Household food insecurity and its impact on child and adolescent health outcomes in Western High-Income Countries: a rapid review of mechanisms and associations.

Sarah Abraham[1], Penny Breeze[1], Hannah Lambie-Mumford[2], Anthea Sutton[1]

[1]Univeristy of Sheffield, School of Health and related Research, Regent Court (ScHARR), 30 Regent Street, Sheffield, S1 4DA

[2]University of Sheffield, Department of Politics and International Relations, Modular Teaching Village, Northumberland Road, Sheffield, S10 1AJ

Corresponding author: Sarah Abraham, [1]Univeristy of Sheffield, School of Health and related Research, Regent Court (ScHARR), 30 Regent Street, Sheffield, S1 4DA, sjabraham1@sheffield.ac.uk, +44 7480223448

Short title: Household food insecurity, child and adolescent health outcomes

[*Disclosure statements, as outlined below. These must be included on the title page and not in the manuscript file, to enable double-blind reviewing; if the paper is accepted, they will be inserted into the manuscript during production. If any are not applicable, please state this.*]

Ethical Standards Disclosure: N/A

Abstract

<u>Objective</u> The primary aim of this rapid review was to provide a summary of the mechanisms by which HFI is associated with child and adolescent health outcomes. The secondary aim was to identify key HFI determinants, provide an updated account of HFI-associated child/ adolescent health outcomes and build a conceptual map to illustrate and consolidate the findings.

<u>Design</u> A rapid review was performed using EMBASE, Medline, Web of Science and The Cochrane library. Inclusion criteria were observational High- income English-language studies, studies evaluating the mechanisms and associations between HFI and child health outcomes using statistical methods.

<u>Setting</u> High income English-speaking countries.

<u>Participants</u> Child (3-10 years) and adolescent populations (11-24 years) and their parents, if appropriate.

<u>Results</u> Eight studies reported on the mechanisms by which HFI is related to child health outcomes, suggesting that maternal mental health and parenting stress play mediating roles between HFI and child/adolescent mental health, behaviour and child weight status. Sixty studies reported on associations between HFI and various child health outcomes. HFI had significant impact on diet and mental health, which appeared to be interrelated. Sociodemographic factors were identified as determinants of HFI and moderated the relationship between HFI and child/adolescent health outcomes.

<u>Conclusions</u> There is a gap in the evidence explaining the mechanistic role of diet quality between HFI and child weight status, as well as the interplay between diet, eating behaviours and mental health on physical child health outcomes. The conceptual map highlights opportunities for intervention and policy evaluations using complex systems approaches.

Key words: Food insecurity, child health outcomes, adolescent health outcomes, mechanisms, conceptual framework

Introduction

Household food insecurity (HFI) is broadly described as an "uncertainty about future food availability and access, insufficiency in the amount and kind of food required for a healthy lifestyle, or the need to use socially unacceptable ways to acquire food" [1]. HFI is usually determined by a lack of household financial resources and can have detrimental impact to the health and well-being of all members of a household, including children.

In 2022, the Food Foundation reported that 4 million children in the UK were experiencing HFI[2] and a previously published rapid review of HFI and child health outcomes found that HFI had detrimental impact on the physical, psychosocial wellbeing of children and adolescents[3]. There is also evidence to suggest that the harmful health impact of HFI in childhood may have detrimental health consequences into adolescence and early adulthood[4, 5]. However, little is known about *how* HFI leads to or is associated to poor child and adolescent health outcomes.

To the authors' knowledge, no review has attempted to synthesise the literature on mechanisms to consider HFI's multiple health impacts and impacts over time. This rapid review aims to fill this evidence gap and additionally provide an updated rapid review of child/adolescent health outcomes associated with HFI, targeting child and adolescent populations in Western high-income countries (HICs), that reflect the UK child/adolescent population.

Aims

The primary aim of this review was to identify and summarise the current literature reporting on the mechanisms by which HFI is associated with child and adolescent health outcomes. The secondary aim of this review was to provide an updated account of the key HFI determinants, and the child/adolescent health outcomes associated with HFI. The review was used to inform a conceptual model of HFI and child/adolescent health outcomes to illustrate and consolidate the review findings, for the purposes of highlighting areas for intervention and policy planning.

Methods

Study design

The aims of this review were met using rapid review methods. The fast-growing academic and policy interest in HFI, coupled with the urgency to synthesise good quality evidence in a timely manner, meant that rapid review methods were preferred over systematic review methods. Rapid reviews use transparent, systematic review search methods to identify and synthesise evidence, while offering flexibility in their methodology. This study design allowed for streamlined search strategies without compromising validity, which aligned with the exploratory and scoping nature of this review[6]. The elements of the systematic review methodology that were adapted for this rapid review were that a grey literature review was not conducted, one reviewer screened and extracted studies, and quality assessment was limited to studies reporting on mechanisms only. The lead author was supported by co-authors in the shaping of the study objectives and search strategy.

Search strategy

An initial scoping search was performed in PubMed and Google Scholar to identify key publications and retrieve keywords for the search strategy. The search strategy was designed to capture studies that would fulfil both the primary and secondary aims of the review. The search was divided into two concepts: (i) food insecurity/food poverty and (ii) quantitative analysis (encompassing statistical, theoretical, and conceptual models relevant to the research problem). An initial scoping search in PubMed found that food insecurity and food poverty were often used interchangeably in studies; thus, both were incorporated as key terms in the search strategy. Searches were conducted in databases: Medline 1946; Web of Science, EMBASE 1947; and the Cochrane Library for articles up to March 2022 (searches were limited to studies published within the past fifteen years). Search terms were used as topic headings and Medical Subject Headings (MeSH) and are present in Table 1. Further studies were retrieved using backwards and forward citation searching of included articles. The scope of the review was limited to the retrieval of peer-reviewed published literature.

Inclusion and exclusion criteria

Observational studies were included to reflect the complex relationships between HFI and child/adolescent health outcomes in real-world settings. Studies were included if their population of interest comprised children (aged 3-10 years), adolescents (aged 11-24 years,

with a mean age <19 years) or child/adolescent-parent dyads. The adolescent age range was based on developmental models, which recognised that important aspects of physical, mental, and social development continue into early adulthood[7]. Younger children (aged under 3 years) were not included in the scope of this review. The health impacts of HFI on children can differ by age group, and infants may be more vulnerable to nutrient deficiencies related to HFI which may contribute to developmental delays in the early years of life[8].

Studies from Western English-speaking HICs, including the UK, Ireland, US, Canada, and Australia were included. Studies from these countries were included to closely generalise the impact of HFI on child/adolescent health outcomes to the UK child/adolescent population. Studies from low- and middle-income countries (LMICs) were excluded due to differences in food systems, nutritional challenges in child/adolescent populations and social policy[9, 10]. HFI in LMICs may be associated with infectious diseases, such as malaria, that are uncommon in Western HICs[11].

Studies were included if the population exposure was defined as HFI or food poverty. The definition of HFI was decided based on the USDA definition of food insecurity: food insecurity is a "household-level economic and social condition of limited or uncertain access to adequate food"[12]. Only quantitative studies were included, as the review sought to summarise studies that had used statistical methods to confirm relationships between HFI and health outcomes. An advantage of focussing on quantitative studies was that they have utility beyond this review, such as providing insight into parameters for modelling based on the conceptual model. While qualitative studies provide valuable insight into individual's lived experiences of HFI, they were excluded as they do not provide the statistical rigour required to identify population-level correlational relationships between HFI, health outcomes, and potential mediators.

Studies were selected based on their reporting of child and adolescent health outcomes. Health outcomes were agreed upon by the authors and discussed for discrepancies. Health outcomes were defined as metabolic risk factors (e.g. BMI/cholesterol/fasting glucose levels), health-related conditions (including physical and psychosocial conditions) and biological processes (e.g. sleep). Further details on inclusion/exclusion criteria are presented in Table 2. The lead author of the paper reviewed titles and abstracts to be included in full-text review,

and inclusion was determined by the same reviewer with support from co-authors, when examining the full text of publications.

Data extraction

The Cochrane data collection form was adapted by removing items that were not relevant for this review, such as experimental designs, e.g. duration of participations, numbers of missing participants, and intention to treat analysis details[13]. Variables extracted included sample size, country, datasets used, participant information (e.g. sociodemographic characteristics), HFI measurement tools, the participant reporting HFI, the health outcome of interest, statistical methods, and key study results. Data extraction was completed by the lead author.

Study quality

The Quality in Prognosis Studies (QUIPS) tool analysed the quality of mechanism studies only for risk of bias, as these were the primary studies of this paper[14]. Studies scored low, medium or high risk of bias based on an established set of thresholds within the QUIPS tool.

Results

Description of included studies.

Figure 1 presents a flow diagram of the search results. After removing duplicates, the search results retrieved n=1977 articles, and their titles and abstracts were screened. A total of n=241 were eligibile for full-text screening, of which n=8 were mechanism studies[15-22], and n=60 were association studies[23-82] (n=52 found by the search strategy and an additional n=8 retrieved by citation searching strategy).

Most studies included were of cross-sectional design (n=59) and remaining were longitudinal (n=10)[17, 19-21, 38, 40, 46, 57, 62, 81, 82]. In terms of geography, n=2 studies were based in Australia[38, 70], n=6 from Canada[39, 50, 51, 58, 62, 67], n=1 from the UK, n=1 from Ireland[65] and n=59 from the US. In terms of child age, n=8 studies included the child age group (3-10 years old)[17, 27, 43, 47, 49, 52, 56, 81], n=29 looked at a mix of child and adolescent populations[15, 18, 24, 28, 31, 32, 38, 42, 48, 50, 53, 54, 57-60, 65, 70, 72-74, 77, 79, 80, 82] and the rest (n=34) studies investigated adolescent populations (11-24 years) only.

Some studies investigated more than one health condition; therefore, there is an overlap in the numbers. Of the total studies included in this review, n=21 investigated weight status, n=3 investigated dental cavities, n= 2 investigated asthma, n=4 on diabetes/prediabetes risk, n=5

investigated blood pressure, n=4 investigated cholesterol and other metabolic markers of disease, n=3 investigated sleep, n=3 investigated smoking, drinking and substance abuse, n=19 investigated diet, n=14 investigated mental health and behaviour, n=2 investigated physical activity, n=3 investigated quality of life, n=10 investigated eating behaviours, n=1 investigated anaemia and n=1 investigated bone mass disparities.

Studies reporting on mechanisms are presented in Table 3, while studies reporting on associations are reported in Table 4. Studies are presented by health outcome, below.

Outcomes

Obesity and overweight

Twenty-one studies investigated the relationship between HFI and child overweight/obesity and found mixed results[16, 18, 20, 22, 25, 34, 36, 40, 41, 44, 45, 51, 53, 59, 66, 68, 69, 71, 80-82]. Eight studies found no direct association between HFI and child overweight/obesity using various markers of weight status, including BMI, waist circumference, trunk fat mass, triceps skin folds, body fat percentage, metabolic syndrome, BMI z-scores, weight status[16, 36, 40, 41, 59, 66, 68, 71]. Eleven studies found a statistically significant association between HFI and greater odds of overweight/obesity OR range: 1.44–1.81 (95% CI 1.13–2.48)[25, 34, 44, 45, 48, 51, 53, 69, 80-82] One study only found an association between greater BMI and HFI in adolescent boys[25], while one study found an association in older children and not younger children (<6 years)[48]. Two studies in this review did not report a statistically significant association between HFI and overweight. However, they did find a greater prevalence of obesity in food insecure populations[34, 45]. Only one study found an association between HFI and reduced odds of obesity[82].

Studies found that the relationship between HFI and child overweight/obesity was determined by child age, child ethnicity, parental education, household income, maternal BMI and severity and timing of HFI[25, 44, 51, 53, 66, 68, 69, 80-82]. For example, children who were food insecure, older, non-White, whose parents had lower educational attainment level, and whose parents were obese were more likely to be overweight. One study found that food insecure girls were more likely to be overweight, compared to food-secure girls but the same comparison was not drawn for boys[59]. Furthermore, persistent HFI and timing of HFI were also associated with both weight extremes. Children who experienced persistent HFI throughout their life from early childhood to early adolescence had higher odds of being

overweight, while children who experienced a single exposure to HFI in early childhood were associated with underweight in early adolescence[53, 80, 82]

Four studies explored the mechanism by which HFI may be associated with weight status[16, 18, 20, 22]. Two studies exploring mechanisms found that an interaction between HFI and maternal stressors had impact on weight status, for children aged 3-10 years old and adolescents aged 10-15 years old, however results were mixed[18, 20]. Both studies did not find a direct association between HFI and child overweight. One study found that an interaction between HFI and maternal stressors amplified the probability of food-secure children being obese or overweight, compared to children living in food insecure households, whose mothers experienced similar stressor levels ($p<0.05$)[18]. In contrast, the second study found that maternal stressors enhanced the likelihood of living with overweight or obesity when an adolescent was exposed to HFI ($p<0.001$)[20].

One study found that while HFI was directly associated with adolescent overweight (OR=1.56, 95% CI 1.13–2.15, $p<0.05$) and obesity (OR=1.96, 95% CI 1.40–2.74, $p<0.05$) an indirect relationship was not mediated by sleep duration ($p=0.23$)[16] Additionally, another study found a direct and indirect relationship between HFI and child overweight, mediated by child psychosocial factors including depression and social status ($p<0.05$)[22]

Diet Quality

Nineteen studies reported and found an association between HFI and diet quality in both children and adolescents, using various diet quality indicators[26, 27, 30-32, 35, 38, 49-52, 54, 65, 69, 71, 72, 74, 79, 81]. Six studies found that food insecure children and adolescents were less likely to consume vegetables compared to their food-secure peers[27, 35, 50, 54, 65, 72]. While three studies found that HFI was associated with reduced consumption of fruit[51, 65, 72]. Four studies in older children (>10 years) found no association between HFI and fruit and/or vegetable consumption[35, 50, 69, 71]. HFI was also associated with reduced healthy and unhealthy food availability in the household[79].

Five studies found that food insecure children and adolescents were less likely to consume dairy than food secure children/adolescents[31, 32, 50, 72]. Studies also found that children and adolescents were likely to consume greater savoury and sweet snacks, sugar-sweetened

beverages and fast foods than those who were food-secure[30, 31, 49, 52, 54, 65, 72, 81]. Moreover, food insecure children and adolescents were more likely to have higher daily energy intake, with lower energy consumption from protein and wholegrains[35, 50, 51, 54, 74, 79]. Additionally, two studies found that HFI was associated with a reduced intake of vitamins A, B6, B12, thiamine, iron, riboflavin, magnesium phosphorous and zinc[32, 50]. The relationship between HFI and diet quality differed by gender, ethnicity and child age[32, 81].

Eating behaviours

Ten studies found that HFI was associated with poor eating habits in children and adolescents, characterised by reduced frequency of family meals, meal skipping, binge eating and overeating in the absence of hunger[24, 26, 30, 37, 45, 52, 60, 65, 71, 79]. Maternal binge eating and breakfast skipping were associated with food insecure adolescents mimicking this behaviour[26]. A US study also found that food insecure children enrolled in a national school lunch programme were likelier to skip lunch than those enrolled in the programme[30]. Two studies found that HFI was related to weight-control eating behaviour, including fasting, laxative use and increased weight loss attempts in children and adolescents[45, 60].

Dental cavities

Three studies found an association between HFI and dental caries, which varied depending on HFI severity and child age [15, 42, 47]. The odds of dental caries were significantly greater (OR=3.51 95% CI 1.71–7.19, p <0.05) in children who experienced severe HFI compared to fully food-secure adolescents. Older food insecure children had greater odds of dental caries[42]. Children who experienced any HFI across all severities had poorer oral health compared to fully food-secure children[47].

One study investigating mechanisms found that HFI was directly associated with untreated dental caries in children and adolescents (OR=1.38, 95% CI 1.11–1.72, p<0.01). In this study, diet quality was not found to be associated with untreated caries, so authors did not perform a mediation analysis[15]. However, HFI was associated with poorer diet quality in this study.

Prediabetes risk

Four studies found evidence demonstrating an association between HFI and increased prediabetes risk[29, 55, 58, 64]. HFI was associated with greater HbA1c concentrations (> 9%, which is high risk) in all studies. Studies reported racial disparities between HFI and prediabetes risk, with higher Hispanic and Black children having greater prediabetes risk (p<0.001) than food insecure children of other races[55]. While another study found higher odds of prediabetes risk among food insecure non-White Hispanic adolescents (adjusted [64] OR (aOR)=2.83 95% CI 2.14–3.73) compared to food insecure adolescents who were of Black race (aOR=1.88 95% CI 1.12–3.14) and Hispanic adolescents (aOR=1.84 95% CI 1.14–2.97)[29].

Hospitalisation risk

Two studies found that food insecure children had greater rates of hospitalisation than food-secure[58]. HFI was associated with hospitalisations (aOR=3.66, 95% CI 1.54–8.66)[58] and emergency department visits (prevalence ratio (PR)=2.95, 95% CI 1.17–7.45)[64].

Blood pressure

Five studies reported mixed evidence for the association of HFI with blood pressure[36, 44, 55, 68, 73]. Three studies found a small positive association, varying by HFI severity, gender, age, ethnicity, and household income[55, 68, 73]. Two studies found little or no association[36, 44].

Cholesterol, fasting glucose and other metabolic markers of health.

Three studies found no association between HFI and various metabolic markers of health[36, 44, 68]. One study found a significant difference only for marginally food insecure groups, where the odds of having elevated serum triglyceride (OR=1.86 95% CI 1.14–2.82), triglyceride/HDL-cholesterol (OR=1.74; 95% CI 1.11–2.82) and apolipoprotein B (Apo B) (OR=1.98 95% CI 1.17–3.36) were greater than those observed in food-secure groups. In this study, marginally food-secure females had greater odds than males of having low HDL-cholesterol (OR=2.69 95% CI 1.14–6.37)[75]

Asthma

Two studies found an association between HFI and asthma, which varied by race, household income and timing of HFI[56, 57]. Food insecurity was associated with greater odds of asthma in non-Hispanic whites and Hispanics. However, odds were lower in non-Hispanic Black children[56] One study found that timing of HFI was an important determinant in the association between HFI and asthma diagnosis[57]. For example, children who experienced HFI a year before entering kindergarten had 13% greater odds of an asthma diagnosis in the third grade (OR=1.13, 95%CI 1.17–1.20), while HFI experienced in the year prior to joining third grade was associated with 53% greater odds of developing asthma in the third grade (95% CI 1.51–1.55)[57].

Anaemia

One study found a positive association between HFI and anaemia. The odds of iron deficiency anaemia among food insecure adolescents were greater than food-secure adolescents (OR= 2.95 95% CI 1.18–7.37 p=0.02) [33].

Bone mass disparities

One US study found HFI to be associated with less bone mass, particularly in food insecure male children, who had significantly lower estimated total body (p=0.05), trunk (p=0.05), spine (p=0.2), pelvis (p=0.05) and left arm (p=0.02) bone mineral content than food-secure males[32]. Food insecure males consumed fewer dairy products, thus having lower calcium intake than recommended. HFI was more prevalent in non-Hispanic Black, Mexican American and Other ethnic groups.

Physical activity

Two studies found that fully food-secure adolescents were more likely to participate in moderate-to vigorous physical activity than food insecure adolescents (p<0.02)[68, 77].

Quality of life

Three studies found that food poverty or HFI were significantly associated with lower quality of life[51] and lower life satisfaction[65, 67] in children and adolescents aged 10-17 years. Moderate to severe HFI was associated with lower health-related quality of life outcomes, particularly psychosocial outcomes (p<0.05)[51].

Sleep

Two studies found a negative association between HFI and sleep (p<0.001)[49, 71]. In both studies, food insecure children and adolescents reported poor sleep quality. One study found that HFI was not associated with mean-centred sleep duration in adolescents[16]

Smoking, alcohol, and substance abuse

HFI was associated with greater odds of cigarette smoking[71], alcohol consumption[71], opioid misuse, and lifetime use of illicit drug use[63, 78]. The relationship between HFI and smoking, alcohol and substance abuse was dependent on age and ethnicity; for example, one study found that food insecure non-Hispanic Black and non-Hispanic white children of older age were more likely to partake in substance abuse behaviour[78].

Mental health and behaviour

Fourteen studies found an association between HFI and detrimental mental health and behavioural difficulties[17, 19, 21, 23, 39, 43, 46, 61-63, 66, 67, 70, 76]. Most studies explored the relationship in older children or adolescents, with only two studies[17, 43] reporting in children under 10 years. Four studies found an association between HFI and anxiety, which was significantly worse in females, older children, and adolescents, which worsened with HFI severity[61, 63, 67, 76]. Reports of anxiety were greater in children and adolescents who were not shielded from HFI by caregivers[67]. Four studies found an association between HFI and increased depression/atypical emotional symptoms[62, 63, 67, 70]. Furthermore, hunger was associated with greater odds of depression and suicidal ideation in adolescents (OR=2.3, 95% CI 1.2–4.3)[62].

Four studies found a positive association between HFI and misconduct, behavioural difficulties and internalising and externalising symptoms in children and adolescents[43, 46, 63, 70]. Persistent HFI was associated with greater misconduct in adolescents (bullying/ fighting/ stealing/ cheating/ lying/ misbehaving) and this was worse in food insecure males than females compared to their food-secure counterparts[46]. Additionally, three studies found that HFI was associated with poor self-esteem in older children and adolescents, and this was stronger in girls than boys [23, 39, 66]. One study found a positive association between HFI and

body dissatisfaction in US adolescents across all races and BMI categories, which was stronger among those with African American race/ethnicity (p<0.001)[23].

Three studies explored mediatory pathways between HFI and child/adolescent mental health and behavioural outcomes. One study found that HFI, reported by the parent in early childhood (aged 5 years), was directly associated with adolescent anxiety and depressive symptoms. The study found that both HFI and housing instability combined had an indirect impact on adolescent anxiety and depression via parenting stress and maternal depression, reported when the child was aged 9 years[19]. A second study found that HFI, at age 5, was not directly associated with adolescent aggressive or depressive behaviour; however, it did have an indirect impact on aggressive behaviour and depressive behaviour via parenting stress reported when the child was aged 9 years[21]. A third study found that HFI was indirectly associated with lowered ability to pay attention, lower inhibitory control and greater externalising behaviours via parental aggravation in children aged 4-5 years[17].

Quality assessment of mechanism studies

Eight mechanism studies, all using data from the US, in children and adolescents aged 3-17 years, were assessed by the QUIPS tool [15-17, 19-22]. Low risk of bias was found in seven[15, 16, 18, 20, 21] out of eight studies, while moderate bias was found in one[12]. Quality assessments are located in the supplementary material.

Conceptual model of results

This review shows that the evidence relating HFI to health outcomes remains mixed. HFI has detrimental health impacts on child health outcomes for prediabetes risk, dental cavities, bone mass, asthma, anaemia, physical activity, quality of life, behaviour, diet quality and mental health. However, it is unclear whether or how HFI is related to child overweight/obesity, blood pressure and cholesterol/ other biomarkers.

The associations and mechanisms found in this review are illustrated in Figure 2. The green arrows represent an odds ratio >1, while the red arrows represent an odds ratio <1. Dashed lines represent mixed evidence.

Discussion

This review identified two key mechanistic pathways between HFI and detrimental child/adolescent health outcomes: (i) diet and (ii) mental health, which appeared to be interrelated in complex ways. There was a strength of evidence supporting the role of parent mental health as a mediator between HFI and greater child/adolescent mental health symptoms and behavioural difficulties [17, 19, 21]. One explanation of this mechanism may be that, HFI contributes to poor caregiver mental health, which results in parents reduced abilities to partake in positive parenting practices and provide parental warmth[83]. This mechanism of action aligns with the Family Stress Model, which suggests that financial strain leads to economic pressures (e.g. HFI), which can contribute to caregiver psychological distress and compromised parenting practices that impact child outcomes[84].

This review found mixed evidence for an association between HFI and child weight-status, depending on a range of factors including, timing, severity of HFI and sociodemographic factors[25, 44, 51, 69, 81, 82]. While one study found that maternal stressors enhanced the association between HFI and child overweight, another found that the association was enhanced for food-secure children[18, 20]. Although no association between HFI and overweight was concluded, there is evidence of higher obesity prevalence among food insecure populations[34, 45]. These findings are echoed in the literature, that has described this as the food insecurity-obesity paradox, which has been explained by a multitude of factors, including that; individuals may eat more when food is in abundance and reduce their intake when food availability is reduced[85]. In this review, food insecure children were more likely to consume unhealthy snacks and fast foods[31, 52, 65]. Unhealthy foods are often cheaper than healthier options, which may contribute to higher obesity rates in food insecure populations who lack the resources to access nutritious food or rely on food banks[85, 86]. However, food bank items may not be adequately nutritionally balanced, which can negatively affect child diet quality and influence child weight status[87].

Evidence of the association between HFI and fruit and vegetable consumption was mixed[35, 50, 72], possibly due to caregiver shielding or intra-household HFI where caregivers may forgo their nutritional needs for their children[88]. HFI was associated with reduced family meal participation and meal skipping, possibly due to low availability of food and increased caregiver stress, making preparing family meals more difficult[24, 79, 89]. An evidence gap identified in this review in terms of mechanisms was that no study at the time this review was

conducted attempted to investigate the role of diet quality, child mental health or child eating behaviours or parent feeding styles as mediators between HFI and child weight status. A study in UK adults found that HFI was indirectly associated with higher BMI, via distress and eating to cope[90]. A similar study approach may be applied to children and adolescents using diet quality, parent feeding styles or child eating behaviours as mediators.

While HFI was associated with untreated dental caries, it was not associated with diet quality, where diet quality was ruled out as a mediator of this relationship[15]. Other non-dietary mediators that could explain this relationship may be barriers to accessing oral healthcare products (e.g. toothbrushing)[91]. Parental stress experienced during food insecurity may influence caregiver ability to encourage dental care. Furthermore, authors may not have observed an association between diet quality and HFI due to the study's cross-sectional design, which could not determine causality between HFI, diet and dental health. A more insightful approach would be to analyse longitudinal data on HFI and health outcomes, as this review has established that timing, duration and severity of HFI exposure, may have differential impact on these correlational relationships [56, 82].

Limitations

A limitation of this review was the rapid review study design, which relied on a single reviewer to screen studies. This design may have introduced study selection bias and/or failed to capture all relevant literature and outcomes to fulfil the study aims [6, 92]. There was a lack of consistency in the measures used to report HFI, with some studies using a validated tool and others using one or two-questions within a survey. A recent scoping review commissioned by the Food Standards Agency highlighted the diversity between HFI tools used to measure HFI in the UK, emphasising a need for research groups, governmental departments and third parties investigating food insecurity to report and recognise the strengths and limitations of the methods used and acknowledging discrepancies between different measures[93]. Most studies included in this review relied on parent-reported HFI, and incorporating child-reported HFI may provide valuable insights into children's own experience of HFI, especially in adolescents who may have a greater awareness of HFI and more autonomy over their food environment. Using child-reported measures could offer a more accurate perspective of HFI for developing interventions tailored to the needs of child/adolescent populations[54, 94].

It was not appropriate to conduct a meta-analysis due to the heterogeneity between outcomes measured, population selected, study comparators, and the varied instruments used to measure HFI across included studies. Additionally, a meta-analysis approach would be overly simplistic to capture the complex systems that impact the relationships between HFI, and child/adolescent health outcomes[95]. In this study, statistical significance was used as a practical tool to conceptualise HFI and its associated health outcomes. While this approach may be considered controversial in light of emerging literature suggesting that over-reliance on statistical significance can lead to incorrect conclusions, effect sizes were also reported to provide a more nuanced understanding of the correlational relationships between HFI and child/adolescent health[96]. This dual approach ensured a balanced interpretation of mechanisms and associations while offering a foundation for further exploration of these complex relationships.

Implications of this review

The review identified a gap in the literature for UK-based studies and highlighted that further research using quantitative methods and longitudinal data may be beneficial for gaining more insight into the mechanisms by which HFI is associated with the plethora of outcomes identified in this review. Due to the inclusion criteria, qualitative evidence and studies of LMICs were excluded. This review can be used to inform future research priorities, such as a qualitative review, that could add depth and accounts of individual experiences of HFI to supplement the findings of this review. Additionally, a review exploring HFI and child/adolescent outcomes and mediators in LMICs could be conducted to compare findings. The conceptual map provides a guide for policymakers to identify where interventions may be beneficial in ameliorating the health impact of HFI in children and adolescents in Western HICs. As such study scope was limited to children and adolescents in Western HICs, physical and mental health outcomes and biological processes (e.g. sleep) to reduce the impact of heterogeneity and improve the validity of the results. Given the complexity of the problem of HFI, the findings may not be appropriate for supporting interventions and policies in other settings (e.g. LMICS), for younger child age groups (e.g. infants <3 years) and for health outcomes that are not explicitly summarised in this review. Policymakers should be aware of these limitations when using this review as evidence for intervention development. However,

the results from this review can help to guide further research in other settings and child populations.

Conclusions

The present rapid review identified that HFI is related to detrimental child physical and psychosocial health outcomes via (i) diet and (ii) mental health pathways. Maternal mental health and parent stress were identified as mediators explaining the relationship between HFI and child/adolescent behaviour and mental health. A paucity of longitudinal studies and studies of UK child populations highlight evidence gaps and priorities for further research. Sociodemographic factors such as ethnicity and household income were identified as key determinants of HFI, and policymakers should take these into account when planning interventions aiming to improve health in food insecure child populations. Additionally, supplementation of this quantitative review with qualitative evidence will provide a complete picture of this research problem.

References

1. Anderson SA (1990) Core Indicators of Nutritional State for Difficult-to-Sample Populations. *The Journal of Nutrition* 120, 1555-1598.

2. Foundation F (2022) New data shows food insecurity major challenge to levelling up agenda. . https://foodfoundation.org.uk/press-release/new-data-shows-food-insecurity-major-challenge-levelling-agenda 2022)

3. Aceves-Martins M, Cruickshank M, Fraser C *et al.* (2018) Public Health Research. In *Child food insecurity in the UK: a rapid review*. Southampton (UK): NIHR Journals Library Copyright © Queen's Printer and Controller of HMSO 2018. This work was produced by Aceves-Martins et al. under the terms of a commissioning contract issued by the Secretary of State for Health and Social Care. This issue may be freely reproduced for the purposes of private research and study and extracts (or indeed, the full report) may be included in professional journals provided that suitable acknowledgement is made and the reproduction is not associated with any form of advertising. Applications for commercial reproduction should be addressed to: NIHR Journals Library, National Institute for Health Research, Evaluation, Trials and Studies Coordinating Centre, Alpha House, University of Southampton Science Park, Southampton SO16 7NS, UK.

4. Paquin V, Muckle G, Bolanis D *et al.* (2021) Longitudinal Trajectories of Food Insecurity in Childhood and Their Associations With Mental Health and Functioning in Adolescence. *JAMA Netw Open* 4, e2140085.

5. Dubois L, Bédard B, Goulet D *et al.* (2023) Experiencing food insecurity in childhood: influences on eating habits and body weight in young adulthood. *Public Health Nutr* 26, 2396-2406.

6. Butler G, Deaton S, Hodgkinson J *et al.* (2005) Quick but not dirty: rapid evidence assessments as a decision support tool in social policy. *Government Social Research Unit*.

7. Sawyer SM, Azzopardi PS, Wickremarathne D *et al.* (2018) The age of adolescence. *Lancet Child Adolesc Health* 2, 223-228.

8. Drennen CR, Coleman SM, Ettinger de Cuba S *et al.* (2019) Food Insecurity, Health, and Development in Children Under Age Four Years. *Pediatrics* 144.

9. Turner C, Kalamatianou S, Drewnowski A *et al.* (2020) Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review. *Adv Nutr* 11, 387-397.

10. Bell Z, Nguyen G, Andreae G *et al.* (2024) Associations between food insecurity in high-income countries and pregnancy outcomes: A systematic review and meta-analysis. *PLOS Medicine* 21, e1004450.

11. Pérez-Escamilla R, Dessalines M, Finnigan M *et al.* (2009) Household food insecurity is associated with childhood malaria in rural Haiti. *J Nutr* 139, 2132-2138.

12. Agriculture UDo (2024) Definitions of Food Security. https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-u-s/definitions-of-food-security/

13. (EPOC) CC-EPaOoC (2017) Data collection form. epoc.cochrane.org/resources/epoc-specific-resources-review-authors

14. Hayden JA, van der Windt DA, Cartwright JL *et al.* (2013) Assessing bias in studies of prognostic factors. *Ann Intern Med* 158, 280-286.

15. Bahanan L, Singhal A, Zhao Y *et al.* (2021) The association between food insecurity, diet quality, and untreated caries among US children. *J Am Dent Assoc* 152, 613-621.

16. Do EK, Bowen GA, Ksinan AJ *et al.* (2021) Sleep, Food Insecurity, and Weight Status: Findings from the Family Life, Activity, Sun, Health, and Eating Study. *Child Obes* 17, 125-135.

17. Gee KA & Asim M (2019) Parenting While Food Insecure: Links Between Adult Food Insecurity, Parenting Aggravation, and Children's Behaviors. *Journal of Family Issues* 40, 1462-1485.

18. Gundersen C, Lohman BJ, Garasky S *et al.* (2008) Food security, maternal stressors, and overweight among low-income US children: results from the National Health and Nutrition Examination Survey (1999-2002). *Pediatrics* 122, e529-540.

19. Hatem C, Lee CY, Zhao X *et al.* (2020) Food insecurity and housing instability during early childhood as predictors of adolescent mental health. *J Fam Psychol* 34, 721-730.

20. Lohman BJ, Stewart S, Gundersen C *et al.* (2009) Adolescent overweight and obesity: links to food insecurity and individual, maternal, and family stressors. *J Adolesc Health* 45, 230-237.

21. Marçal K (2022) Pathways from Food and Housing Insecurity to Adolescent Behavior Problems: The Mediating Role of Parenting Stress. *J Youth Adolesc* 51, 614-627.

22. Willis DE & Fitzpatrick KM (2016) Psychosocial factors as mediators of food insecurity and weight status among middle school students. *Appetite* 103, 236-243.

23. Altman EA, Ritchie LD, Frongillo EA *et al.* (2019) Food Insecurity Is Associated with Body Dissatisfaction among Children in California. *J Acad Nutr Diet* 119, 1732-1737.

24. Appelhans BM, Waring ME, Schneider KL *et al.* (2014) Food preparation supplies predict children's family meal and home-prepared dinner consumption in low-income households. *Appetite* 76, 1-8.

25. Bauer KW, MacLehose R, Loth KA *et al.* (2015) Eating- and weight-related parenting of adolescents in the context of food insecurity. *J Acad Nutr Diet* 115, 1408-1416.

26. Bruening M, Lucio J Brennhofer S (2017) Mother and Adolescent Eating in the Context of Food Insecurity: Findings from Urban Public Housing. *Matern Child Health J* 21, 1911-1917.

27. Canter KS, Roberts MC Davis AM (2017) The role of health behaviors and food insecurity in predicting fruit and vegetable intake in low-income children. *Children's Health Care* 46, 131-150.

28. Drucker ER, Liese AD, Sercy E *et al.* (2019) Food insecurity, childhood hunger and caregiver life experiences among households with children in South Carolina, USA. *Public Health Nutr* 22, 2581-2590.

29. Duke NN (2021) Food Insecurity and Prediabetes among Adolescents Taking a School-based Survey. *Am J Health Behav* 45, 384-396.

30. Duke NN (2021) Adolescent-Reported Food Insecurity: Correlates of Dietary Intake and School Lunch Behavior. *Int J Environ Res Public Health* 18.

31. Dykstra H, Davey A, Fisher JO *et al.* (2016) Breakfast-Skipping and Selecting Low-Nutritional-Quality Foods for Breakfast Are Common among Low-Income Urban Children, Regardless of Food Security Status. *J Nutr* 146, 630-636.

32. Eicher-Miller HA, Mason AC, Weaver CM *et al.* (2011) Food insecurity is associated with diet and bone mass disparities in early adolescent males but not females in the United States. *J Nutr* 141, 1738-1745.

33. Eicher-Miller HA, Mason AC, Weaver CM *et al.* (2009) Food insecurity is associated with iron deficiency anemia in US adolescents. *Am J Clin Nutr* 90, 1358-1371.

34. Fleming MA, Kane WJ, Meneveau MO *et al.* (2021) Food Insecurity and Obesity in US Adolescents: A Population-Based Analysis. *Child Obes* 17, 110-115.

35. Fram MS, Ritchie LD, Rosen N *et al.* (2015) Child experience of food insecurity is associated with child diet and physical activity. *J Nutr* 145, 499-504.

36. Fulay AP, Vercammen KA, Moran AJ *et al.* (2022) Household and child food insecurity and CVD risk factors in lower-income adolescents aged 12-17 years from the National Health and Nutrition Examination Survey (NHANES) 2007-2016. *Public Health Nutr* 25, 922-929.

37. Fulkerson JA, Kubik MY, Story M *et al.* (2009) Are there nutritional and other benefits associated with family meals among at-risk youth? *J Adolesc Health* 45, 389-395.

38. Gasser CE, Mensah FK, Kerr JA *et al.* (2017) Early life socioeconomic determinants of dietary score and pattern trajectories across six waves of the Longitudinal Study of Australian Children. *J Epidemiol Community Health* 71, 1152-1160.

39. Godrich SL, Loewen OK, Blanchet R *et al.* (2019) Canadian Children from Food Insecure Households Experience Low Self-Esteem and Self-Efficacy for Healthy Lifestyle Choices. *Nutrients* 11.

40. Gundersen C, Lohman BJ, Eisenmann JC *et al.* (2008) Child-specific food insecurity and overweight are not associated in a sample of 10- to 15-year-old low-income youth. *J Nutr* 138, 371-378.

41. Gundersen C, Garasky S Lohman BJ (2009) Food insecurity is not associated with childhood obesity as assessed using multiple measures of obesity. *J Nutr* 139, 1173-1178.

42. Hill B (2020) Evaluating the association between food insecurity and dental caries in US children 1-19 years: results from the National Health and Nutrition Examination Survey (NHANES) 2013-2014. *J Public Health Dent* 80, 14-17.

43. Hobbs S & King C (2018) The Unequal Impact of Food Insecurity on Cognitive and Behavioral Outcomes Among 5-Year-Old Urban Children. *J Nutr Educ Behav* 50, 687-694.

44. Holben DH & Taylor CA (2015) Food Insecurity and Its Association With Central Obesity and Other Markers of Metabolic Syndrome Among Persons Aged 12 to 18 Years in the United States. *J Am Osteopath Assoc* 115, 536-543.

45. Hooper L, Telke S, Larson N *et al.* (2020) Household food insecurity: associations with disordered eating behaviours and overweight in a population-based sample of adolescents. *Public Health Nutr* 23, 3126-3135.

46. Jackson DB & Vaughn MG (2017) Household food insecurity during childhood and adolescent misconduct. *Prev Med* 96, 113-117.

47. Jackson DB & Testa A (2021) Household food insecurity and children's oral health: Findings from the 2016-2018 National Survey of Children's Health. *J Public Health Dent* 81, 150-161.

48. Kaur J, Lamb MM Ogden CL (2015) The Association between Food Insecurity and Obesity in Children-The National Health and Nutrition Examination Survey. *J Acad Nutr Diet* 115, 751-758.

49. King C (2017) Soft drinks consumption and child behaviour problems: the role of food insecurity and sleep patterns. *Public Health Nutr* 20, 266-273.

50. Kirkpatrick SI & Tarasuk V (2008) Food insecurity is associated with nutrient inadequacies among Canadian adults and adolescents. *J Nutr* 138, 604-612.

51. Kirk SF, Kuhle S, McIsaac JL *et al.* (2015) Food security status among grade 5 students in Nova Scotia, Canada and its association with health outcomes. *Public Health Nutr* 18, 2943-2951.

52. Kral TVE, Chittams J Moore RH (2017) Relationship between food insecurity, child weight status, and parent-reported child eating and snacking behaviors. *J Spec Pediatr Nurs* 22.

53. Kuku O, Garasky S Gundersen C (2012) The relationship between childhood obesity and food insecurity: A nonparametric analysis. *Applied Economics* 44, 2667-2677.

54. Landry MJ, van den Berg AE, Asigbee FM *et al.* (2019) Child-Report of Food Insecurity Is Associated with Diet Quality in Children. *Nutrients* 11.

55. Lee AM, Scharf RJ, Filipp SL *et al.* (2019) Food Insecurity Is Associated with Prediabetes Risk Among U.S. Adolescents, NHANES 2003-2014. *Metab Syndr Relat Disord* 17, 347-354.

56. Mangini LD, Hayward MD, Dong YQ *et al.* (2015) Household Food Insecurity is Associated with Childhood Asthma. *J Nutr* 145, 2756-2764.

57. Mangini LD, Hayward MD, Zhu Y *et al.* (2019) Timing of household food insecurity exposures and asthma in a cohort of US school-aged children. *BMJ Open* 8, e021683.

58. Marjerrison S, Cummings EA, Glanville NT *et al.* (2011) Prevalance and associations of food insecurity in children with diabetes mellitus. *J Pediatr* 158, 607-611.

59. Martin KS & Ferris AM (2007) Food insecurity and gender are risk factors for obesity. *J Nutr Educ Behav* 39, 31-36.

60. Masler IV, Palakshappa D, Skinner AC *et al.* (2021) Food insecurity is associated with increased weight loss attempts in children and adolescents. *Pediatr Obes* 16, e12691.

61. Maynard MS, Perlman CM Kirkpatrick SI (2019) Food insecurity and perceived anxiety among adolescents: An analysis of data from the 2009–2010 National Health and Nutrition Examination Survey (NHANES). *Journal of Hunger & Environmental Nutrition* 14, 339-351.

62. McIntyre L, Williams JV, Lavorato DH *et al.* (2013) Depression and suicide ideation in late adolescence and early adulthood are an outcome of child hunger. *J Affect Disord* 150, 123-129.

63. McLaughlin KA, Green JG, Alegría M *et al.* (2012) Food insecurity and mental disorders in a national sample of U.S. adolescents. *J Am Acad Child Adolesc Psychiatry* 51, 1293-1303.

64. Mendoza JA, Haaland W, D'Agostino RB *et al.* (2018) Food insecurity is associated with high risk glycemic control and higher health care utilization among youth and young adults with type 1 diabetes. *Diabetes Res Clin Pract* 138, 128-137.

65. Molcho M, Gabhainn SN, Kelly C *et al.* (2007) Food poverty and health among schoolchildren in Ireland: findings from the Health Behaviour in School-aged Children (HBSC) study. *Public Health Nutr* 10, 364-370.

66. Niemeier J & Fitzpatrick KM (2019) Examining food insecurity among high school students: A risks and resources model. *Appetite* 135, 20-27.

67. Ovenell M, Azevedo Da Silva M Elgar FJ (2022) Shielding children from food insecurity and its association with mental health and well-being in Canadian households. *Can J Public Health* 113, 250-259.

68. Parker ED, Widome R, Nettleton JA *et al.* (2010) Food security and metabolic syndrome in U.S. adults and adolescents: findings from the National Health and Nutrition Examination Survey, 1999-2006. *Ann Epidemiol* 20, 364-370.

69. Poulsen MN, Bailey-Davis L, Pollak J *et al.* (2019) Household Food Insecurity and Home Food Availability in Relation to Youth Diet, Body Mass Index, and Adiposity. *J Acad Nutr Diet* 119, 1666-1675.

70. Ramsey R, Giskes K, Turrell G *et al.* (2011) Food insecurity among Australian children: potential determinants, health and developmental consequences. *J Child Health Care* 15, 401-416.

71. Robson SM, Lozano AJ, Papas M *et al.* (2017) Food Insecurity and Cardiometabolic Risk Factors in Adolescents. *Prev Chronic Dis* 14, E110.

72. Soldavini J & Ammerman AS (2021) Marginal, Low, and Very-Low Food Security among Children Are Associated with Intake of Select Dietary Factors during Summer. *J Acad Nutr Diet* 121, 728-737.

73. South AM, Palakshappa D Brown CL (2019) Relationship between food insecurity and high blood pressure in a national sample of children and adolescents. *Pediatr Nephrol* 34, 1583-1590.

74. Tan ML, Laraia B, Madsen KA *et al.* (2019) Child Food Insecurity Is Associated with Energy Intake among Fourth- and Fifth-Grade Girls. *J Acad Nutr Diet* 119, 1722-1731.e1722.

75. Tester JM, Laraia BA, Leung CW *et al.* (2016) Dyslipidemia and Food Security in Low-Income US Adolescents: National Health and Nutrition Examination Survey, 2003-2010. *Prev Chronic Dis* 13, E22.

76. Tevie J & Shaya F (2018) Does food security predict poor mental health? *Journal of Public Mental Health* 17, 3-10.

77. To QG, Frongillo EA, Gallegos D *et al.* (2014) Household food insecurity is associated with less physical activity among children and adults in the U.S. population. *J Nutr* 144, 1797-1802.

78. Turner VE, Demissie Z, Sliwa SA *et al.* (2022) Food Insecurity and Its Association With Alcohol and Other Substance Use Among High School Students in the United States. *J Sch Health* 92, 177-184.

79. Widome R, Neumark-Sztainer D, Hannan PJ *et al.* (2009) Eating when there is not enough to eat: eating behaviors and perceptions of food among food insecure youths. *Am J Public Health* 99, 822-828.

80. Wirth SH, Palakshappa D Brown CL (2020) Association of household food insecurity and childhood weight status in a low-income population. *Clin Obes* 10, e12401.

81. Yang TC, Sahota P, Pickett KE *et al.* (2018) Association of food security status with overweight and dietary intake: exploration of White British and Pakistani-origin families in the Born in Bradford cohort. *Nutr J* 17, 48.

82. Zhu Y, Mangini LD, Hayward MD *et al.* (2020) Food insecurity and the extremes of childhood weight: defining windows of vulnerability. *Int J Epidemiol* 49, 519-527.

83. Huang J, Oshima KM Kim Y (2010) Does food insecurity affect parental characteristics and child behavior? Testing mediation effects. *Soc Serv Rev* 84, 381-401.

84. Masarik AS & Conger RD (2017) Stress and child development: A review of the Family Stress Model, pp. 85-90: Elsevier Science.

85. Dinour LM, Bergen D Yeh MC (2007) The food insecurity-obesity paradox: a review of the literature and the role food stamps may play. *J Am Diet Assoc* 107, 1952-1961.

86. Oldroyd L, Eskandari F, Pratt C *et al.* (2022) The nutritional quality of food parcels provided by food banks and the effectiveness of food banks at reducing food insecurity in developed countries: a mixed-method systematic review. *J Hum Nutr Diet* 35, 1202-1229.

87. Fallaize R, Newlove J, White A *et al.* (2020) Nutritional adequacy and content of food bank parcels in Oxfordshire, UK: a comparative analysis of independent and organisational provision. *J Hum Nutr Diet* 33, 477-486.

88. Hanson KL & Connor LM (2014) Food insecurity and dietary quality in US adults and children: a systematic review123. *The American Journal of Clinical Nutrition* 100, 684-692.

89. Berge JM, Fertig AR, Trofholz A *et al.* (2020) Associations between parental stress, parent feeding practices, and child eating behaviors within the context of food insecurity. *Prev Med Rep* 19, 101146.

90. Keenan GS, Christiansen P Hardman CA (2021) Household Food Insecurity, Diet Quality, and Obesity: An Explanatory Model. *Obesity (Silver Spring)* 29, 143-149.

91. Weigel MM & Armijos RX (2023) Food insecurity is associated with self-reported oral health in school-age Ecuadorian children and is mediated by dietary and non-dietary factors. *Public Health Nutr* 26, 23-32.

92. Grant MJ & Booth A (2009) A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal* 26, 91-108.

93. Lambie-Mumford H LR, Okell A (2023) *Household food insecurity in the UK: data and research landscape*.

94. Bernard R, Hammarlund R, Bouquet M *et al.* (2018) Parent and Child Reports of Food Insecurity and Mental Health: Divergent Perspectives. *Ochsner J* 18, 318-325.

95. Rutter H, Savona N, Glonti K *et al.* (2017) The need for a complex systems model of evidence for public health. *Lancet* 390, 2602-2604.

96. Grant RL & Hood R (2017) Complex systems, explanation and policy: implications of the crisis of replication for public health research. *Critical Public Health* 27, 525-532.
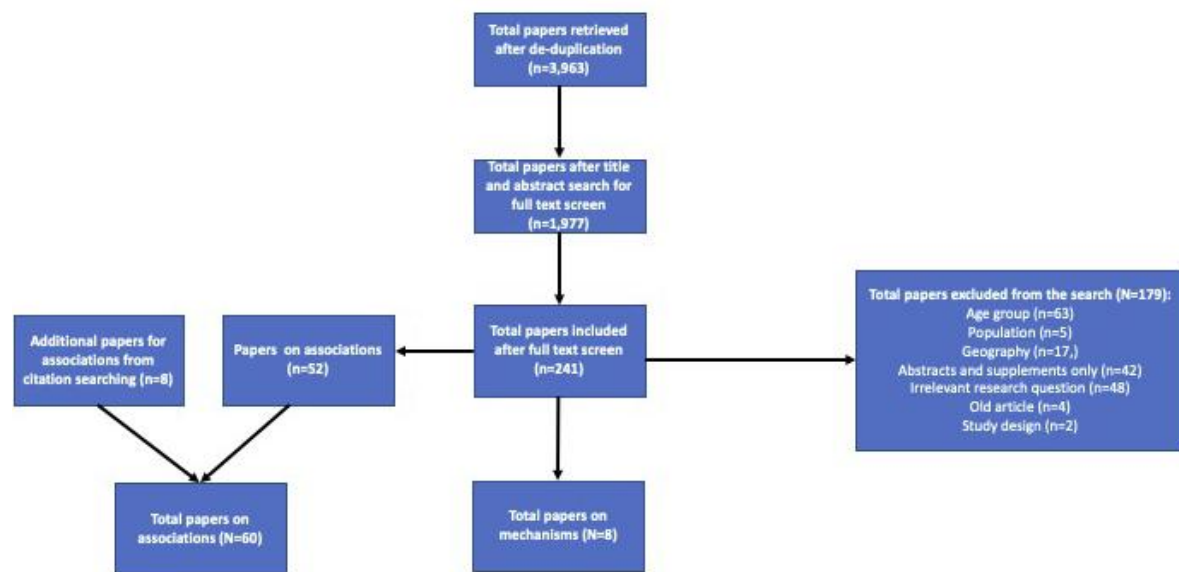
Figure 1 *Summary of search results for studies assessing the mechanisms by which HFI relates to child and adolescent health outcomes, and studies assessing the association of HFI and various child and adolescent health outcomes (including appropriate parental outcomes). *Backwards and forward citation searching strategy identified additional studies assessing associations of HFI and child and adolescent health outcomes.*
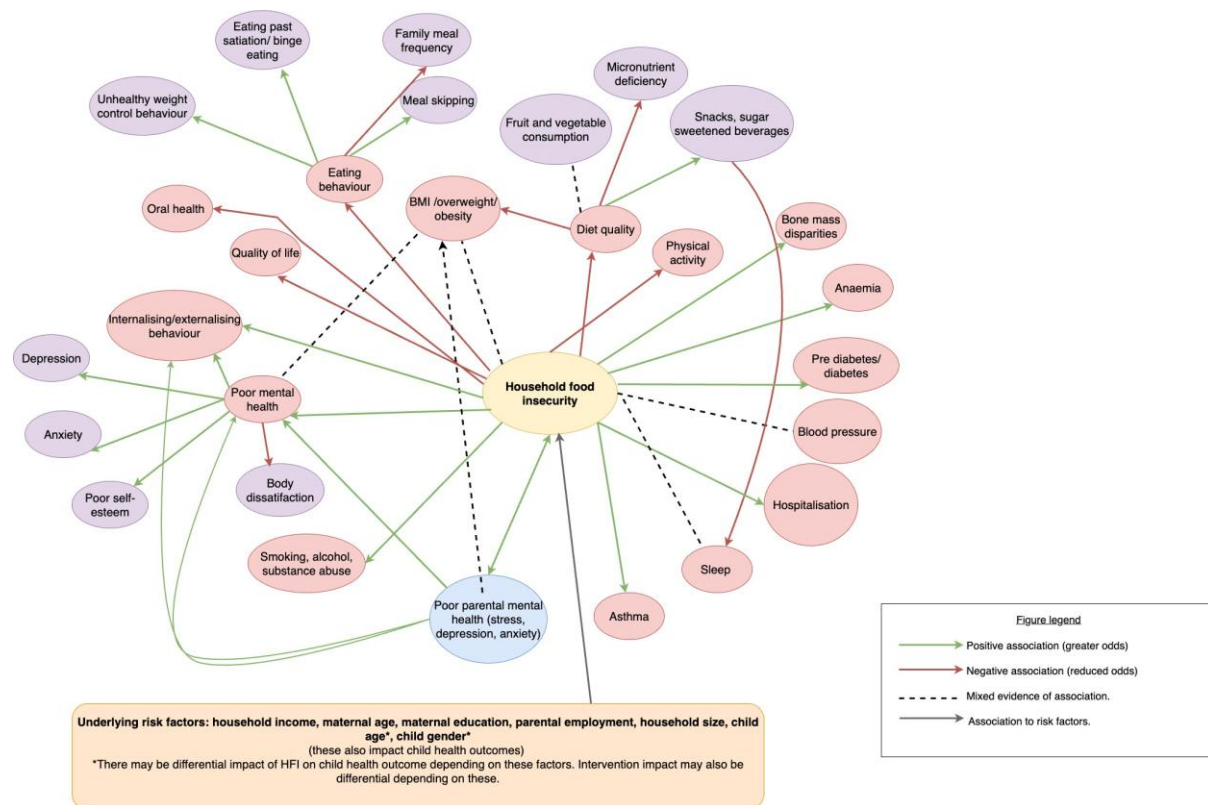
Figure 2 *Conceptual framework of review results of mechanisms and associations reported between HFI and child/adolescent health outcomes and parental mental health outcomes. Red arrows indicate odds ratio >1 between HFI and outcomes, green arrows indicate odds ratio >1 between HFI and outcomes, thick dashed line indicates mixed evidence regarding an association between HFI and outcomes or between outcomes.*

Table 1:Search strategy including search concepts, search terms and their combinations.

Concept	No	Search statement
Concept 1: Food Insecurity	1	*Food Insecurity/
	2	*Food Security/
	3	Food insecurity. Ti.
	4	Food security. Ti.
	5	Food poverty. Ti.
	6	1 or 2 or 3 or 4 or 5
Concept 2: Quantitative analysis	7	*Statistics as Topic/
	8	Structural equation model*. Ti, ab.
	9	Regression. Ti, ab.
	10	Conceptual model*. Ti, ab.
	11	ical model*. Ti, ab.
	12	7 or 8 or 9 or 10 or 11
	13	6 AND 12

Table 2: Inclusion and exclusion criteria used to include studies.

Criteria points	Inclusion	Exclusion
Population	• Children and adolescents • Households with children • Child-parent dyads	• Non- human studies • Adults only studies (> 24 years)
Geography	• High income developed countries	• Low-middle income countries • Developing countries that do not reflect the UK child and adolescent population
Study design	• Observational studies	• Clinical trials • Systematic review
Settings	• Communities, schools, households	
Exposure of interest	• Household food insecurity • Food poverty	
Outcome of interest	• Impact of exposure on any child/adolescent health outcomes • Association between exposure and mediators of non-communicable diseases and conditions • Variables identified as mechanisms	
Language	• English language studies	• Non- English language studies
Date of publication	• Articles published in the last 15 years	• Articles published over 15 years ago
Publication type	• Journal articles	• Conference papers • Supplementary papers • Poster presentations

Table 3: Included studies that evaluate mechanisms by which HFI may be related to child/adolescent health outcomes. Abbreviations: aOR: adjusted odds ratio, CI: confidence interval, HFI: household food insecurity, OR: odds ratios, QA: quality assessment, SE: standard error. USDA, United States Department of Agriculture.

Study	Country	Dataset (design)	Sample size	Child-age (years)	Food insecurity Measure (person reporting)	Health outcome	Statistical method	Key results	QA
Bahanan et al., (2021)[15]	US	NHANES 2011/2012 and 2013/2014 (cross-sectional)	N=4822	5-17	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Dental cavities • Dietary quality	• Multiple logistic regression predicting caries from HFI and diet quality. • Bivariate analyses • Classic mediation methods (Baron and Kenny approach) • Confounders included age, sex, race, family income, food programme participation, household size, dental visits and total number of teeth	• Untreated dental caries were more likely to occur in food insecure than food-secure children (aOR=1.38, 95% CI 1.11-1.72) • Very low HFI (aOR=1.59, 95% CU 1.12-2.26) and marginal HFI (aOR=1.48, 95%CI 1.10-2.01) was associated with untreated caries but low HFI was not (aOR=1.20, 95% CI 0.92-1.55) • Food security was associated with greater whole fruit consumption (p=0.01) and plant protein consumption (p=0.008) but diet quality was not	Low

							associated with untreated caries (p=0.07).	
Do et al., (2021)[16]	US	FLASHE study (cross-sectional)	N=1544	12-17	US Food Security 2-item screener (parent)	• Obesity/ overweight • Sleep	• Multinomial regression to test for association between outcomes and HFI • Conditional processing modelling to evaluate moderating and mediating roles of HFI and sleep • Cofounders included: Age, gender, race/ethnicity, parent weight status, parent education, and parent income.	• HFI was associated with overweight (OR=1.56 95% CI 1.13-2.15) and obesity (OR=1.96 95% CI 1.40-2.74) p<0.05 • HFI was associated with overweight (aOR=1.40 95% CI 1.00-2.00) p<0.05. • HFI was not associated with mean-centred sleep duration (β= -0.08, SE= 0.23, p=0.73) • Sleep did not mediate the relationship between HFI and weight status • HFI did not moderate the relationship between mean centred sleep duration (p=0.109) or weight status (p=0.206) • HFI did not moderate a relationship between	Low

							sleep and weight status.
Gee and Asim (2019)[17]	US	Early Childhood Longitudinal Study Kindergarten Class of 2010-2011 (longitudinal)	N=7820	4-5	First 10 items USDA Survey Module (parent)	• Parental aggravation • Child behaviour, internalising and externalising	• First-difference regression analysis to estimate how HFI related to parenting aggravation. • Structural equation to test whether parenting aggravation mediated relationship between HFI (reported 12 months prior to Spring of 1st grade) and children's outcomes (reported in Spring of 1st grade) • Confounders included: Parent cohabitation	• HFI associated with parental aggravation (β=0.376, SE=0.12, p<0.01) which was indirectly related to children's lowered ability to pay attention (β=- 0.062, SE=0.026. p<0.05), inhibitory control (β= -0.093, SE= 0.027, p<0.001), externalising behaviours (β= 0.43, SE=0.12, p<0.001) but not internalising behaviours (β= 0.008, SE= 0.10). No direct paths from HFI to these child health outcomes were observed. Low

					status, employment, receipt of food stamps, number of siblings, household socioeconomic status, access to medical care, parent-teacher meeting participation.		
Gundersen et al., (2008a)[18]	US	NHANES 1999-2002 (cross-sectional)	N= 841	3-17	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Obesity/ overweight • Four maternal stress indices (cumulative mental stressor index, cumulative physical	• Probit maximum likelihood models used to assess associations with a child's probability being at risk of overweight. Five models estimated: 1. HFI 2. HFI and 4 maternal stressor indices 3. HFI, the 4 maternal stressors, and interaction of	• HFI alone was not associated with child overweight/obesity (β= -0.15, 95% CI -0.38-0.09). • The impact of maternal stressors on child overweight is reduced when household was food insecure (β= 0.05, 95% CI 0.00-0.10) • When stratified by age, an association between cumulative maternal stressors and HFI found	Low

					stressor index, cumulative family structure stressor index, total cumulative stressor index).	4. these indices with HFI 4. HFI and a total cumulative maternal stressor index 5. HFI, the total cumulative maternal stressor index and the interaction of this index with HFI • Confounders included: child age, income-to-poverty ratio, child ethnicity, maternal BMI, maternal age and maternal education.	for children aged 3-10 years old, which was linked to being overweight (β= 0.08, 95% CI 0.02-0.15, p<0.05). Effect was not seen in children aged 11-17.
Hatem et al., (2020)[19]	US	Fragile Families and Child Well-Being Study (longitudinal)	N=2626	15	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Adolescent mental health • Maternal depression and stress	• Structural equation modelling • Confounders included: Child gender, health insurance, child race/ethnicity, maternal and household characteristics at	• HFI at age 5, had a direct relationship with adolescent anxiety symptoms (β=0.913 95% CI 0.064-1.814, p<0.001). • An indirect effect from HFI and housing instability at age 5 was observed via maternal	Moderate

					year 3: education, cohabitation, employment, income (based on the family income to the federal poverty line) and parent incarceration.			• A direct association was observed for HFI at age 5 and greater depressive symptoms in adolescence ($\beta= 0.626$, 95% CI 0.052-1.226). • An indirect effect was observed for housing instability and HFI via parenting stress to maternal depression to adolescent depression ($\beta=0.008$, 95% CI 0.002-0.016). • Maternal depression predicted higher parenting stress ($\beta=0.161$, 95% CI 0.096-0.227).	depression to parenting stress to adolescent anxiety ($\beta=0.055$, 95% CI 0.007-0.110).	
Lohman et al., (2009)[20]	US	Welfare, Children and Families: A three-city study – a study	N=1011	10-15	USDA module 18-item questionnaire of HFI experience over past 12 months	• Overweight/obesity • Individual/maternal/family stressors	Logistic regression modelling, two models: 1. HFI and the stressor indices 2. HFI, the stressor indices and the	• Maternal stressors interact with HFI, and both are associated with child overweight/ obesity, and this was statistically significant (OR= 1.79 95% CI	Low

		of families below 200% of the poverty line (longitudinal)				(parent)		(individual stressor index, maternal stressor index and family stressor index)	interaction of these indices with HFI • Confounders included: • Age, gender, ethnicity, television viewing, disability limitations and low birth weight. Maternal immigration status, in receipt of food stamps, education, BMI and age. Household's income to needs ratio.	0.82-3.92, p<0.001)
Marcal (2022)[21]	US	Fragile Families and child well-being longitudinal survey (longitudinal)	N=2454	15	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Adolescent mental health • Parenting stress		• Structural equation modelling • Confounders included: Maternal age, ethnicity, education, household income, cohabitation status, family history of mental disorder, child	• HFI reported at age 5 years, was not directly associated with greater adolescent depressive behaviours (β=-0.109, 95% CI -0.253-0.002) or aggressive behaviours (β=-0.031, 95% CI -0.134-0.058) • HFI reported at age 5 years was indirectly	Low

						gender.			associated with adolescent aggressive behaviours (β= 0.025, 95% CI 0.009-0.049) and depressive behaviours (β= 0.032, 95% CI 0.0132-0.064) via parenting stress reported when the child was aged 9 years.	
Willis and Fitzpatrick (2016)[22]	US	Data from a school in Northwest Arkansas in 2012 (cross-sectional)	N=324	10-13	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Weight status	• Ordinary least squares regression • Confounders included: gender and ethnicity	• HFI was associated with weight status (p<0.001) • This relationship was mediated by social status (β=-0.112, p<0.05) and depression (β=0.109, p<0.05).	Moderate

Table 4: Included studies that evaluate associations between HFI and various child/adolescent health outcomes. Abbreviations: ApoB: Apolipoprotein B-100, B: beta, BMI: body mass index, CI: confidence interval, HBA1c: haemoglobin A1C, HDL: high density lipoproteins, OR: odds ratio, PR: prevalence ratio, RR: relative risk, SD, standard deviation, SE, standard error, TG, Triglycerides.

Study	Country	Dataset (design)	Sample size	Child-age (years)	Food insecurity Measure (person reporting)	Health outcome	Statistical method	Key results
Altman et al., (2019)[23]	US	N/A data obtained for analysis from a randomised trial (trial)	N=4822	10-14	Child-Food Security Assessment over prior 12 months (child)	• Mental health • Self-esteem/ body dissatisfaction	• Multivariable logistic regression • Confounders included: Race/ethnicity, free/reduced priced school meals (proxy for socioeconomic status), age and gender.	• Food insecure adolescents had greater odds of reporting body dissatisfaction, and this was prevalent across children of all ethnic groups and BMI categories. • The association was stronger in children of normal weight (OR= 1.76 p<0.001) and of African American ethnicity (OR=2.32 p<0.001).
Appelhans et al., (2014)[24]	US	Home Environment Comparison	N=103	6-13	USDA module 18-item	• Food availability • Child eating	• Logistic regression • Confounders included: Negative	• Increased food security was associated with increased availability of home food

		Study (cross-sectional)			questionnaire of HFI experience over past 12 months (parent)	behaviours	cooking attitudes, financial strain, household size, caregiver employment status and education	supplies (p=0.02) and more frequent family meals (very low HFI OR=1.95 95% CI 0.55-6.81, low HFI OR=3.44 95% CI 1.29-9.18, marginal HFI OR=1.51 95% CI 0.57-3.97) and home-made dinners (very low HFI OR=1.51 95% CU 0.34-6.84, low HFI OR=
Bauer et al., (2015)[25]	US	EAT 2010 and Project F-EAT (cross-sectional)	N=2807	14	6 item- US Household Food Security Survey Module assessment of HFI experience over past 12 months (parent)	• Weight status (obesity) • Parental feeding styles	• Chi-square tests and F-tests • Confounders included: Mothers BMI, household income, number of children living in the house (under 18 years old), mothers' education, employment status, race/ethnicity, adolescent age and gender	• Association found between HFI severity and BMI percentiles in males (food-secure mean (SD)= 65.8 (0.3), low food security mean (SD) = 72.0 (0.30), very low food security mean (SD) = 70.01 (0.30) (p=0.02)
Bruening et al., (2017)[26]	US	Exploratory pilot study recruitment from six public housing sites	N=55	12-16	6 item- US Household Food Security Survey	• Mother eating habits and behaviours. • Child eating habits and	• Multivariate mixed linear • Logistic regression • Confounders included: Maternal	• Adolescent intake of fast food (p<0.001), binge eating (p=0.011), intuitive eating (p=0.032) and partaking in family meals (p=0.001) was

		2014 (cross-sectional)			Module assessment of HFI experience over past 12 months (parent)	behaviours	age, US born status, cohabitation status, education status, household, child age and gender	significantly associated with mothers after. The odds of these associations between mother and child were greater in food insecure households.
Canter, Roberts and Davis (2017)[27]	US	Recruitment while receiving services or through other organisations providing services to low-income parents/caregivers 2013 (cross-sectional)	N=148	5-10	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Dietary quality • Physical activity	• Structural equation modelling • Confounders included: Child gender, race/ethnicity, annual income, household size, children in the household (under 18 years)	• HFI was significantly associated with lower consumption of vegetables (p<0.05) • Children who did more physical activity were more likely to consume more vegetables (p<0.01).
Drucker et al., (2019)[28]	US	The Midlands Family Study (cross-sectional)	N=511	<18	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Parental characteristics: caregiver life experience	• Multinomial logistic regression • Confounders included: Child age, gender, ethnicity, household income	• HFI was significantly associated with negative caregiver life experiences (OR= 1.16, 95% CI 0.88-1.04, p <0.05) which is in turn was associated with greater odds of child hunger (OR=1.08, 95% CI 1.05-1.11, p <0.05)

Duke (2021a)[29]	US	2019 Minnesota Student Survey (cross-sectional)	N=12537 5	12-19	1 question on the survey: "During the past 30 days have you had to skip meals because your family did not have enough money to buy food?' (adolescent)	• Prediabetes risk • BMI/weight status	• Multivariable logistic regression • Confounders: Low quality diet, physical activity, BMI, sleep, age, gender, socioeconomic indicator (free or reduced-price lunch), region, ethnicity	• HFI was associated with prediabetes (OR=1.93, 95% CI 1.59=2.32, p <0.001). • Significant associations highest between HFI and prediabetes were observed for non-Hispanic Black African Americans (OR= 1.88, 95% CI 1.52-2.31, p<0.001), Hispanic/Latino (OR=2.49, 95%CI 2.06-3.01, p<0.001) and non-Hispanic White students (OR=2.20, 95% CI 1.49-3.25, p<0.001) • BMI strong predictor of prediabetes (OR=4.34, 95% CI 3.84-4.90, p<0.001)
Duke (2021b)[30]	US	2019 Minnesota Student Survey (cross-sectional)	N=12537 5	12-19	1 question on the survey: "During the past 30 days have you had to skip meals because your family did not have enough money to buy food?' (adolescent)	• Dietary intake and quality • Eating behaviour	• Multivariable logistic regression • Model 1: association between HFI and food/beverage consumption accounting for sociodemographic covariates and housing instability • Model 2 multivariable	• Results are from model 2 but are similar to model 1 results as well. • Food insecure adolescents were more likely to consume less than the minimum recommended intake for fruit (OR=0.76 95% CI 0.69-0.82, p<0.001), dairy (OR=0.67, 95% CI 0.58=0.76, p<0.001) and vegetables (OR=0.86, 95% CI 0.75-0.98, p <0.001) than those who are food-

						association between HFI and food/beverage consumption accounting for sociodemographic covariates, housing instability and indicators of physical and emotional health • Confounders included: Gender, age, race/ethnicity, free or reduced-price lunch, region, housing instability		secure • Food insecure adolescents were more likely to consume more sugar sweetened beverages (OR=1.21, 95% CI 1.12-1.30, p <0.001) and fast-food items (OR=1.62, 95% CI 1.49-1.76, p<0.001) than food-secure adolescents • Food insecure adolescents had greater odds of skipping lunch than food-secure adolescents (OR=1.80, 95% CI 1.67-1.95, p <0.001).
Dykstra et al., (2016)[31]	US	Part of a larger survey of convenience sample of mothers (cross-sectional)	N=821	2-13	6 item- US Household Food Security Survey Module assessment of HFI experience over past 12 months (parent)	• Dietary intake and quality	• Linear regression– accounting for within school clustering of outcomes • Confounders included: Child age, gender, free or reduced-price lunch status, ethnicity	• HFI was associated with reduced dairy consumption food insecure 37.8% vs 49.4% in food-secure children, p<0.03) • HFI associated with increased candy consumption (11.5% vs 8.4%) than food-secure children, p<0.03.

Eicher-Miller et al., (2011)[(32)]	US	NHANES 1999-2004 (cross-sectional)	N=11247	12-15	USDA module 18-item questionnaire of HFI experience over past 12 months (parent if child <11)	• Iron deficiency. • Anaemia	• Logistic regression •Confounders included: Poverty to income ratio, race ethnicity, smoker in the house, birth weight, age, gender, use of dietary supplement, household participant in welfare or food assistance programmes	• HFI associated with 2.95 times greater odds of iron defiency anaemia (OR=2.95, 95% CI 1.18-7.37, p=0.02).
Eicher-Miller et al., (2009)[(33)]	US	NHANES 2001-2004 (cross-sectional)	N=5270	8-19	USDA module 18-item questionnaire of HFI experience over past 12 months (parent if child <11)	• Dietary intake • Micronutrient defiency • Bone mass disparities	• Multiple linear regression for BMC content (gender specific) • Multiple logistic regression for micronutrient analysis (genders together) • Confounders included: Survey cycle year, race/ethnicity, poverty income ratio, smoking, use of dietary supplement,	• HFI was associated with reduced odds of consuming the USDA food guide recommended serving of dairy (OR=2.5 95% CI 1.1-5.8, p=0.03) in male adolescents • HFI was associated with reduced odds of consuming recommended calcium intake (OR=2.3 95% CI 1.3-4.0, p<0.01) • HFI was associated with less bone mineral content in the total body (p=0.04), spine (p=0.02), left arm (p=0.05), and trunk (p=0.05) in males

					participation in welfare or food assistance programmes		aged 8-11.
Fleming et al., (2021)[34]	US	NHANES 2007-2016 (cross-sectional)	N=4777	13-18	Household: USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Weight status, obesity	• Multivariable logistic regression • Confounders included: Age, race, sex, household poverty level, routine access to healthcare	• There was a higher prevalence obesity in food insecure than food-secure child populations (PR=1.3 95% CI 1.2-1.5, p<0.001). • HFI was not statistically significantly associated with obesity (OR=1.19, 95% CI 1.0-1.4, p=0.08).
Fram et al., (2015)[35]	US	NHANES 2007-2016 (cross-sectional)	N=3605	12-17	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Dietary intake • Adolescent awareness of HFI	• Mixed-effects linear and logistic regression • Alpha 0.05 for significance and alpha <0.10 considered marginal significance • Confounders included: child age, gender and intervention group	• HFI was associated with higher consumption of energy (OR=49.61, 95% CI 9.80-89.43, p= 0.02), fat, (OR=0.45, 95% CI 0.013-0.89, p = 0.05), sugar (OR=0.79, 95% CI 0.0098-1.57, p=0.05) and fibre (β=0.13, 95% CI 0.023-0.24, p=0.02). • HFI was associated with reduced consumption of vegetables (β = -1.52, 95% CI -4.11 – 1.08, p=0.25) and

								increased consumption of fruit (β= 1.36, 95% CI -2.44-5.16m p=0.48), but this was not significant.
								• Adolescents showed awareness of HFI in terms of their cognition, emotions, and physical (hunger) recognition
Fulay et al., (2022)[36]	US	NHANES 2007-2016 (cross-sectional)	N=5076	12-17	USDA module 18-item questionnaire of HFI experience over past 12 months (parent	• Child weight status • BMI • Metabolic biomarkers (glucose, TAG, cholesterol) • Blood pressure	• Multivariable linear regression • Confounders included: Age, sex, race/ethnicity, activity level, household income: poverty, respondent education level and marital status	• No significant association was determined between HFI and child BMI (β=0.14 95% CI -0.01-0.28), systolic blood pressure (β=0.18, 95% CI -1.07 – 1.43, diastolic blood pressure (β=-0.09, 95% CI -1.25-1.07), and metabolic biomarkers (including total cholesterol (β =-1.07, 95 % CI -4.69 – 2.55, fasting TAG (β= 3.81 95% CI -4.61-12.24), and fasting blood plasma glucose (β=0.97, 95% CI =0.52-2.47) • All models adjusted for age, ethnicity, gender, smoking, sedentary time, activity, respondent education, marital status and income • All p-values >0.05

Fulkerson et al., (2009)[37]	US	Team COOL (cross-sectional)	N=145	15-18	One-item assessment in survey (adolescent): "How often during the past 12 months have you been hungry because your family couldn't afford more food?"	• Dietary intake • Child mental health • Eating behaviour	• Mixed model logistic and linear regression • Confounders included: Race/ ethnicity, SES< age, gender	• Adolescents who did not participate in family meals had greater odds of being overweight (OR=2.8, 95% CI 1.1-6.9, p<0.05) and food insecure (OR=6.0 95% CI 2.2-16.4, p<0.05) than children who are family meals. • Family meals were associated with food security, increase breakfast (p<0.05) and fruit consumption (p<0.01) as well as lower rates of depressive symptoms in adolescents (p<0.05)
Gasser et al., (2017)[38]	Australia	Longitudinal study of Australian Children (longitudinal)	N= 4,569-5107	2-15	One item on the questionnaire asked to parent "whether over the last 12 months, due to shortage of money, they had financial limits on the type of food	• Dietary intake/quality	• Multinomial logistic regression • Confounders included: Childs number of older siblings, child from multiple births or not, parental education, socioeconomic status, age, ethnicity, parents age	• Poorer children tended to report higher on the "never healthy" rather than "always healthy" domain compared to children of higher socioeconomic groups (OR=16.40, 95% CI 9.40-28.61 p<0.05).

					they could buy"						
Godrich et al., (2019)[39]	Canada	Canadian Children's Lifestyle and School Performance Study II (cross-sectional)	N=5281	10-11	6 item- US Household Food Security Survey Module assessment of HFI experience over past 12 months (parent)	•	Child mental health (self-esteem)	• Multivariable logistic regression • Confounders included: Gender, region of residence, parent educational attainment, household income and bodyweight status	• HFI was associated with higher odds of poor self-esteem insecure in girls (OR=2.19, 95% CI 1.57-3.07, p<0.001) and severely food insecure boys (OR=1.68, 95% CI 1.11-2.53, p=0.014)
Gundersen et al., (2008b)[40]	US	The Three City Study (longitudinal)	N=1031	10-15	3-items taken from child specific questions of USDA module 18-item questionnaire of HFI experience over past 12 months	•	Obesity/overweight/ BMI	• Logistic regression • Confounders included: Child ethnicity, race/ethnicity. Household: needs ratio caregiver education level; immigration level, whether the family eat meals together, housing stability,	• HFI was associated with overweight, but this was not statistically significant difference observed (OR=0.97, 95% CI 0.65-1.86, p=0.72)

					(parent).			caregiver marital status, caregiver age and household size	
Gundersen et al., (2009)[41]	US	NHANES 2001-2004 (cross-sectional)	N=2516	8-17	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Obesity measures (BMI, waist circumferences, triceps skinfold, trunk fat mass and percentage of body fat	• Logistic regression • Confounders included: child age, race/ethnicity, gender, annual household income:poverty	• No statistically significant association reported. • For the risk of obesity: • BMI & food insecure OR = 1.14 (95% CI 0.84-1.54) • Weight circumference & food insecure OR= 1.136 (95% CI 0.848-1.523) • Triceps skinfold and HFI = OR= 1.070 95% CI (0.754-1.519) • Trunk fat mass and HFI OR= 1.21 95% CI 0.858-1.465) • Body fat % and HFI OR= 1.051 (95% CI 0.821-1.346) • No p-values provided in this article.	
Hill (2019)[42]	US	NHANES 2013/2014 (cross-sectional)	N=4406	1-19	USDA module 18-item questionnaire of HFI experience over past 12 months	• Dental cavities	• Logistic regression • Confounders included: Race/ethnicity, age, income: poverty, assistance programmes, dental caries status	• Children from very low food-secure households were more likely to have dental caries than food-secure children (OR=3.51, 95% CI 1.71-7.19, p=0.0003) • Odds were greater in older age groups (p<0.0001)	

(parent)

Author	Country	Study (design)	N	Age	Exposure measure	Outcome	Analysis/Confounders	Results
Hobbs and King (2018)[43]	US	Fragile Families and Child Wellbeing Longitudinal Study (cross-sectional)	N=2046	5	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Child mental health and behaviour problems	• Unconditional quantile regression • Confounders included: Mothers race/ethnicity, low birth weight, maternal education mother cohabitation status, mothers' employment status, parent smoking and drug use, mother immigration status, assistance programme	• HFI was associated with more behavioural problems (externalising and internalising) and the association was greater in children with the most behaviour problems (p<0.05)
Holben and Taylor (2015)[44]	US	NHANES 1999-2006 (cross-sectional)	N=7435	12-18	USDA module 18-item questionnaire of HFI experience over past 12 months	• Obesity/ overweight/ BMI • Blood pressure • Cholesterol, triglyceride, HDL, LDL	• Logistic regression • Confounders included: age, sex and ethnicity	• Children who were marginally food-secure, low food-secure, and very low food-secure were 1.3-1.4 times more likely to be overweight than children experiencing high food security (p=0.036)

					(parent)			• Children who were marginally food-secure were 1.2-1.4 times more likely to be obese than children who were fully food-secure (p=0.036) • Marginally, low and very low food security was associated with 1.4 to 1.5 times greater central obesity than high food security (p=0.002). • There was no statistically significant difference in mean blood pressure across levels of HFI (High vs marginal OR= 0.83, 95% CI 0.54-1.28, High vs low OR= 0.99, 95% CI 0.54-1.81, High vs very low OR= 1.49, 95% CI 0.94-2.34) (p=0.31) • There was no difference in mean glucose(p=0.59) and triglyceride levels (p=0.97) between food security severities.
Hooper et al., (2020)[45]	US	EAT and Project-F-EAT (cross-sectional)	N=2285	10-22	Short form 6-item USDA based form of the past 12 months	• Obesity/ overweight/ BMI • Child eating behaviour	• Logistic and negative binomial regression • Analyses performed	• The prevalence of obesity among food insecure populations was higher than in food-secure (42.3% vs 39.8%; p=0.039)

			(parent)				• separately between males and females • Confounders included: Age, gender ethnicity/race, parental education		• In analyses, adjusting for gender, ethnicity, age and parental education HFI was not associated with overweight (35.6% vs 37.6%, p=0.39). • FI adolescents reported lower breakfast consumption per week (p=0.005) • FI adolescents partook in more unhealthy weight control behaviours (fasting <0.001, eating very little food p=0.006, skipping meals p=0.001, laxative use p=0.018, diuretic use 0.001) compared to food-secure adolescents (p<0.001)
Jackson and Vaughn (2017)[46]	US	Early Childhood Longitudinal Study, Kindergarten class 1998-1999 (longitudinal)	N=7028	13-14	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Child mental health, misconduct behaviours	• Logistic regression • Confounders included: Age, race/ethnicity BMI, neurological defects, SES composite score (parental education, employment, occupational prestige, income,		• Persistent HFI was associated with misconduct disorder in males (OR=1.73, 95% CI 1.44-2.07) • Misconduct rate was 96% higher in persistently food insecure males than food-secure males • Misconduct rate was 39% higher in persistently food insecure females than food-secure females

						neighbourhood disadvantage), low parental involvement, physical punishment and parent depression	
Jackson and Testa (2021)[47]	US	National Survey of Children's Health 2016-2018 (cross-sectional)	N=99962	9-10	One question on cross-sectional survey with multiple choice answers "Which of these statements best described the food situation in your household in the past 12 months?"	• Oral health	• Logistic regression and negative binomial regression, four models: 1) unadjusted models for each child oral health outcome, 2) adjusting for covariate, 3) further adjustments for socioeconomic, insurance and oral health care variables	• Moderate-Severe HFI was associated with poorer oral health across all models (model 3 results OR=1.91, 95 % CI 1.61-2.27, p<0.01) and tooth decay/ dental cavities (model 3 results OR=1.56, 95 % CI 1.38-1.75, p <0.01).
Kaur et al., (2015)[48]	US	NHANES 2001-2010 (cross-sectional)	N=9701	2-11	USDA module 18-item questionnaire of HFI	• Obesity	• Logistic regression • Confounders included: Sex, ethnicity, poverty to income ratio	• HFI was associated with obesity in children aged 6-11 (OR=1.81 95% CI 1.33-2.48, p<0.001) but not in younger children aged 2-5 years old

					experience over past 12 months (parent)		and survey period	• (OR= 0.88, 95% CI 0.51-1.51, p=0.64). • Models were adjusted for sex, ethnicity, poverty-to-income ratio and survey period.
King (2017)[(49)]	US	Fragile Families and Child Wellbeing Study (cross-sectional)	N=2829	5	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Sleep • SSB consumption	• Multivariate ordinary least squares regression • Confounders included: Gender, maternal education, income: poverty, ethnicity, number of children in the household and parent relationship status	• HFI associated with increased consumption of soft drinks compared to food-secure children (51.4% vs 41.2%, p<0.001). • HFI associated with trouble sleeping at night compared to food-secure children (30.1% vs 25%, p<0.001)
Kirk et al., (2015)[(51)]	Canada	The Children's Lifestyle and School Performance Study (cross-sectional)	N=5853	10-11	Short form 6 item version of the US Household Food Security Survey Module	• Obesity/ overweight • Dietary intake/quality • Quality of life • Child mental health	• Linear and Poisson regression models with robust standard errors • Confounders included: Parent education, area of residence, gender	• Marginal, moderate and severe HFI were associated with greater BMI z-scores, when models adjusted for gender and area of residence. • Children who are food insecure are less likely to meet recommended fruit and vegetable (PR=0.73-0.83, p<0.05), and dairy (0.83-0.86, p<0.05) targets from Canadas Food Guide • Moderate or severe food

								• insecurity associated with higher energy intake(p<0.05) • HFI is associated with poorer quality of life (measured using EQ5D). high food security vs moderate HFI (β= -0.02, 95% CI -0.04 - -0.01, p<0.05) high food security vs severe HFI (β= -0.03, 955 CI -0.04-0.01). Models adjusted for gender and area of residence.
Kirkpatrick and Tarasuk (2008)[50]	Canada	Canadian Community Health survey (cross-sectional)	N=3348	1-18	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Dietary intake	• ANOVA • Confounders included: Household income, household education level (adults and children), immigration status, household size (number of adults and children), smokers	• HFI was not associated with fruit and vegetable servings in children aged 4-8 years old (p=0.16). • HFI associated with servings of grains in 4-8 years old (0.0 • • HFI was associated with nutrient deficiencies in vitamin B6, vitamin B12, zinc, vitamin A, phosphorous, vitamin A and magnesium among older children and adolescents. • HFI was associated with increased energy consumption (p=0.09) and less energy consumed from protein

products (p<0.01)

Kral, Chittams and Moore (2017)[52]	US	Cross-sectional analysis part of larger laboratory-based feeding study (cross-sectional)	N=50	8-10	Short form 6 item- US Household Food Security Survey Module assessment of HFI experience over past 12 months (parent)	• Parent feeding style and child eating behaviour	• Wilcoxon Rank-Sum tests • T-tests • Chi squared and Fisher's test. • Logistic regression • Confounders included: Mothers race/ethnicity, age, education, household income, child meal and snack patterns, frequency of mother telling child to clear their plate	• Children who were obese were more likely to be food insecure than food-secure (OR=4.9, 95% CI 1.15-20.8, p=0.02). • Food insecure children were more likely to overeat when they were not hungry (p<0.03) and consume more snacks than children who were food-secure (45.9% vs 15.4%, p=0.02) • Food insecure children were more likely to consume 5 or more snacks than per day than food-secure children (15.4% vs 0%, p=0.02)
Kuku et al., (2011)[53]	US	Child Development Supplement data of larger dataset Panel Study of Income Dynamics	N=959	0-12	USDA module 18-item questionnaire of HFI experience over past 12 months	• Obesity	• Parameter probit regression • Non-parameter regression • Confounders included: Race/ethnicity, gender, income:	• No association was observed between HFI and obesity in parametric probit regression • In non-parametric analysis, the probability of obesity rises as HFI increases, except at extreme HFI where it lowers. • Higher levels of HFI are

		(PSID) (cross-sectional)			(parent)		poverty	associated with obesity in girls, in boys' lower levels of HFI and an increase in HFI affirmative responses is associated with higher probability of obesity. • The association between HFI severity and obesity differs among ethnic groups.
Landry et al., (2019)[54]	US	TX Sprouts (cross-sectional)	N=598	8-11	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Dietary intake and quality	• Mixed effects linear regression • Confounders included: Race/ethnicity, gender, participation in food assistance programmes, average energy intake and BMI percentile	• HFI was associated with lower consumption of green beans (2.3% vs 1.9%, p=0.016) plant protein and seafood (2.0% vs 1.6%, p=0.006) and increased consumption of added sugar (7.4% vs 8%, p=0.002) compared to food-secure children.
Lee et al., (2019)[62]	US	NHANES 2003-2014 (cross-sectional)	N=2662	12-19	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Blood pressure • Prediabetes	• Logistic regression • Confounders included: Age, gender, income, race/ethnicity, household income: poverty	• Food insecure adolescents were more likely to have hypertension (OR=1.65 95% CI 1.38-2.1.98, p<0.05) and be diagnosed as prediabetic (OR= 1.96 95% CI 1.17-3.19, p<0.05) compared to food-secure adolescents

Mangini et al., (2015)[56]	US	Early Childhood Longitudinal Study-Kindergarten Cohort (cross-sectional)	N=1109	8-9	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Asthma	• Multivariate logistic regression • Analysed overall and by race/ethnicity • Confounders included: Race/ethnicity, household poverty: income, child gender, maternal nativity, maternal education, child health insurance, height, weight, and household income	• HFI was associated with higher odds of asthma (OR=1.04, 95% CI 1.02-1.06, p<0.001) • Food insecure children had double the odds of reporting asthma compared to food-secure children who were wealthier (OR=2.00, 95% CI 1.97-2.03, p<0.001)
Mangini et al., (2019)[57]	US	Early Childhood Longitudinal Study-Kindergarten Cohort (longitudinal)	N=6731	4-14	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Asthma	• Two multiple logistic regression models: 1) estimation of OR by asthma diagnosis at third grade exposure to HFI in year prior to kindergarten, then exposure in the year prior to kindergarten and third grade, 2)	• Children who experienced HFI the year before joining kindergarten had greater odds of an asthma diagnosis in the third grade (OR=1.18 95% CI 1.17-1.20, p<0.001) • Children who experience food insecurity in the year before third grade are more likely to be diagnosed with asthma compared to food-secure children (OR=1.53 95% CI 1.51-1.55, p<0.001)

									• estimation of OR of asthma diagnosis at fifth or eighth grade by exposure to HFI in second grade • Confounders included: Household poverty, race/ethnicity, sex, health insurance coverage, BMI and maternal nativity and parental depression		• Children were more likely to have an asthma diagnosis from third to eighth grade if their parents' experienced depression before they joined kindergarten (OR=1.23, 95% CI 1.22-1.25, p<0.001)
Marjerris on et al., (2011)[58]	Canada	Two general paediatric practices from Nova Scotia (cross-sectional)	N=183 families	7-16	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Diabetes • Hospitalisation		• Backwards stepwise elimination, logistic regression • Confounders included: Parent education, household income, child age, number of other family members with medical conditions		• HFI was associated with greater HBA1c concentration (9.5% ±2.13% vs 8.96% ±1.50%, p=0.039, but this was insignificant when child's age and parents' education in multivariate analysis. • HFI was associated with higher rates of hospitalisation (OR=3.66, 95% CI 1.54-8.66, p<0.05).

Martin and Ferris (2007)[59]	US	Convenience sample (cross-sectional)	N=200 parents and N=212 children	2-12	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Obesity/ overweight	• Multinomial regression • Confounders included: Income below 100% of poverty, child age, gender, parent cohabitation status, parent education status	• Children with family incomes below 100% poverty line half as likely to be overweight than those with higher incomes (OR=0.47, p=0.05) • HFI was associated with overweight, but this was not statistically significant (OR=1.41 95% CI 0.67-2.99, p=0.37) • Female gender and having an obese parent were associated with greater odds of child overweight (OR=2.56, p=0.01)
Masler et al., (2020)[60]	US	NHANES 2005-2012 (cross-sectional)	N=6077	8-15	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Child eating behaviours	• Multivariate logistic regression, separate models for 1) HFI and weight loss attempts, 2) HFI and weight control practices • Confounders included: Age, sex, race/ethnicity, poverty status and weight class	• No association was found between overweight/obese children, food insecurity and unhealthy weight loss behaviours (p values range 0.75, 0.98, 0.12 for marginal food-secure, low food-secure and very low food-secure, respectively. • Very low food security and healthy weight is associated with greater odds of attempted weight loss (OR=1.51, 95% CI 1.00 – 2.26, p<0.05) and unhealthy

							weight control in children (OR=1.42, 95% CI 1.04-1.93, p<0.05)
Maynard et al., (2019)[61]	US	NHANES 2009-2010 (cross-sectional)	N=935	12-17	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Child mental health/ anxiety	• Logistic regression examined the interaction between HFI and sex/gender separately, as this was statistically significant, the model was repeated stratified by sex. • Confounders included: Race/ethnicity, household size, parental education, family poverty:income ratio, child gender	• HFI associated with greater odds of experiencing high levels of anxiety compared to (OR= 1.64, 95% CI 1.04-2.60) food-secure children, considering both genders. • Female gender (OR=1.85 95% CI 1.18-2.91) and increasing age (OR=1.28, 95% 1.16-1.43) were associated with higher levels of anxiety • In the stratified model, food insecure females had greater odds of high anxiety (OR=0.3.03, 95% CI 1.59-5.80), but relationship was not observed in male gendered children. • P-values not reported but significance was reported by the author.

McIntyre et al., (2013)[62]	Canada	Canadian National Longitudinal Survey of Children and Youth 1994-2008/2009 (longitudinal)	N=22831	13-17	1 question to assess child hunger (adolescent)	• Child mental health-depression, and suicide	• Logistic regression. • All analyses were weighted using longitudinal weights. • No interaction terms found nor included in the analyses. • Confounders included: Child age, gender, housing stability, lived with biological mother, lived with alone mother depression, household education, household income, household size	• Food insecure adolescents who reported hunger were more likely to experience depression/suicide ideation (OR=2.3, 95% CI 1.2-4.3, p=0.006)
McLaughlin et al., (2012)[63]	US	National comorbidity survey replication adolescent supplement (cross-sectional)	N=6483 adolescent – parent dyads	13-17	2 dichotomous questions about hunger over the past 12 months (parent)	• Child mental health	• Logistic regression • Confounders included: Parent education, household income, relative deprivation and subjective social	• HFI was associated with increased odds of anxiety (OR=1.1, 95% CI 1.0-1.2), behaviour disorder (OR=1.2, 95% CI 1.1-1.3), substance disorders (OR=1.2, 95% CI 1.0-1.3) and mood disorders (OR=1.1, 95% CI 1.0-1.2).

							status, age, gender, race/ethnicity	• All p-values <0.05 significant
Mendoza et al., (2018)[64]	US	SEARCH for Diabetes in Youth (cross-sectional)	N=226	10-20 (mean age 15.6)	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Diabetes • Hospitalisations	• Logistic regression for high-risk glycaemic control • Binomial regression for emergency department visits and hospitalisations • Confounders included: Age, sex, race/ethnicity, socioeconomic status, study site, diabetes duration, health insurance and insulin regimen.	• HFI was associated with greater odds of increased HBA1c (OR=2.37 95% CI 1.10-1.59, p<0.05) • HFI was associated with greater emergency department visits (PR=2.95 95% CI 1.17-7.45, p=0.02) • HFI was not statistically significantly associated with hospitalisations but had higher prevalence than in food-secure youths (PR=2.96, 95% CI 0.92-9.51, p=0.07).
Molcho et al., (2007)[65]	Ireland	Health Behaviour in School-aged children study (cross-sectional)	N=8424	10-17	Food poverty question in survey "some young people go to school or to bed hungry	• Dietary intake • Eating behaviour	• Logistic regressing modelling • Confounders included: Age and social class (according to fathers' education)	• Food poverty significantly associated with consuming less fruit and vegetables and wholemeal bread (OR range 0.66-0.81, 95% CI range 0.45-0.99) • Food poverty was associated

					because there is not enough food at home. How often does this happen to you?"			with increased consumption of crisps, fried potato, and hamburger (OR range 1.29-1.72, 95% CI range 1.00-1.85) • Increased consumption of fast food differed among girls and boys • Food poverty was associated with reduced breakfast intake within the week for girls this was 1.72 (OR 95% CI 1.50-1.9) and 1.29 for boys (95% CI 0.99-1.59) • All values significant at p<0.05.
Niemeier and Fitzpatrick (2019)[66]	US	Sample of high school students from Northwest Arkansas (cross-sectional)	N=1493	13-16	Household: USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Obesity/ overweight • Mental health • Self esteem	• Ordinal regression using the Polytomous Universal Model • Confounders included: Gender, ethnicity, parents' immigration status, free and reduced lunches	• HFI was associated with poor self-esteem (p<0.01), less frequent family meals and weaker relationships with peer (p<0.001) • No association was found between HFI and weight status

Ovenell et al., (2022)[67]	Canada	Canadian Community Health Survey (cross-sectional)	N=28871	12-17	Household: USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Child mental health	• Poisson regression • Confounders included: Gender, race/ethnicity, household size, household income, highest household education, high BMI, survey cycle	• Children who experienced food insecurity and were not shielded by its impacts had elevated risk of anxiety (RR=1.44, 95% CI 1.02-2.03) and poor mental health (RR=1.45 95% CI 1.06-1.99) and poor life satisfaction (RR=1.64 955 CI 1.15-2.35) • Children who were shielded from HFI had higher risk of anxiety (RR=1.45, 95% CI 1.02-3.03 and fair or poor mental health (OR=1.56 95% CI 2.07-2.09) and did not differ significantly from food-secure children with respect to other mental health outcomes. • All significant findings: p<0.05.
Parker et al., (2010)[68]	US	NHANES 1999-2006 (cross-sectional)	N=3126	12-19 (mean age 15)	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Obesity/ overweight • Physical activity • Blood pressure • Metabolic syndrome (indicated by cholesterol,	• Logistic regression • Confounders included: Age, sex, race/ethnicity, household income, smoking status, highest household education	• Food-secure children were more likely to report doing vigorous exercise compared to food insecure children (p<0.05). • HFI (marginal, low and very low) was not associated with metabolic syndrome. • Model 1 results adjusted for

triglyceride	ethnicity, age and gender: Marginal (OR= 1.04 95% CI 0.38-2.86), low = (OR=1.49, 95% CI 0.79-2.82), very low (OR=1.18, 95% CI 0.47-2.95).
	• Model 2 results adjusted for by ethnicity, age, gender, income, smoking status and education: Marginal (OR=0.94, 95% CI 0.35-2.51), low (OR=1.12, 95% CI 9.57-2.17), and very low (OR=0.89, 95 % CI 0.35-2.23).
	• No statistically significant association was found in the prevalence of by HFI severity, including blood pressure and triglyceride, glucose, high-density lipoprotein across food insecurity severities (p>0.05).
	• There was no association between HFI and metabolic syndrome across HFI severities when using full food security as reference (full vs marginal OR = 1.04, 95 % CI 0.38-2.86, full vs

							low OR = 1.49, 95 CI 0.79-2.82, full vs very low OR=1.18, 95% CI 0.47-2.95) after adjusting for ethnicity, sex and age. Similar results observed when adding covariates household income, smoking level and education
Poulsen et al., (2019)[69]	US	Electronic health record data (cross-sectional)	N=408 parent-child dyads	10-15	6-item USDA based form of the past 12 months (parent reported)	• Obesity/overwe ight • Dietary intake • Food availability	• Multivariable linear regression • Confounders included: child age, child sex, child race/ethnicity, parent age, family income, parent education and youth history of medical assistance	• In unadjusted analyses HFI associated with greater mean BMI z-scores (β=0.33, 95% CI 0.06-0.61, p =0.018), waist circumferences (β=0.26, 95% CI 0.04-0.48, p=0.027) and % body fat (β=0.45, 95% CI 0.15-0.75, p=0.020) • In analyses adjusted for age, gender, ethnicity, parental age and income, HFI was associated with greater waist circumference (β=0.27, 95% CI 0.03-0.50, p=0.02), % body fat ((β=0.43, 95% CI 0.12-0.75, p=0.006) but not BMI z-scores ((β= 0.30, 95% CI -0.00, 0.60, 0.051) • Children from homes with

									low food availability had reduced fruit and vegetable intake (β=0.08, SE =0.02, p=0.003) • HFI was not associated with daily fruit and vegetable consumption in adjusted analyses (β= -0.06, 95% CI -0.56 – 0.43, p=0.805)
Ramsey et al., (2011)[70]	Australia	Census collector districts, Brisbane Statistical Sub-Vision (cross-sectional)	N=185 households	3-17	USDA module 16-item questionnaire of HFI experience over past 12 months (parent)	• Child mental health and behaviour	• Multinomial logistic regression • Confounders included: Household income, education, employment status, household structure (how many dependents and parent marital status)	• HFI was associated with negative internalised emotional symptoms such as depression (OR=2.44 95% CI 1.11-5.38, p=0.05) • Food insecure children and adolescents were also more likely to exhibit problem behaviour, but this was borderline statistically insignificant (OR=2.35 95% CI 1.04-5.33, p=0.06) and also present conduct problems (OR=1.69 95% CI 0.84-2.47, p=0.03).	
Robson et al., (2017)[71]	US	Youth Risk Behaviour survey (cross-sectional)	N=4994	12-18	Single item on the survey "During the past 30 days, how often	• Obesity and overweight • Sleep • Cigarette smoking	• Univariate logistic regression • Confounders included: Race/ ethnicity, child	• HFI was associated with reduced consumption of breakfast throughout the week (OR=2.27 95% CI 1.6-3.21, p<0.001)	

				did you go hungry because there was not enough food in your home?" (adolescent)	• Alcohol consumption • Dietary intake • Eating behaviour	age, child gender, neighbourhood safety, school grade	• HFI was associated with sleeping less than 8 hours per days (OR=1.60 95% CI 1.15-2.23, p=0.006) • HFI was statistically significantly associated with smoking (OR=1.81, 95% CI 1.31-2.40, p<0.001) and drinking OR=1.39, 95% CI 1.07-1.80m p=0.01) • No significant association between HFI and obesity was found (OR=1.107. 95% CI 0.82-1.4) p=0.61
Soldavini and Ammerman (2021)[72]	US	USDA Summer Electronic Benefit Transfer for Children Demonstration Project (cross-sectional)	N=11873	3-17	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Dietary intake	• Multiple linear regression • Confounders included: Child gender, caregiver race/ethnicity, caregiver education, household income: poverty threshold, household composition, household size, number of children in the household, participation in	• Marginal, low, and very low food security was associated with lower consumption of fruits and vegetables. • Very low food security was associated with lowest consumption of fruit and veg compared to food-secure children across all age groups (p<0.001). • Children aged 5-8 experiencing low food security consumed less wholegrains than food-secure children (B= -0.16, 95% CI -0.31 – -0.00, p<0.05).

					food assistance programmes	• Children aged 13-17 experiencing very low food security consumed less wholegrains than food-secure children (B=-0.42, 955 CI -0.83-0.01, p<0.05). • Children aged 5-8 from marginally food-secure households consumed more added sugar 0.97, 955 CI 0.03-1.91, p <0.05), this was also observed in 3–4-year-old children who were low food-secure (B=-2.85, 95% CI -4.50- - 1.20, p<0.001). • Low food-secure 3–5-year-olds more sugar from sugar-sweetened beverages compared to food-secure children (B=-1.84, 95% CI –3.15-0.54, p<0.05). • All food insecure children consumed less dairy than food-secure children (p<0.001)	
South et al., (2019)[73]	US	NHANES 2007-2014 (cross-sectional)	N=7125	8-17 (mean age 12)	USDA module 18-item questionnaire of HFI	• Blood pressure	• Multivariable logistic regression • Confounders included: BMI, race/ethnicity,	• HFI was associated with high blood pressure (OR=1.26, 95% CI 1.04-1.54, p<0.05)

					experience over past 12 months (parent)				child age, child gender, household income	
Tan et al., (2019)[74]	US	Children's PowerPlay! Campaign (cross-sectional)	N=3547	9-11	5 questions from Child Food Security Assessment (child)	• Dietary intake		• Multivariable mixed-effects linear and logistic regression • Confounders included: Gender, ethnicity/race, poverty level and survey year.		• HFI in girls was associated with an increase in total kilocalories consumed (135 calories per day, p<0.005) and 60 calories from snacks per day at the highest severity of FI; p<0.05) compared with girls that were food-secure • The same relationship was not seen for male children. • This study found no association between HFI and meal patterns, including missing meals for either gender.
Tester et al., (2016)[75]	US	NHANES 2003-2010 (cross-sectional)	N=1072	12-18	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Fasting TC, LDL-C, TG, HDL-C, TG/HDL-C ratio, and (Apo B)		• Logistic regression • Confounders included: Race/ethnicity, household income, household size, poverty income ration, parent cohabiting, maternal education		• Marginal HFI was associated with elevated TGs (OR=1.86, 95% CI 1.14-3.06), TG/HDL-C (OR=1.74, 95% CI 1.11-2.82) and Apo B (OR=1.98, 95% CI 1.17-3.36). • Marginally food-secure females had lower HDL-cholesterol than males (OR=2.69 955 CI 1.14-6.37).

							• P-value not reported but significance stated.
Tevie and Shaya (2018)[76]	US	NHANES 2005-2012 (cross-sectional)	N=6334	12-18	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Child mental health	• Multivariate logistic regression for three models 1) a cut off for poor mental health days of <14 days considered baseline, 2) cut off of <7 days, and 3) a cut off of <4 days. • Confounders included: Poverty: income, gender, race/ethnicity, child age, child gender, parent education level.	• Adolescents who experienced very low food security were more likely to suffer from bad mental health estimated by model 1(OR=2.06, 95% CI 1.63-2.58, p<0.0001), model 2 (OR=1.98, 95% CI 1.67-2.29, p<0.0001) and model 3 (OR=1.94, 95% CI 1.14-3.28, p=0.01) compared to adolescents from food-secure households.
To et al., (2014)[69]	US	NHANES 2003-2006 (Cross-sectional)	N=3049	6-17	USDA module 18-item questionnaire of HFI experience over past 12	• Physical activity	• Linear regression for identifying associations between HFI and time spent doing physical activity or being sedentary	• HFI was associated with less participation in moderate to vigorous physical activity (β=-5.24, p=0.02) but there was no association between HFI and sedentary minutes (β= 8.87, p=0.07).

					Question		Outcome		Analysis		Results
					months (parent)				• Confounders included: Age, gender, race/ethnicity, parent marital status, education, household size and household income		
Turner et al., (2022)[78]	US	Youth Risk Behaviour Survey 2017 (cross-sectional)	N=43857	14-19	1 question "during the past 30 days how often did you go hungry because there was not enough food in your house?" (adolescent)	• Substance abuse • Cigarette smoking • Alcohol consumption			• Bivariate analyses using chi-square tests. • Logistic regression calculated for adjusted prevalent ratios (PR) • Confounders included: Gender, age, ethnicity, school grade, sexual identity, current binge drinking, current marijuana use	• Results from bivariate analyses: Food insecure adolescents were more likely to participate in binge drinking, abuse of illegal substances such as marijuana as well as prescription drugs (p<0.05) • Results from multivariable logistic regression: HFI was also associated a lifetime usage of prescription opioid substance abuse (PR=.1.38, 95% CI 1.12-1.71, p=0.005) and use of illicit drugs (PR=1.70, 95% CI 1.22-2.37, p=0.003).
Widome et al., (2009)[79]	US	Project EAT 1998-1999 class (cross-sectional)	N=4746	<18	2 items adapted from the USDA hunger core food security	• Dietary intake • Eating behaviour			• Multiple linear regression • Confounders included: Age, grade level,	• HFI was associated with greater consumption of fat (p<0.01) and ate fewer family meals (p<0.001) and breakfast (p=0.001)

					module HFI experience over the past 12 months (parent)		gender, race/ethnicity, family income	• HFI was associated with less food availability of unhealthy and healthy food in the household (p<0.001) across all hunger frequencies. • Both food-secure and food insecure understood the benefits of healthy eating, across all hunger frequencies.
Wirth et al., (2020)[80]	US	Chart review of children visiting clinic (cross-sectional)	N=2688	2-17	HVS screening measure binary rating system over the past 12 months (child)	• Overweight/ obesity	• Logistic regression • Confounders included: Race/ethnicity, gender, insurance type, weight status, tobacco exposure, household composition, neighbourhood poverty rate	• Food insecure children and adolescents were less likely to be obese compared to food-secure (RRR=0.56 95% CI 0.36-0.87) • HFI was negatively associated with obesity (OR=0.55, 95% CI 0.35-0.86, p<0.01).
Yang et al., (2018)[81]	UK	Born in Bradford study (longitudinal)	N=1101 children	4-5	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• BMI z-score • Dietary intake	• Quantile and logistic regression- each ethnic group (White British and Pakistani analysed separately) • Confounders included: Mothers' ethnicity, maternal	• White British mothers were more likely to report HFI than Pakistani mothers (11% vs 7%, p <0.01). • From 12 months of age to 4-5 years old, prevalence of overweight and obesity increased both among food secure (10% to 22%) and food

	age, maternal cohabitation status, maternal education, household size, subjective financial insecurity, IMD.	insecure (8% to 22%) Pakistani origin children. • In regression models: BMI z-score increased by 0.25 units (95% CI 0.20-0.29) for Pakistani-origin children who were food secure and 0.40 units (95% CI 0.22-0.59) for their food insecure counterparts. • Among White British children the prevalence of overweight increased among food secure children (12% to 25%) but a decrease was observed among food insecure children (24% to 19%). • In White British children greater increases were observed for BMI z-scores among food-secure children (β=0.17, 95% CI 0.13-0.21). This was statistically significant. In White British food insecure children, a smaller increase in BMI z-scores was observed (β=0.06, 95% CI -0.05-0.17). • Pakistani mothers were more likely to live in the most deprived areas or receive means-tested benefits compared to

White British mothers.

Zhu et al., (2019)[82]	US	Early Childhood Longitudinal Study-Kindergarten Cohort 1998-2007 (longitudinal)	8-14	USDA module 18-item questionnaire of HFI experience over past 12 months (parent)	• Obesity/ overweight	• Logistic regression with Bonferroni adjustment • Confounders included: Child gender, race/ethnicity, birth weight, health insurance, household poverty (at/above or below the poverty threshold), parent depression, maternal nativity and maternal education.	• Children who experienced HFI in 5th grade had higher BMI z scores in 5th (OR=0.19 95% CI 0.07-0.30, p<0.05) and in the 8th grade (OR=0.17 95% CI 0.06-0.27, p<0.05) • Children who were food insecure had higher risk of overweight/obesity in 3rd, 5th and 8th grade compared to food-secure children (p<0.05).