 2012	Canada	2004	2280	Children (9–18 years)	CCHS	USDA 18-item tool (nv)
Marmash 2021	USA	Not stated	83	Adults (food pantry clients)	Food pantry, Connecticut	USDA 18-item tool (v)
Marshall 2021	USA	2017 and 2019	627	Children	Public schools, District of Columbia and Tennessee	HVS (v)
McArthur 2018	USA	2017	456	Adults (higher education students)	University, North Carolina	USDA 10-item tool (v)
Mei 2021	USA	2018	1033	Adults (higher education students)	University of Michigan	USDA 6-item tool (v)
Muirhead 2009	Canada	2007	843	Adults (working poor)	Telephone survey	3-item tool (nv)
Oh 2003	South Korea	2001	370	Children (community welfare centre users)	Community welfare centers, Seoul	Radimer-Cornell scale modified (nv)
Peltz 2019	USA	2016	7959	Children	Medical Expenditure Panel Survey	USDA 10-item tool (v)
Pilgrim 2012	UK	2002–2006	1618	Children (3 years)	Southampton Women's Survey	USDA 6-item tool modified (nv)
Rosas 2009	USA	2005–2006	301	Children	Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) longitudinal birth cohort study	USDA 6-item tool (v)
Rossen 2015	USA	2007–2010	5136	Children (2–15 years)	NHANES	USDA 18-item tool (subscale) (v)
Ryan 2022	USA	2019–2020	257	Adults (higher education students)	Private urban university, New York	USDA 6-item tool (v)
Sharkey 2011	USA	2006	1878	Adults	Communities, Texas	1-item tool (nv)
Sharkey 2012	USA	2010	50	Children (highly deprived)	Texas Border Colonias	Radimer–Cornell scale modified (nv)
Soldavini 2021	USA	2012	11 873	Children (3–17 years)	US Department of Agriculture Summer Electronic Benefit Transfer for Children Demonstration Project	USDA 18-item tool (v)
Spees 2017	USA	2012–2013	251	Adults (food pantry clients)	Food pantries, Ohio	USDA 6-item tool (v)
Spiker 2016	USA	2009–2012	276 children; 276 adults	Children and adults (mother–child dyads)	Health clinics, Maryland	USDA 6-item tool (v)
Taylor 2017	USA	2005–2012	20 363	Adults	NHANES	USDA 18-item tool (v)
Tingay 2003	UK	Not stated	431	Adults	General practices, London	USDA 6-item tool (v)
Tomayako 2017	USA	2013–2015	450 children; 450 adults	Children and adults (Native American parent–child dyads)	Healthy Children, Strong Families	HVS (v)
Trapp 2015	USA	2010–2011	222	Children (low family income)	Primary-care–based obesity prevention/reversal study	USDA 18-item tool (v)

Prevalence of exposure in population	Comparisons	Outcome measurement tool (s)	Summary of findings[a]	Quality appraisal score (maximum)		
				Selection (4/5[b])	Comparability (2)	Outcome (3)
20.3%	Free sugar (SSBs)	24-h dietary recall	0/+	**	*	**
69.8%	Free sugar (total; SSBs)	NCI DSQ	0 (total); 0 (HSFs)	**	**	**
19.9%	Free sugar (SSBs; juice)	Self-completion beverage frequency questionnaire	0 (SSBs); 0 (juice)	***	–	**
21.5%	Free sugar (HSFs)	Self-completion online questionnaire	0	***	–	**
14%	Free sugar (total; SSBs; juice)	NCI DSQ	+ (total); + (SSBs); 0 (juice)	*	*	**
24%	Dental visiting	Computer-assisted telephone interview	–	***	*	**
62.7%	Free sugar (SSBs; juice; HSFs)	1-month FFQ	0 (SSBs); 0/– (HSFs); + (juice)	*	**	*
13%	Dental visiting	Self-reported health care use data supplemented with information collected a sample of health care providers	0	***	**	**
4.6%	Free sugar (total; SSBs; juice; HSFs)	3-month FFQ	+ (total); + (SSBs); 0 (juice); 0 (HSFs)	**	–	**
39%	Free sugar (SSBs)	Harvard FFQ for Hispanic children	0	**	**	**
16%	Free sugar (total; juice)	1-2×24-h recall (AMPM)	0 (total); 0 (juice)	***	**	**
41%	Free sugar (SSBs)	Self-completion online questionnaire	+	***	**	**
23.7% (rural); 17.2% (urban)	Free sugar (SSBs)	Self-completion mailed surveys	+	***	*	**
64%	Free sugar (total)	24-h dietary recall	+	**	*	**
64%	Free sugar (total; SSBs)	NCI DSQ	0 (total); 0 (SSBs)	****	**	**
73%	Dental visiting	Student-administered questionnaire	–	**	–	*
28%	Free sugar (total; SSBs; juice)	24-h dietary recall (AMPM)	0 (total, children); 0 (total, adults); 0 (SSBs, children); 0 (SSBs, adults); 0 (juice, children); 0 (juice, adults)	**	**	**
17.9%	Free sugar (total; SSBs; juice; HSFs)	2×24-h recall (AMPM)	0 (total); + (SSBs); 0 (juice); 0/– (HSF)	***	*	**
20%	Free sugar (HSFs)	FFQ	0	**	*	**
61%	Free sugar (SSBs; juice)	DSQs	0/+ (SSBs, children); 0/– (SSBs, adults); 0 (juice, children); + (juice, adults)	**	–	**
25%	Free sugar (SSBs)	CDQ	0	**	*	*

(Continues)

TABLE 1 (Continued)

First author; year	Country	Year(s) of data collection	*n*	Population (description)	Setting	Measurement of food insecurity (validation status)
Warren 2022	Canada	2015	19 742	Children and adults	CCHS	USDA 18-item modified (nv)
Yeh 2021	Taiwan	2020	1649	Children (7–15 years)	Boyo Social Welfare Foundation	5-item tool (v)
Zizza 2008	USA	1999–2002	5640	Adults	NHANES	USDA 18-item tool (v)

Abbreviations: AMPM, automated multiple-pass method; BEVQ-15, beverage intake questionnaire 15; BKFS, block kids food screener; BMI, body mass index; CCHS, Canadian Community Health Survey; CHD, coronary heart disease; FFQ, food frequency questionnaire; HSFs, high-sugar foods; HVS, Hunger Vital Sign™ (Hager 2010); KNHANES, Korea National Health and Nutrition Examination Survey; NHANES, National Health and Nutrition Examination Survey; nv, not validated; SNAP, Supplemental Nutrition Assistance Program; SSBs, sugar sweetened beverages; USDA, United States Department of Agriculture; v, validated; WIC, Special Supplemental Nutrition Programme for Women, Infants and Children.

[a]Indicates a negative association; 0/− indicates some outcomes reported a negative association, some no association; 0 indicates no association; 0/+ indicates some outcomes reported a positive association, some no association; + indicates a positive association.

[b]Four for cohort and case-controlled studies, Five for cross-sectional studies.

[c]Approximately two-thirds (63.7%) of participants were aged ≤11 years of age so study is grouped with children.

[d]Children (<18 years of age) constituted only 20% of household members so study is grouped with adults.

[e]Mean age of participants was 10.6 years of age so study is grouped with children.

[f]Approximately two thirds (65.1%) of participants were aged 18–25 so study is grouped with adults.

Thirteen studies reported outcomes relating to adults and thirteen for children.

For both adults and children the balance of evidence was in favour of no association between food security status and fruit juice consumption (Figure 2G,H).

3.7 | High sugar food consumption

Eighteen cross-sectional studies and one cohort study provided evidence of the relationship between food insecurity and high sugar foods. Data were collected between 1988 and 2019. Eleven studies reported outcomes relating to adults and seven for children.

The majority of studies in both adults and children reported no association between food insecurity and high sugar foods (Figure 2I,J).

3.8 | Evidence for the association between food insecurity and toothbrushing

One cross-sectional study provided evidence for the association between food insecurity and toothbrushing. This was conducted in 2002 in New Zealand and included 3275 children.[42]

Authors reported a significant relationship between food security factors (as measured via a non-validated tool) and reported failure to brush the previous day.

This study was judged to be at risk of bias as this analysis did not control for potential confounding variables. The body of evidence was downgraded to very low quality due to risk of bias.

3.9 | Evidence for the association between food insecurity and dental visiting

Six cross-sectional studies provided evidence for the relationship between food insecurity and dental visiting. These were conducted between 2002 and 2016 in the USA ($n=3$), Canada ($n=2$) and New Zealand ($n=1$). Three studies included children and three included adults. In total 192 275 participants were included in these studies.

All studies in adults (52 173 participants) reported lower frequency of dental visiting in food insecure participants. Adults with food insecurity were also more likely to visit the dentist only in response to an oral health problem. The picture was more heterogeneous in children (Figure 3A,B).

Several of the studies which provided evidence for this association used a non-validated tool to assess food insecurity ($n=4$) or did not control for potential confounding variables ($n=4$). The body of evidence was downgraded to very low quality due to risk of bias.

4 | DISCUSSION

4.1 | Summary of the principal findings

This review builds upon previous research which has demonstrated the association between food insecurity and dental caries.[16–18,20] This aim was to synthesize and appraise the available evidence to clarify the associations between food insecurity and selected dietary and non-dietary behaviours implicated in the development of dental caries in order to identify potential targets for oral health

Prevalence of exposure in population	Comparisons	Outcome measurement tool (s)	Summary of findings[a]	Quality appraisal score (maximum)		
				Selection (4/5[b])	Comparability (2)	Outcome (3)
12.4%–12.9% children); 8.4%–10.3% (adults)	Free sugar (SSBs; juice)	24-h dietary recall	0 (SSBs, children); 0/+ (SSBs, adults); 0 (juice, children); 0/− (juice, adults)	**	–	*
52.2%	Free sugar (SSBs)	Simple FFQ	0/+	***	*	**
14.8%	Free sugar (total)	24-h dietary recall method	+	***	–	*

improvement interventions and make recommendations for further research.

The search identified 71 eligible observational studies, most of which provided evidence about the relationship between food security status and free sugar consumption. Whilst the majority of these reported no association with food insecurity, there was a sizeable minority which reported higher free sugar consumption in the food insecure. This relationship was true for both children and adults. A subgroup analysis of SSB consumption found approximately equal number of studies reporting higher SSB consumption in individuals reporting food insecurity to those reporting no association. There was also consistent, albeit limited, evidence for reduced dental visiting in adults experiencing food insecurity. The relationship between food insecurity and dental visiting in children was less clear. A single study reported an association between food insecurity and reported failure to toothbrush the previous day in children. No other studies assessing the relationship between food security status and access to or use of oral hygiene aids were identified. Most of the included studies in the review had methodological weaknesses regarding the selection and recruitment of participants, method of exposure ascertainment or measurement and control of potential confounding factors.

4.2 | Strengths and weaknesses of the review

The review employed a comprehensive search strategy across multiple electronic databases. This would have ensured that the majority of eligible studies in the scientific literature were identified. However, only one database containing grey literature was searched (SCOPUS) and, given the current prominence of food insecurity, it is therefore possible that not all potential sources of evidence were identified. Furthermore, no unpublished evidence (either unpublished studies or unpublished data from the included studies) was sought.

When assessing references for eligibility, studies that did not report eligible outcomes were excluded and authors were not contacted. This may have excluded studies which measured, but did not report, eligible outcomes. For example, several excluded studies reported compliance with the sugar domain of the Healthy Eating Index, a measure of diet quality used to assess how well a set of foods aligns with key recommendations and dietary patterns published in the Dietary Guidelines for Americans.[43] Since such outcomes did not meet the inclusion criteria, these studies may have been excluded despite the fact authors may have originally recorded, but not reported, free sugar intake in a form that would have been suitable for inclusion.

In order to be eligible for inclusion, studies had to measure current food security status. However, the impact of food insecurity has been demonstrated to be cumulative over the lifecourse.[44] Children of parents who experienced food insecurity during their own childhood typically consume more SSBs and sweets than the children of parents who grew up in deprived households but did not report food insecurity.[45] It is therefore important that future studies consider not only current experiences of food insecurity but the contextual history of food availability within a family, household or community. This should be assessed in terms of when this was experienced, for how long and the severity of the food insecurity.

This review employed vote counting in the evidence synthesis due to the heterogeneity of included studies. This enabled the weighting between the body of evidence showing a positive association between the exposure (food insecurity) and selected outcome with that showing no association. However vote counting provides no information on the magnitude of effects and does not account

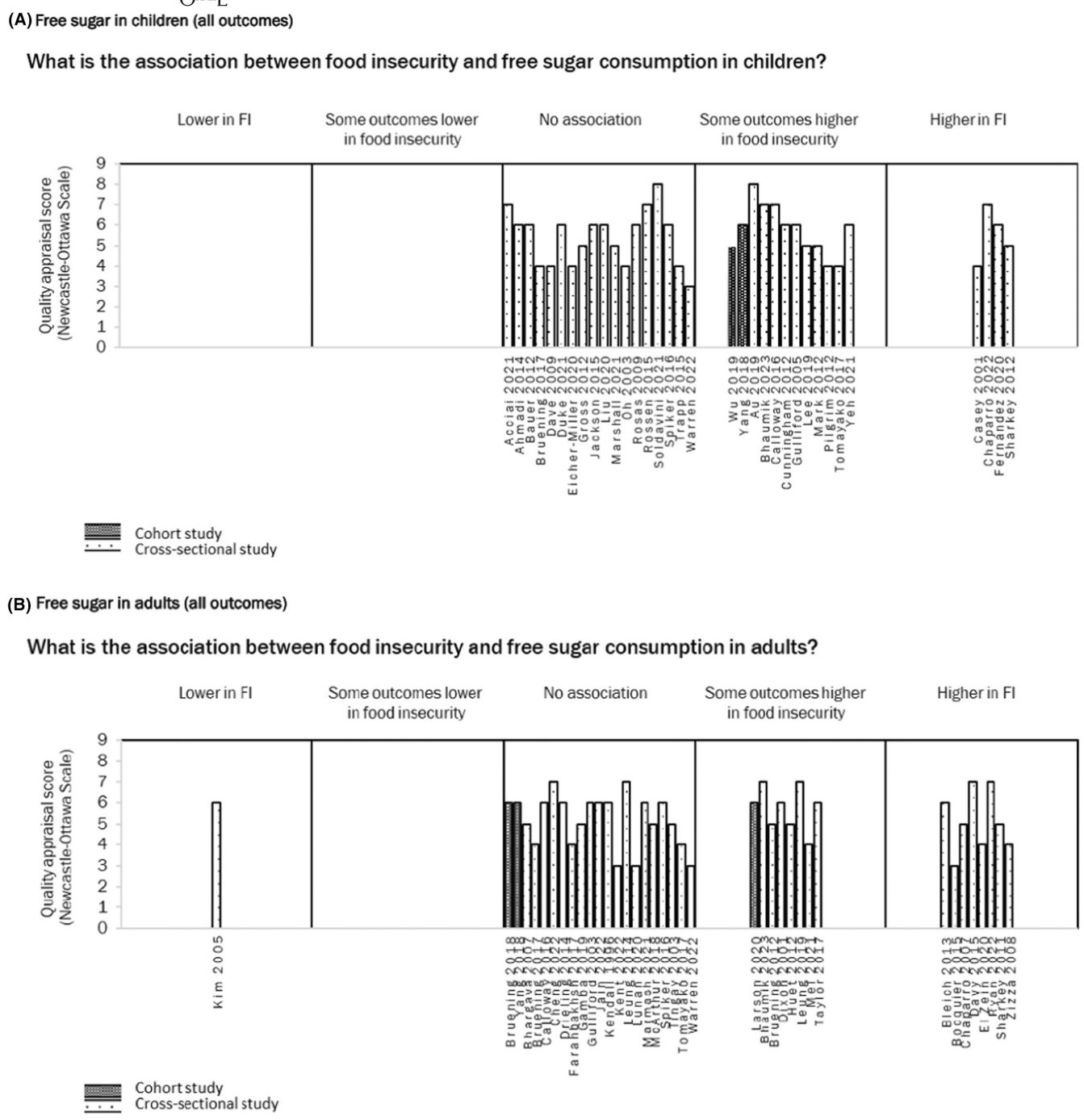

FIGURE 2 Harvest plots showing the evidence for the association between food insecurity and free sugar consumption in adults and children. (A) free sugar in children (all outcomes); (B) free sugar in adults (all outcomes); (C) total free sugar in children; (D) total free sugar in adults; (E) SSBs in children; (F) SSBs in adults; (G) fruit juice in children; (H) fruit juice in adults; (I) high sugar foods in children; (J) high sugar foods in adults.

for differences in the relative sizes of the studies.[46] These limitations should be considered when interpreting the findings of this review.

4.3 | Applicability and quality of included studies

The vast majority of the evidence in this review related to the relationship between food insecurity and free sugar consumption. Despite this, there was a high degree of heterogeneity in how free sugar was expressed. Volume, frequency and calorie-based measures for quantifying sugar consumption can be problematic since foods and beverages (typically SSBs) can vary greatly in their sugar content and because some items will contain nutritive calories (such as flavoured milk).[47] It therefore makes comparison with more standardized measures, such as grams of added sugar, challenging and precluded, in this case, meta-analysis of the included studies.

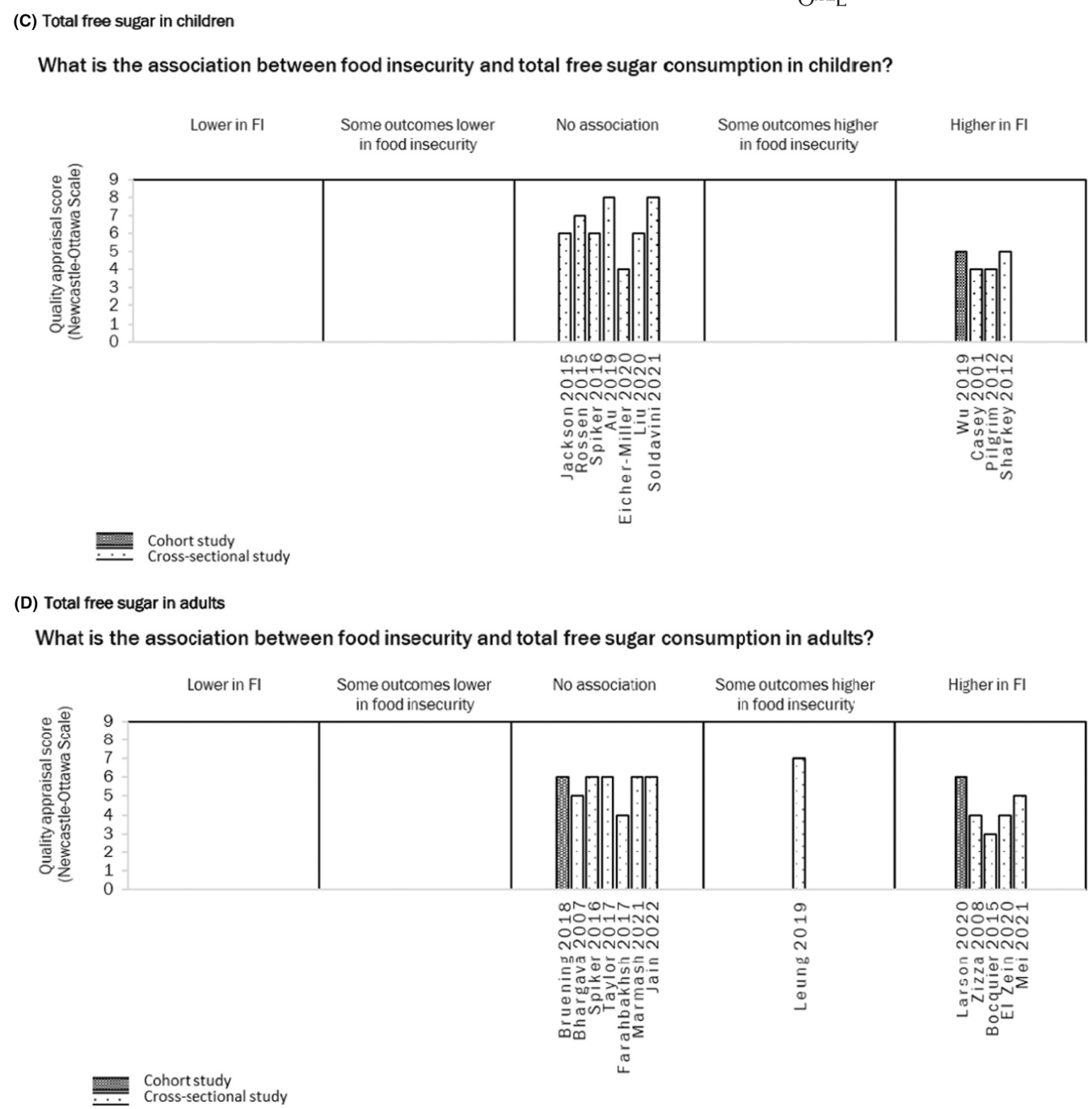

FIGURE 2 (Continued)

Similarly, we did not include studies who only reported outcomes related to dietary practices, such as adding sugar to infant feeds.

Much of the current evidence regarding the relationship between food insecurity and dental caries development in high-income countries comes from the USA. Since 1995 the USA has regularly monitored and reported food insecurity, whilst in other high-income countries, such as the UK, it has been the rapid rise of food banks that has drawn attention to this longstanding, if rarely quantified, problem.[48] Due to the paucity of data from non-US sources, it is unclear how applicable the findings of the current review are to other countries, particularly those with non-westernized dietary patterns or different dental care systems.

Many of the included studies had methodological weaknesses, most commonly relating to the selection of participants or control of potentially confounding variables. It should be recognized that it was not the primary objective of some of the included studies to examine the relationship between food security status and the caries-related health behaviours. In some cases this was a secondary objective or a covariate extracted from multivariate regression model. This means that studies were not necessarily powered to detect differences in

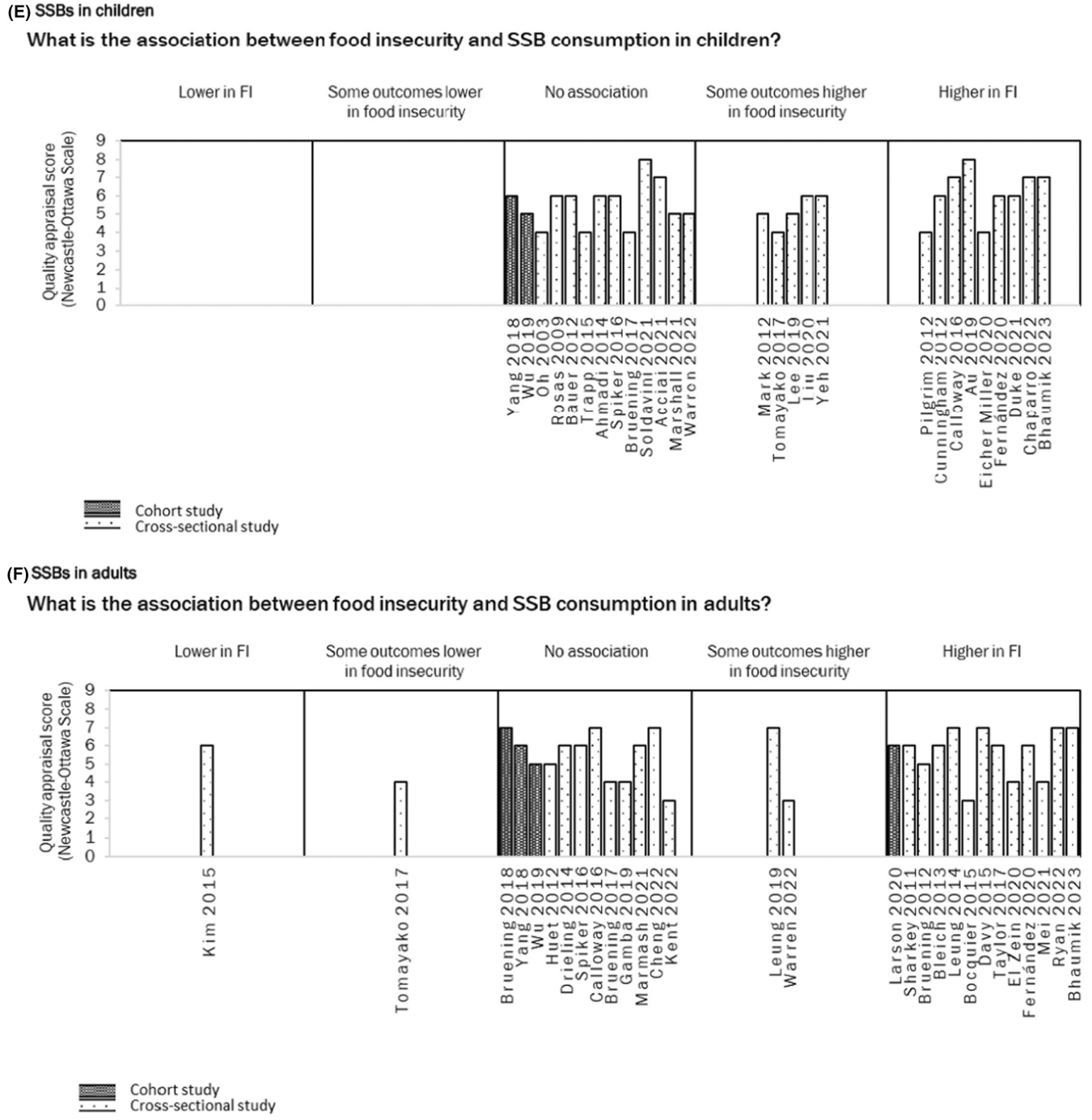

FIGURE 2 (Continued)

free sugar consumption or oral health-related behaviours between food secure and insecure populations or may not have described the exposure or outcome in sufficient detail to secure high quality appraisal scores.

4.4 | Comparison to what is already known

Previous reviews have addressed the relationship between food insecurity and dietary outcomes, specifically added sugar consumption in children.[25,49] One reported no association,[25] whilst the other reported strong and consistent evidence of higher added sugar intake among food-insecure children aged 6–11 years.[49] There were similarly heterogeneous findings in the current review—whilst the majority of studies reported no association between food insecurity and free sugar consumption in children, there were in each free sugar subgroup (total, from SSBs, juice or high sugar foods) a minority of studies reporting higher sugar intake in food insecure individuals. There are a number of possible explanations for this.

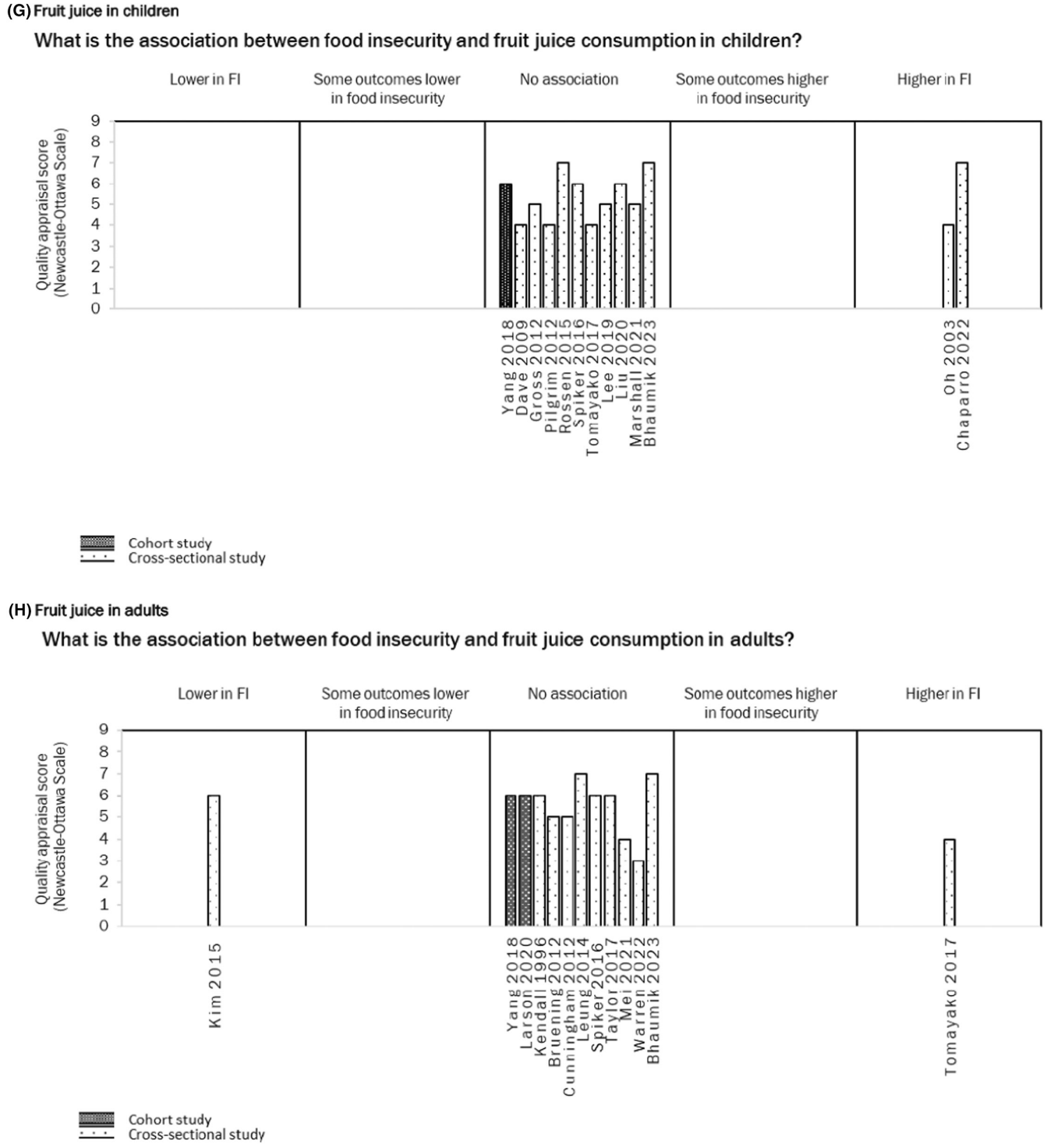

FIGURE 2 (Continued)

The relationship between food insecurity and free sugar consumption may not be consistent across all populations and settings. There may be particular social groups where free sugar consumption is higher in those experiencing food insecurity. This was seen in a Canadian study where low-income, food-insecure girls had higher SSB intake but no relationship was observed among male participants,[50] and in a Taiwanese study where food insecurity was positively associated with SSB intake in children but not in adolescents.[51] Similarly, it may be that there are particular dietary items responsible for findings of positive association between food insecurity increased free sugar consumption. An example of this was observed in Tomayako et al. in which children from food insecure households had significantly higher intake of soda and sports drinks intake but no statistically significant differences in consumption of

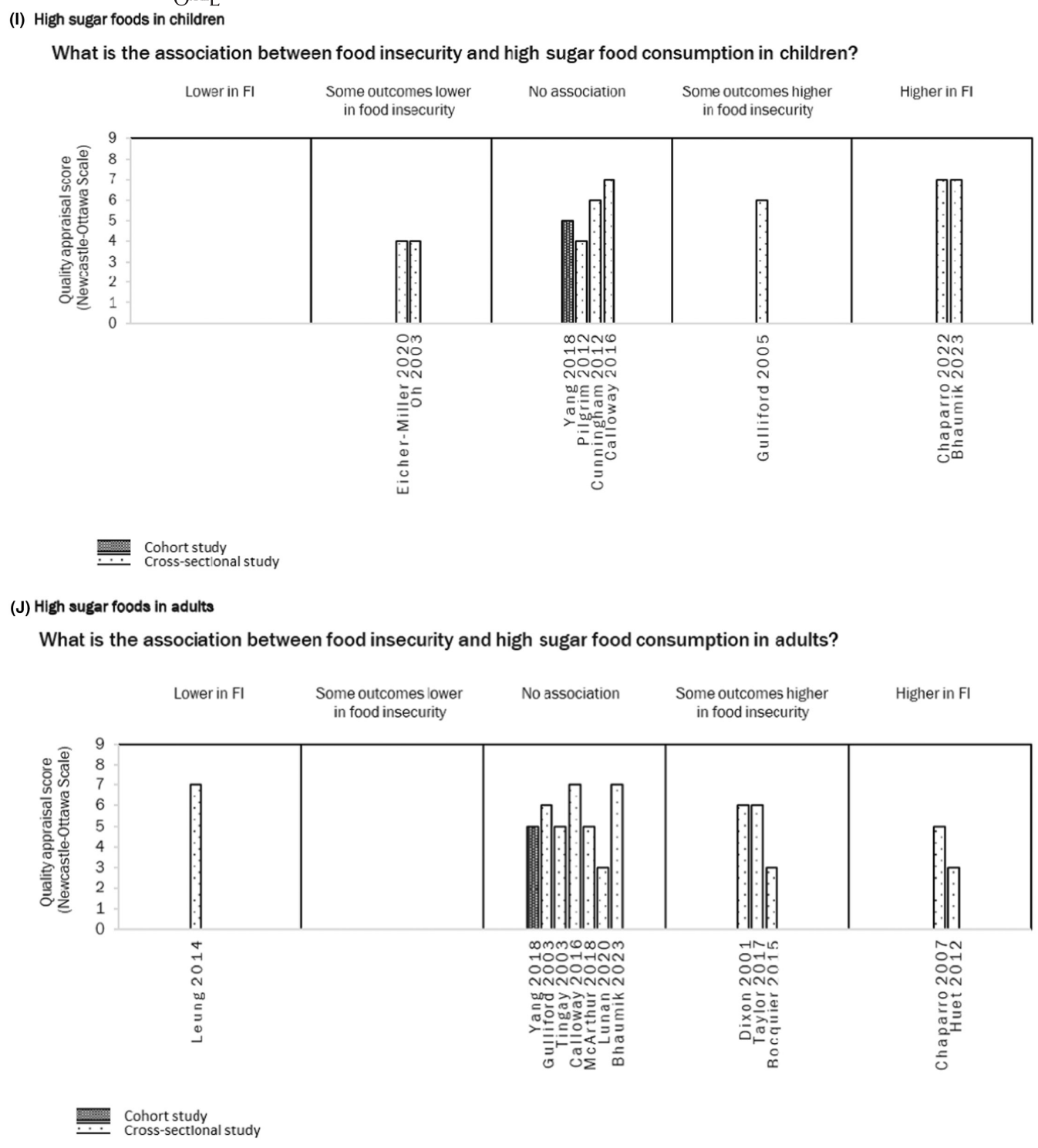

FIGURE 2 (Continued)

'other SSBs'.[52] Similarly, the association between food insecurity and free sugar consumption may vary geographically depending on legislation relating to sugar taxation, food labelling and food marketing.

It is also apparent that the relationship between food insecurity (normally measured across a 12-month period) and dietary intake (typically recorded by a 24-h dietary recall or weekly food frequency questionnaire) is dynamic. It has been suggested that individuals who positively screen for food insecurity likely alternate between times of adequate food availability and food scarcity.[53] During periods of unpredictable food supply, the chances of food insecure households engaging in poverty-related food restriction may increase, promoting dependence on inexpensive and energy-dense foods, typically high in free sugars.[54,55] Emmons observed significant differences in the food and drink consumed by low income individuals between the first and fourth week of the month.[56] Since many of the studies included in the review relied

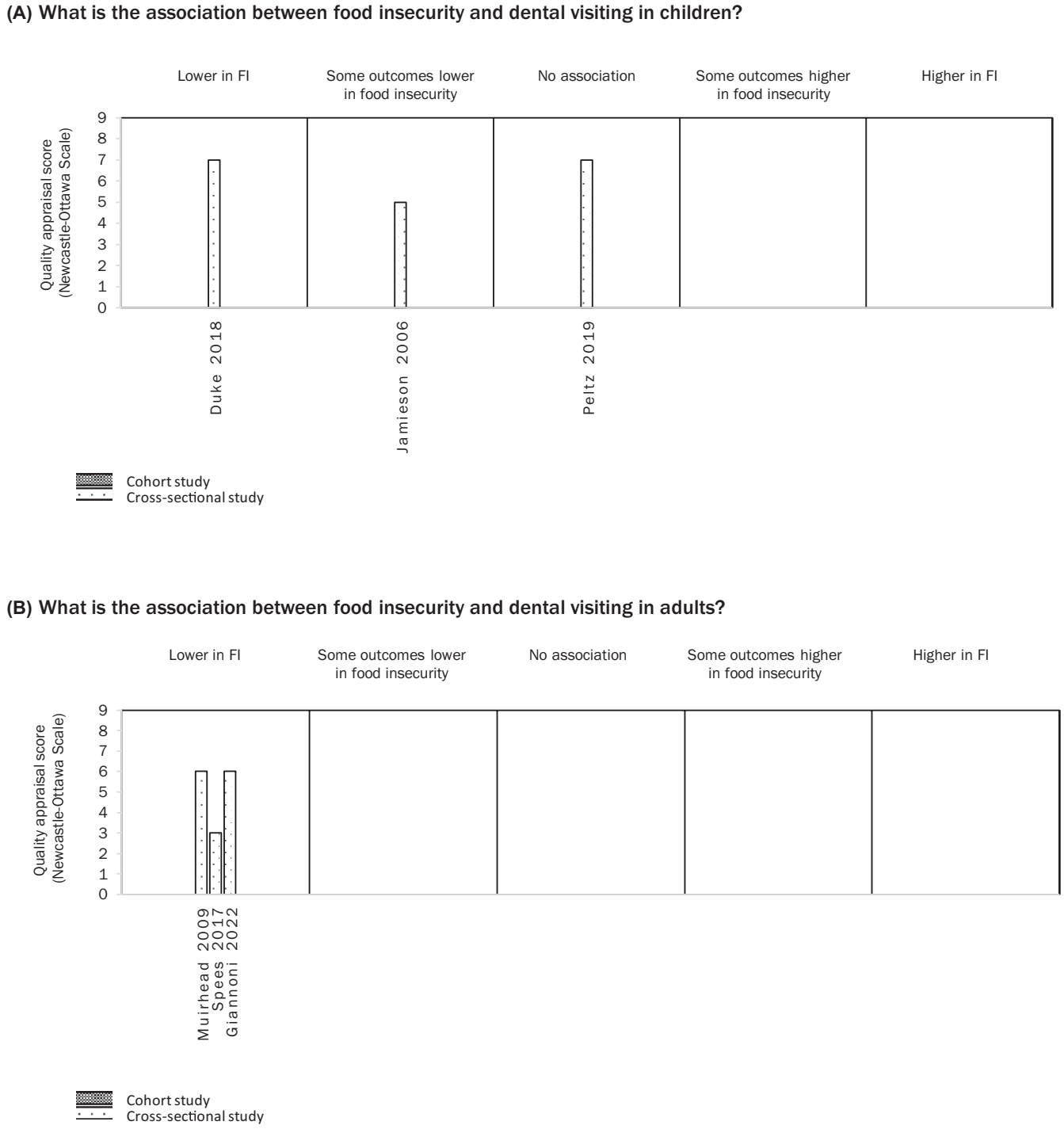

FIGURE 3 Harvest plots showing the evidence for the association between food insecurity and dental visiting. (A) children; (B) adults.

on a single 24-h dietary recall, they may not have captured distinct points in time when households were expected to be at their most food insecure.

A key consideration when assessing potential differences in free sugar intake between food secure and insecure individuals are consumption levels across the whole population. In studies such as Au,[57] and Casey,[58] free sugar intake in both groups far exceeded national guidelines, meaning studies required high statistical power in order to identify small differences between food secure and food insecure populations. Although most of the studies included several hundred participants, most did not describe a sample size calculation. In populations where the prevalence of food insecurity was low or the likely effect size was small, studies may have been vulnerable to type II error.

Since the evidence linking food insecurity to free sugar intake is ambiguous, there may be other factors mediating the association

between food insecurity and dental caries. One potential factor may be access to dental care. Economic hardship affects health care utilization,[59] with financial constraints compelling affected individuals and households to make decisions about spending. Food-insecure households experiencing spending dilemmas are known to prioritize fixed costs such as rent, whilst sacrificing more flexible purchasing, such as food.[60] It is possible that dental care also represents a competing financial demand for non-insured, food-insecure households with no recourse to state-funded dentistry. Adults experiencing food insecurity are also less likely to have dental insurance coverage.[19] This would appear to be supported by the small number of studies exploring the relationship between food insecurity and dental visiting in adults included in the review. These consistently reported that food-insecure adults were less likely to engage in regular dental visiting and more likely to visit the dentist only in response to an oral health problem. The picture in children was more mixed, possibly due to greater access to state-funded dental care for children. For example in the USA, states are required to provide dental benefits to children covered by Medicaid and the Children's Health Insurance Program, but choose whether to provide dental benefits for adults.[61]

4.5 | Implications for research

Previous systematic reviews have called for more longitudinal studies examining the relationship between food insecurity and oral health.[17,20] Only four out of the 71 studies included in this review were of a cohort design. High quality studies employing longitudinal methods would allow greater elucidation of temporality and dose–response relationship between food insecurity and health-related behaviours implicated caries development than is afforded by cross-sectional techniques which currently dominate the evidence base.

Dental care utilization (what was measured in the studies included in this review) is only one dimension of dental access. A distinction should be made between 'entry access' and 'effective access'.[62] Since cost of care is known to influence treatment decisions,[63] not only may food insecure individuals be less likely to attend a dental appointment, they may be less likely to obtain effective interventions to improve their oral health outcomes when they do consult. This latter dimension of access and how this is influenced by financial hardship, including food insecurity, requires further research.

The use of oral hygiene aids to facilitate the effective disruption of the plaque biofilm and fluoridated dentifrices which control the caries process by adjusting the balance between demineralisation and re-mineralization of enamel are well established as effective caries prevention strategies.[64–66] Inadequate access to these products is a further potential mediator of the association between food insecurity and caries.[67] Whilst it is established that individuals experiencing food insecurity are less likely to be able to access appropriate menstrual products,[68] this review identified only one eligible study which looked at the association of food security status and toothbrushing frequency in children. There were no studies which assessed the relationship between food insecurity and access to fluoridated toothpaste or other oral hygiene aids, the frequency of interdental cleaning or mouthwash use or which examined the frequency of toothbrushing in adults with food insecurity. Since food insecure households have, by definition, insufficient financial resources to purchase sufficient food to sustain an active and healthy life, it is not unreasonable to suggest that many may also have inadequate access to oral hygiene products. Access to such products and household environments conducive to instigating and maintaining appropriate mouth care practices warrants further consideration in the literature.

4.6 | Implications for policy and practice

Food insecurity and oral health inequalities both present serious challenges to society. Both are public health problems modulated by psychosocial, behavioural and environmental factors arising at different levels of the socioecological model of health.[69–71] Key questions remain as to whether societal actions to address food insecurity reduce the prevalence and severity of dental caries and what are the specific value of oral health interventions for food insecure populations. There is a need therefore, to build the evidence base about what works in practice, both to prevent the health disparities associated with food insecurity and to enable those affected to achieve more equitable outcomes.

5 | CONCLUSIONS

This review did not identify clear associations between food insecurity and behaviours commonly implicated in the development of dental caries that would explain the relationship between food insecurity and dental caries. The body of evidence regarding the association between food insecurity and free sugar consumption was inconsistent in both children and adults, with some studies reporting a positive association and others reporting no association. The number of studies reported higher free sugar intake, particularly in the form of SSBs, in both children and adults experiencing food insecurity leads authors to conclude a true positive association may exist in some populations or in relation to specific product types. The limited evidence available indicates that food-insecure adults are less likely to engage in regular dental visiting and more likely to visit the dentist only in response to an oral health problem. The picture in children is more mixed, possibly due to greater access to state-funded dental care. Common methodological weaknesses across the evidence base related to the selection of participants or control of potentially confounding variables. Consequently, the quality of evidence for all outcomes was downgraded to very low. High quality, longitudinal studies are required to explore the relationship between food insecurity and behaviours such as free sugar consumption, oral hygiene practices and dental visiting and relate these to the subsequent

clinical outcomes of dental caries. More research is also needed to explore access to appropriate oral hygiene products and household environments conducive to habitual oral self-care in food insecure populations.

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CONFLICT OF INTEREST STATEMENT

Authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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