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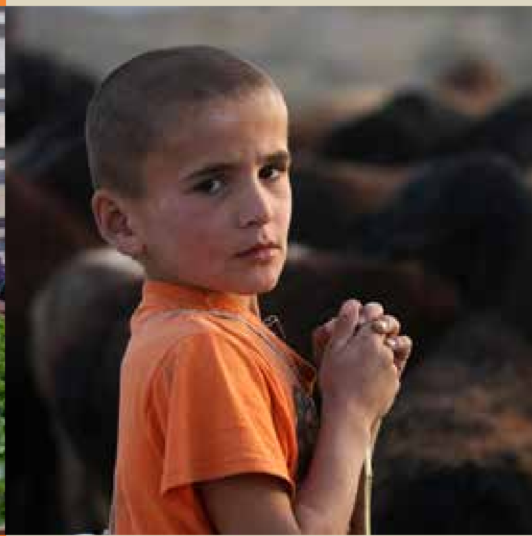

A review of studies examining the link between food insecurity and malnutrition

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A review of studies examining the link between food insecurity and malnutrition

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This paper was commissioned by FAO through the project Voices of the Hungry (VoH). VoH collects information on food insecurity (restricted food access) as experienced by individuals in over 140 countries using the Food Insecurity Experience Scale (FIES). The project also aims to assist countries interested in adopting the FIES as part of national food security monitoring efforts.
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Abstract

A review of 120 studies published since 2006 was undertaken to examine the relationship between food insecurity at the household or individual level and the following nutrition indicators: child stunting, child wasting, low birth weight, exclusive breastfeeding of infants < 6 months of age, anaemia in women of reproductive age, child overweight and adult obesity. While there is some evidence of a direct association between food insecurity and stunting for children in lower-middle and upper-middle income countries, evidence of links between food insecurity and either child wasting or overweight is almost absent, with the exception of an association with overweight among girls in middle- and high-income countries. The obesity–food insecurity link is most predominant among women in high-income countries, while it is almost absent in men. In addition, food insecurity increases the risk for low birth weight in infants and anaemia in women. Methodological concerns that pose challenges for valid comparison of results relate to study design, data analysis techniques, use of different indicators of household/individual food security and malnutrition, and the limited availability of high-quality micro-level data from large-scale surveys. Most studies report correlation rather than causal associations between food insecurity and nutrition indicators; longitudinal micro-level data from large-scale surveys can help establish causal association and capture the dynamic nature of food insecurity. Food insecurity emerges as a predictor of undernutrition as well as overweight and obesity, highlighting the need for multisectoral strategies and policies to combat food insecurity and multiple forms of malnutrition.

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Abbreviations and acronyms

AOR	Adjusted Odds Ratio
BMI	Body Mass Index
DHS	Demographic and Health Survey
EBF	Exclusive Breastfeeding
EBFSS	Experience-Based Food Security Scales
EBIA	Escala Brasileira de Insegurança Alimentar (Brazilian Food Insecurity Scale)
ELCSA	Escala Latinoamericana y Caribeña de Seguridad Alimentaria (Latin American and Caribbean Food Security Scale)
ENSANUT	Encuesta Nacional de Salud y Nutrición (National Health and Nutrition Survey)
ENSMI	Encuesta Nacional de Salud Materno Infantil (National Maternal-Infant Health Survey)
FI	Food Insecurity
FIES	Food Insecurity Experience Scale
HAZ	Height-for-Age Z-score
HFI	Household Food Insecurity
HFIAS	Household Food Insecurity Access Scale
HHs	Households
HICs	High-Income Countries
HIV	Human Immunodeficiency Virus
ID	Iron Deficiency
LBW	Low Birth Weight
LICs	Low Income Countries
LMICs	Lower-Middle Income Countries
MANA	Programa de Mejoramiento Alimentario y Nutricional de Antioquia (Food and Nutrition Improvement Plan for Antioquia)
MINIM	Maternal and Infant Nutrition Intervention in Matlab
UMICs	Upper-Middle Income Countries
US HFSSM	United States Household Food Security Survey Module
WIC	Special Supplemental Food Program for Women, Infants, and Children
y	year

Introduction

Food security is a complex and multidimensional phenomenon defined as a state when “all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (1). A key component of food insecurity is lack of access to a sufficient quantity of nutritious food, which is a potential risk factor for malnutrition in children and adults (2-4). However, evidence on the association between household or individual food insecurity and malnutrition is not conclusive in the existing literature. Establishing a causal effect of food insecurity on nutritional consequences is a challenging task, due to several methodological concerns related to study design, analytical techniques, the diversity of food insecurity and malnutrition indicators used, and above all, the limited availability of high quality micro-level data from large scale surveys (5-7). Yet, it is important to explore this relationship because malnutrition has enormous economic and social costs (8-9). Poor nutrition in early childhood has long-term costs in terms of adverse health, schooling, and consequent effects on the labour market in later life (10-11). In the context of low- or lower-middle income countries, nutritional deprivation in early life poses one of the greatest obstacles to poverty reduction by perpetuating the cycle of poverty, poor nutrition, low human capital, and low productivity (10). In subpopulations in high-income countries, food insecurity may be a risk factor for obesity which may cause adverse intergenerational health consequences (12).

Given the above considerations, the aim of the present study was to gather evidence on the nature and extent of the association between food insecurity (specifically the experience of not having *access* to safe, nutritious and sufficient food due to lack of money or other resources) and selected indicators of malnutrition in adults and children across the globe. Establishing these relationships is important in the context of both resource-poor and resource-rich settings and with the emergence of new concerns such as the ‘double burden of malnutrition’ (13-14), defined as the coexistence of undernutrition and overweight/obesity. Multiple types of malnutrition may occur simultaneously within populations, households, or even individuals. The issue is timely and relevant to the Global Nutrition Targets 2025 (15) as well as the Sustainable Development Goals (SDGs) that aim to eliminate poverty and achieve zero hunger, good health and well-being for all.

A detailed review of the literature was undertaken to extract the key findings on the relationship between food insecurity and selected nutrition indicators. The food security indicators used in the studies that were reviewed were based on the class of experience-based food security scales (EBFSS), which quantitatively capture food-related behaviours and experiences associated with difficulties in accessing food due to resource constraints (16). Several reliable and validated experiential scales exist, including the United States Household Food Security

Survey Module (US HFSSM), the Food Insecurity Experience Scale (FIES) (16), the Household Food Insecurity Access Scale (HFIAS) (17), the Household Hunger Scale (HHS) (18), and the Latin American and Caribbean Food Security Scale (ELCSA) (19). The key nutrition indicators considered in the studies are: stunting, wasting and overweight in children, adult obesity, low birth weight (LBW), exclusive breast feeding of infants < 6 months (EBF) and anaemia in women of reproductive age.

Conceptually, the pathways from food insecurity to malnutrition can be incorporated into the theoretical paradigm of the Socio-Ecological Model (20), which offers a bioecological framework of human development. This approach places an emphasis on both the immediate and broader environment as important for human development, incorporating time as an important influence from infancy through to adulthood. Within this context, food insecurity can be viewed as a factor that has long-term impact on an individual's nutritional status throughout the various stages of the life cycle.

The framework, which has applications in several fields, including nutrition and public health, comprises individual/intrapersonal, interpersonal, community and enabling environments. The influences within and between each environment are bi-directional, with the relationships having impact both away from and towards the individual. Individual (intrapersonal) factors comprise age, sex, socio-economic status, race/ethnicity, physical health, knowledge and skills, and personal preferences. The second level (interpersonal) relates to relationships with peers, partners, and family that may influence the outcome. For example, a mother's education level can influence her child's growth and development.
The third level (community) considers the settings in which individuals live, learn and work, including early care and education programs, schools, work sites, community centres and food service establishments. The settings thus define a larger social context in which the individual does not directly function, but which influence development from childhood to adulthood by interacting with some element in his/her intra- and interpersonal environment. For example, a high-quality community childcare program that benefits the entire family might reduce the negative impact of food insecurity on child growth, thus moderating the strength of the association between food insecurity and child nutritional status.

Settings also have the potential for broader population-level impact if they are integrated with strategies coming from multiple sectors, which broadly comprise the enabling environment – the outermost layer in the individual's development. These sectors include governments, education, health care, transportation, public health, community organizations, businesses and industries, all of which play an important role by influencing people's access to healthy food and opportunities to be physically active, or they influence social norms and values. This level therefore looks at broad societal factors that help create a climate in which the individual can grow as a healthy and productive economic agent. Thus, health, economic, educational and social policies are important spheres of influence at this level.

The effect of these elements of the enabling environment have a cascading influence throughout the interactions of all other layers. For example, a revised healthcare system at the macro level might reduce out-of-pocket healthcare expenditure and improve health services for the vulnerable population (e.g. households from low-income or minority communities), consequently lessening the impact of food insecurity on individual nutritional outcomes at the micro level.

The organization of the paper is as follows: the next section presents the methods used in the review. Section three reports key findings, while section four discusses them. The final section discusses gaps in the existing literature and section six concludes with potential policy implications of the results.

Methods

This section discusses the search strategy and criteria for inclusion of papers. The scope of the literature review is limited to papers that report empirical associations between household or individual food insecurity (FI) and the selected indicators of malnutrition.

SEARCH STRATEGY

Databases 'Pubmed' and 'Scopus' were searched using key words such as household food security, food insecurity, food access, and various combinations of the following terms in the title and abstract: undernutrition, overnutrition, anthropometry, malnutrition, nutritional status, stunting, wasting, overweight, obesity, Body Mass Index (BMI), anaemia, haemoglobin, low birth weight, exclusive breast feeding. The above searches were also combined with the words child and/or women and/or adults and/or maternal. The abstracts of papers were read to identify those likely to meet the inclusion criteria (stated below).

The above search strategy produced a Master List which was further enriched by adding additional papers available from the reviews on the relevant topics (for example, (21-24). The abstracts of the papers that cited those reviews were also read. Finally, additional papers were extracted from the bibliography of the papers included in the Master List unless they were already counted in. The final list comprised 180 studies conducted in various settings.

CRITERIA FOR INCLUSION OF PAPERS

The criteria for inclusion of papers in the final sample were as follows: first, studies were included if household food insecurity (HFI) was measured using some variation of an EBFSS and using a validated questionnaire (locally adapted, abbreviated or translated). Second, studies using continuous measures of weight and height (height-for-age z-score, weight-for-height z-score, BMI z-score) were included, in addition to studies using categorical measures such as stunting, wasting, obesity/overweight. For adults, any BMI measure (continuous or categorical) was considered acceptable, while for children, weight percentiles for age and other categorizations were accepted. Third, only papers published between 2006 and February 2018 were included in the review; however, a handful of studies that were published before 2006 were included due to their seminal importance in this literature. Fourth, only published journal articles were included in the review, with the exception of one report on Guatemala (25). The above criteria resulted in 120 studies being included in the final sample.

Findings

Findings are reported according to the association found between food insecurity and the various forms of malnutrition: positive, negative, no association, or mixed results. A positive association generally implies a direct and statistically significant association between food insecurity and malnutrition indicator (i.e. food insecurity increases the risk of malnutrition), while a negative association implies a statistically significant inverse association (i.e., food insecurity decreases the risk of malnutrition). Mixed results indicate those studies that report a mix of positive, negative or no association for different age, gender or geographical groups within the same study. For children, findings are reported according to two broad age groups: under-five and above five.[1] Malnutrition in the first five years of life has long-term consequences for health and cognitive development in later life and therefore children under five should be studied separately. As far as obesity is concerned, it is harder to detect the significance of any particular change in BMI in younger children as it changes across different age groups. Therefore, studies often typically report overweight/obesity statistics separately for older children and adults (27).

FOOD INSECURITY AND UNDERNUTRITION

In this section, the findings on the association between FI and indicators of undernutrition are reported. The indicators used are stunting, wasting, LBW, EBF and anaemia in women. The studies are concentrated in low (LICs), lower-middle (LMICs) or upper-middle income countries (UMICs). There is limited evidence from high-income countries (HICs).

Child stunting

Of the 30 studies that examined the relationship between FI and stunting (TABLE 1) 16 studies identified a significant positive association between FI and stunting for children under five, i.e. children in food insecure households were more likely to be stunted than children in food-secure households (2, 28-42). Four studies found a significant positive association between food insecurity and stunting for children above five years (43-46). One study reported mixed results (25) for children under five, while two revealed mixed findings for children older than five years (47-48). Several studies from Africa, Asia, Latin America and North America reported no association for either under-five children (49-52) or for children above five years (44, 53-55).

[1] However, often there is considerable overlap because some studies cover broad age-ranges such as 2–11 years, e.g. Kaur *et al.* (26).

Child wasting

Of the fifteen studies reviewed (TABLE 2) (2, 28, 30, 33, 35, 38, 40-42, 45, 50-52, 56-57), only three reported a positive association between food insecurity and child wasting, mostly in LICs or LMICs (28, 51, 56); the three were conducted with children under-five years of age.

Low birth weight

Although the number of studies on the association between food insecurity and LBW is limited (TABLE 3), two studies from HICs (58-59) and one from low-income settings (60) reported that FI is significantly associated with LBW.

Anaemia in women of reproductive age

Seven out of eight studies (TABLE 4) found a significant or mixed association between HFI and anaemia in women, from countries as diverse as Ecuador (61), Bangladesh (62), Cambodia (50), Guatemala (25), Mexico (63-64) and the United States of America (65).

Exclusive breastfeeding

A limited number of studies are available on the association between FI and EBF practices (TABLE 5). Out of the eight studies reviewed, three reported a significant negative association between food insecurity and exclusive breastfeeding in Canada (66) and Kenya (67). Four studies reported no association (68-71). Lastly, one study (72) on HIV affected mothers in Uganda reported mixed evidence: while moderate or severe HFI was not associated with EBF at 6 months, among those women still exclusively breastfeeding at 4 months, those experiencing food insecurity were significantly more likely to cease EBF. Two studies estimated infant feeding practices as the outcome variable, one component of which was EBF (68, 70).

FOOD INSECURITY AND OVERWEIGHT/OBESITY

Evidence on the association between the experience of FI and obesity/overweight is growing, and a large body of evidence (55 studies in this review) is available from resource-rich and resource-poor settings alike (TABLE 6).

Child overweight

Out of thirteen studies on the link between FI and overweight (TABLE 6) in children under five years of age, four reported a positive association or mixed results (73-76), while the others found no association (30, 41, 77-83). Metallinos-Katsaras *et al*. (75) reported a negative association between HFI (with and without hunger) and overweight for girls aged less than two years but positive association for girls aged two to five years experiencing food insecurity with hunger. No association was reported for boys.

Out of the twenty-two studies reviewed for children over five years of age, twelve studies reported some kind of association – positive, negative or mixed. Four studies (83-85, 215) reported a significant positive association, one reported an inverse relationship (86) and seven studies reported mixed results (3-4, 26, 48, 87-89). For example, Jyoti *et al*. (3) found a positive association for girls alone. Kaur *et al*. (26) found a positive association between food insecurity of the adults interviewed and obesity among 6-11-year-old children, while no association was found between childhood obesity and child food security, as measured by questions posed to the adult respondents but relating to experiences of children in the household. In general, the evidence that food insecurity increases the risk of overweight is more pronounced for girls (3-4, 76, 90, 215).

Adult obesity

Twelve studies out of the twenty-three reviewed found that food insecurity was significantly associated with overweight/obesity in adults. Five of these were in LMIC/UMIC settings (31, 37, 83, 91-92) and seven in HICs (93-99) (TABLE 6).

Fifteen of the studies focussed on women (or women and children) only (31, 38, 45, 52, 61, 83, 91-92, 94-95, 99-103). Of these fifteen studies, seven (31, 83, 91-92, 94-95, 99) reported significant associations between FI and obesity in women. Laraia *et al*. (2013; 2015) investigated the relationship in the context of pregnant women. Eight studies focused on men and women/children as the study population (37, 93, 96-98, 104-106), five of which reported a positive association between food insecurity and obesity in women only.

These results corroborate those reported in other literature reviews which suggested HFI is a risk factor for obesity among women but not men (6, 21-24, 94).

Discussion

This literature review reveals that the evidence on the association between FI and malnutrition in children and adults is largely inconclusive. Due to methodological differences across studies, the comparability of results is challenging. However, a few key points emerge:

- Some evidence exists of an association between FI and child stunting. The positive FI–stunting link is predominantly in UMICs and LMICs as opposed to LICs.
- Limited evidence is available on the association between FI and child wasting, and this association is predominantly in LIC/LMIC settings.
- Despite the limited number of studies, there is evidence of an association between FI and birth weight of infants, with food insecurity increasing the risk of LBW.
- While some studies on the association between food insecurity and anaemia in women report mixed results, overall results indicate that FI is a risk factor for anaemia.
- The evidence of an association between FI and overweight in children is limited though some evidence of a positive association exists for school-aged girls.
- The evidence on the association between FI and obesity is absent for men. However, there is evidence of a positive association for adult women from HICs. In general, evidence is absent in LICs/LMICs.
- Limited evidence is available on the association between EBF and FI since the number of studies that used experience-based food security measures is very limited.

Given the above, the following questions arise:

1. To the extent that studies find evidence of positive or negative association between FI and nutritional status, what could be the mediating factors in these relationships? In other words, what are the pathways from FI to malnutrition in adults and children?
2. What factors could explain the lack of association between FI and some forms of malnutrition?
3. How can the contradictory evidence in the literature on the FI–malnutrition link be reconciled?

PATHWAYS FROM FOOD INSECURITY TO MALNUTRITION IN ADULTS AND CHILDREN

Multiple pathways can link FI and malnutrition in children and adults. It is important to identify such mediators to facilitate effective policy formulation.

Food insecurity to stunting and wasting in children

FI is assumed to affect the nutritional status of children by compromising quantity and quality of dietary intake (107-109). Food-insecure households are more likely to have children who suffer from lower nutrient intakes (110). The evidence from studies that examined the mediating role of dietary diversity in the relationship between food insecurity and nutritional status is mixed, however. Ali *et al*. (42) did not find dietary diversity to be a mediator in the association between FI and child undernutrition for Bangladesh, Ethiopia and Viet Nam. However, using longitudinal data, Humphries *et al*. (48) reported dietary diversity to be a mediator in the association between FI and anthropometric indicators for school-aged children in Viet Nam, India, Peru and Ethiopia. The use of cross-sectional versus longitudinal data (48) and the different age groups of children (42, 48) could provide some explanation for the differences in results. Furthermore, in the context of high-income countries, children in severely food-insecure households were less likely to meet the guidelines set out in the US Food Pyramid (54).

Another pathway from FI to poor child nutritional status is the perinatal nutrition of mother and the child, including the internatal period for the mother (110). There is overwhelming evidence that perinatal nutrition affects health and well-being of all age groups (111). Maternal food insecurity during pregnancy has been found to be associated with poorer foetal health outcomes (58). Almond *et al*. (112) found that the availability of food stamps (a form of social protection aimed at addressing food insecurity) reduced the incidence of LBW births through improvements in nutrition. HFI may also compromise child health by compromising maternal diet and health (113). For pregnant women, FI may cause lower-than-recommended weight gain during pregnancy and is associated with intrauterine growth restriction (12), a risk factor for stunting. Additionally, short-term management strategies often include limiting portion sizes and skipping meals for the caregiver, especially the mother (114), and compromised maternal nutrition may eventually influence child growth negatively (10).

Another key pathway from FI to child growth is via feeding practices. Food insecurity has been shown to be negatively associated with both initiation and duration of breastfeeding (115-116), with some studies reporting a strong negative association between FI and EBF (66, 70). The consequences for child nutritional status stem from the fact that the 1 000 days between conception and a child's second birthday is a window of supreme opportunity for child health promotion. Indeed, EBF up to six months and adequate complementary feeding up to two years of age ensures normal child growth (117-118).

Furthermore, FI may be linked to child undernutrition through caretaker mental health (29, 119). As a stressor, FI may contribute to unfavourable parenting practices (81, 120), one manifestation of which is a negative effect on breast-feeding (121). Casey, Goolsby, Berkowitz *et al*. (122) have reported maternal depression to have negative effects on early childhood growth, particularly height-for-age, via unresponsive parenting. FI is also associated with anaemia in women (61-62), and some studies suggested that iron deficiency (ID) may be a risk factor for maternal depressive symptoms (123), which in turn may affect child health status (122). A less-studied pathway by which FI can affect maternal stress level, and consequently child health, is through substance use (124).

FI could also lead to compromised immune system functions, putting a child into what is referred to as an infection–malnutrition cycle (110). Food insecurity is associated with inadequate food intake, which can lead to immunodeficiency increasing susceptibility to infection and thus resulting in poor nutritional outcomes (109, 125). These adverse consequences are exacerbated by poor sanitary conditions. Additionally, when nutrition is suboptimal, it takes a child longer to recover from an illness, and the repetition of this cycle can worsen overall health. For example, Pérez-Escamilla *et al*. (126) found HFI to be associated with malaria in rural Haiti. Malaria, in turn, has been reported as a risk factor for stunting and wasting among young children in a recent cohort study in Ethiopia (127).

Food insecurity to anaemia

FI can lead to anaemia through inadequate intake of micronutrients (128-129). Poor micronutrient intake in food-insecure households can be a result of underconsumption of food, or overconsumption of energy-dense but nutrient-poor diets that may be less costly (130-131), as healthy food is often more expensive (132). Fischer *et al*. (63) hypothesize that HFI may lead to anaemia among adult women from Mexico through three diet-related pathways: first, a lack of adequate consumption of iron; second, through a diet lacking sufficient consumption of micronutrients that facilitate iron absorption and utilization (such as vitamin C); and third, by consuming foods rich in phytic acid that may decrease the absorption of iron, hence increasing the risk of anaemia.

Food insecurity to exclusive breastfeeding

The literature also identifies pathways by which FI may undermine a mother's ability to adopt EBF practices. Food insecurity can motivate maternal employment outside of the home, and there is strong evidence of a negative impact of maternal work on breastfeeding practices in both HICs and LIC/LMICs (133-134). Food insecurity may also impact maternal self-efficacy, which in turn may adversely affect initiation and duration of EBF (135). HFI has been associated with higher rates of maternal depression and stress in low income settings such as Ethiopia (136) as well as in high income settings such as the United States of America (137), which in turn is a significant predictor of reduced breastfeeding self-efficacy, exclusivity and duration of breast feeding (138-139). Additionally, women in food-insecure households are more likely to experience diabetes mellitus, a condition that has been found to affect breastfeeding initiation and duration negatively (140-141). Psychological and physiological stress associated with severe food insecurity may affect subsequent milk output (142-143).

Researchers argue that in situations where FI causes severe maternal malnutrition, physiological mechanisms may alter breast milk output or the concentration of certain fats and micronutrients (144-145). On the other hand, food insecurity may also increase the practice of EBF by limiting economic access to alternative infant foods, as long as attitudes to EBF are positive (146).

Food insecurity to low birth weight

Nutritional quality of the diet, in terms of micronutrients, might be the key nutritional pathway from FI to birth outcome. A systematic review of 45 articles showed that preconception and periconception intake of vitamin and mineral supplements by the mother was associated with a reduced risk of preterm deliveries and having a LBW baby (147). The key non-nutritional pathway linking FI and birth weight of children is maternal mental health, including depressive symptoms and anxiety (59). As stated before, FI has been associated with depression and anxiety among mothers (122, 141), and pregnant women experiencing depressive symptoms are at risk for dysfunctional placentation and intrauterine growth restriction, which affect birth outcomes such as preterm birth (148-149).

Food insecurity to overweight in children and obesity in adults

The mechanisms linking FI and obesity/overweight are relatively well understood, and a few theoretical frameworks have been offered in the literature to explain this association. Nettle *et al.* (6) propose the *insurance hypothesis,* which claims that individuals store more fat when they receive cues that access to food is uncertain. One extension of this hypothesis is to developmental influences on obesity: experiences in early life, such as poor nutrition in-utero (150), childhood exposure to food scarcity (151), or psychosocial stress in general (152-153) can predispose individuals to maintaining higher levels of body fat, not just as children, but subsequently as adults. Dhurandhar (154) proposes the *Resource Scarcity Hypothesis* which argues that randomly priming individuals to cues that imply resource-scarcity causes them to be more likely to choose and consume high-calorie food items (155), specifically in low socio-economic status individuals. The hypothesis is that positive energy balance arises as low social-economic status is associated with chronically higher energy intake (via low income and social stress), low resting metabolic rate and low activity energy expenditure. Low socio-economic status individuals may be more susceptible to the perception of low food security (156).

Food assistance programs may moderate the association between HFI and child overweight status (157) to some extent. However, binge-eating habits when food is plentiful, arise from the episodic nature of FI and can lead to obesity (158-159), and such cyclical food restrictions lead to quicker weight gain when refeeding (160). Monthly food assistance benefits, for example, can be associated with a 'feast–famine' cycle (158) if they are not adequate to guarantee sufficient food until the end of the month. This could potentially contribute to obesity in children. In lean periods, parents may restrict treats, thereby increasing child demand and intake of these foods when households later have more money to spend (54). Motbainor *et al*. (51) offer such an explanation of cyclical food restriction for the FI–BMI link in the low-income setting of Ethiopia with respect to lean/plenty seasons in agriculture.

Food-insecure individuals may also become overweight by consuming a low-quality diet. Food insecurity is associated with consumption of cheap and energy-dense food (foods high in added sugar and fat), overconsumption of which may cause weight gain (132, 161–162). Women from food-insecure households in particular may rely on low-cost, highly processed, high-calorie foods to cope with a limited household budget (132). HFI may result in reduced micronutrient intake among women of child-bearing age (163-164), decreased fruit and vegetable consumption, and a significant increase in disordered eating patterns (164). Additionally, due to the occurrence of feast–famine types of episodic food insecurity, HFI may cause fluctuations in eating habits. Such fluctuations may cause metabolic alterations, so that even without eating more calories, it is possible to increase weight (165). Finally, childhood stunting, which is a potential outcome of food insecurity, can be a risk factor for weight gain in later life (166). Early life exposure to HFI may also result in food hording and thus set long-term trajectories of weight gain (132, 167).

Acculturation, a process of socio-cultural and behavioural change that stems from the blending of cultures, may modify the relationship between FI and BMI (168). Some of the most noticeable group-level effects of acculturation include changes in food, clothing, and language. A recent analysis of Latino children in the United States of America demonstrated that, among children of families with lower acculturation, FI was associated with lower BMI (86). While among urban Latino women with higher acculturation FI was positively associated with obesity, among women with lower acculturation there was no association between FI and obesity (169). Lower acculturation in this context may be associated with consumption of a healthier diet closer to that of the country of origin, meaning one containing more beans and fruit (170).

FI and overweight in children may be linked through parenting and infant feeding practices (81). Adults in food-insecure households are significantly more likely to exhibit less positive parenting than other adults (3, 124).[2] Inappropriate feeding practices such as non-exclusive breast-feeding and untimely introduction of

[2] Unfavourable parenting practices as mediators of the FI–malnutrition link can influence both undernutrition indicators and obesity.

complementary feeding may eventually lead to childhood obesity (171). Furthermore, FI is related to more restrictive and pressuring maternal feeding styles compared with food-secure mothers (69), a risk factor for current and future weight gain. By decreasing the ability of children to self-regulate eating behaviours, controlling feeding practices can pose a risk for childhood obesity (172). HFI may also lead to child overweight by affecting the diet of food-insecure mothers. Poor diet quality in pregnancy poses a risk for gestational weight gain (173), which in turn may result in future weight gain in the child (174). The mother–child obesity cycle could thus persist (175).

The key non-nutritional pathway from FI to overweight and obesity is poor mental health. FI has been found to be associated with poor mental health status independent of other indicators of low socio-economic status, in both resource-rich (176) and resource-poor (177) settings. Specifically, it has been associated with anxiety (136), depression (176), and stress (178). Stress brought on by food insecurity may cause non-homeostatic eating and may lead to the selection of “comfort” foods, or highly palatable foods that are rich in fat, sugar, and sodium (179-180) and have been found to physiologically reduce stress (181). Furthermore, in the presence of marginal food insecurity, women who struggle with weight and dieting issues may be at risk for excessive weight gain. Marginal food insecurity and dietary restraint might affect weight through the cyclical food restriction patterns, the “yo–yo” type diet (182) or dieting followed by overeating, that could lead to weight gain (173). Finally, an additional pathway that requires further attention involves the role of physical inactivity (24).

EXPLAINING THE LACK OF ASSOCIATION BETWEEN FOOD INSECURITY AND MALNUTRITION

Several studies found no evidence of an association between FI and malnutrition in children or adults, indicating that while food security may be a necessary condition for good nutrition outcomes, it is insufficient on its own.

One key explanation for this lack of association might be related to conceptual concerns. EBFSS capture short-term food insecurity, while malnutrition indicators such as stunting represent long-term deprivation. Moreover, EBFSS measure *access* to food as opposed to food *utilization,* which directly influences nutritional status. Availability and access to food do not ensure food security, as proper absorption of food by the body is also necessary to be food secure (183). Factors such as nutrition knowledge and practices, and access to quality health care, clean water and sanitation are crucial to ensure good nutrition in this context (184-186).

Second, a conglomeration of social, economic and cultural factors other than FI influence the nutrition of individuals. For example, household-level poverty (187), maternal nutritional status (10, 188), intrahousehold allocation of resources (189-

190), women's status (191-192), diet quality and food choice (193-194), food environment (195) and improved access to full serviced supermarkets (196) are some of the factors influencing nutritional outcomes of children and adults. The association between supermarket access and obesity is a growing area of research (197-198). Home health care, food preparation, and the provision of a responsive and stimulating environment to a child are other factors confounding the influence of food access on the nutritional status of children. Even in poor communities with limited food access, children might grow normally because of positive family and caregiver behaviours (199-200). Mothers' knowledge of appropriate infant and young child feeding practices is also important (201).

Finally, a factor explaining the lack of association between FI and malnutrition indicators could be methodological (discussed in detail in the next section). Due to methodological issues, even studies which control appropriately for the key predictors of malnutrition may find no association. It is important to keep in mind that the same set of unobserved factors can influence both food insecurity and malnutrition (5). Given that researchers mostly use observed data rather than experimental data to conduct these analyses, such unobservable factors are often not controlled for, resulting in omitted variable bias. Consequently, establishing a causal association between FI and malnutrition remains a challenge.

HOW TO RECONCILE THE CONTRADICTORY EVIDENCE FROM VARIOUS STUDIES EXAMINING THE FOOD INSECURITY–MALNUTRITION LINK

The literature review reveals that the nature and extent of the association between FI and indicators of malnutrition depends considerably on the context and methodology.

First, results vary by *income level* of the country. For children, any association between FI and stunting is noted mostly in LMIC/UMIC settings, while the limited association between FI and overweight (mostly for girls) is more predominant in HICs. It is possible that LMICs or UMICs such as India or Brazil, respectively, are in a stage of nutrition transition where rates of child undernutrition have not yet been overtaken by overweight or obesity in young children. "Occurrence of a shift from under-nutrition to obesity tends to follow a pattern that usually occurs first in adults, followed by adolescents, and only later in time by children" (77) (p.6). A recent meta-analysis (6) showed that food insecurity predicts high body weight only in HICs; in LMICs the average association is zero. In a low-income setting, FI is less likely to result in overweight children because even the cheapest energy-dense food may not provide sufficient energy to cause excess weight gain (53) or to allow the build-up of fat reserves before the next period of scarcity strikes (6).

Age may interact with FI to produce varied outcomes in terms of nutritional indicators. Regarding the FI–stunting link, the proportion of studies reporting positive associations is much larger for under-five children compared to school-aged children. In contrast, FI is found to have no association with wasting for under-five children in most of the studies. As for the FI–obesity/overweight link in children, a larger fraction of zero association is reported for under-five children as opposed to school-age children. The weight–height relationship may be relevant in terms of shedding light on the differential outcomes on stunting–wasting in under-five children with respect to FI (202). Studies have demonstrated that linear growth falters throughout the first 2–3 years of life in many developing countries, whereas weight for-height tends to falter during a more limited age window in the first year of life, after which it either stabilizes or increases (203). As for the obesity–FI link, one explanation for the age-wise variations follow from *sacrifice theory* (21), whereby younger children are more protected by parents in times of scarce food access. Additionally, studies on children generally measure food insecurity through parental reports (204), potentially weakening the ability to discover a relationship. Finally, simple BMI-type measures may be particularly problematic for assessing adiposity in growing children (205).

Results also vary by *gender*: a consensus of the reviews on food insecurity and body weight measures (21-24) is that the limited available evidence on the presence of any association between FI and high body weight in children is noted for older girls (>5 years) only. Additionally, this relationship is most pronounced among women in HICs and almost absent in men. For adult women in HICs, the odds of high body weight are about fifty percent higher for food-insecure individuals compared to food-secure ones (6). This outcome may well relate to the wider finding that low socio-economic status is a more consistent predictor of obesity in women than in men (206).

Results may also vary by *study design* – cross-sectional versus longitudinal. For example, in this review, the majority of studies on the FI–obesity association are cross sectional, eighty percent of which do not report any association between FI and obesity among children/adults. Regarding the FI–undernutrition link, the majority of studies are cross sectional. Given the limited number of longitudinal studies, it would be worth exploring what longitudinal data reveals by conducting more such studies. In the current review, the only three longitudinal studies on the FI–stunting link provided mixed evidence: negative association (47); positive association (29); and mixed results (48).

Studies use a variety of *EBFSS to measure FI* – from a single food adequacy question to full survey modules such as US HFSSM, HFIAS, ELCSA, or adapted local versions of US HFSSM / HFIAS and shorter scales such as the HHS. While most of these measures have been validated and are widely used, locally adapted versions are sometimes not subjected to full psychometric testing. Hence, their suitability in estimating the impact of FI on nutritional status may be questionable. Use of different indicators might also make comparability of estimates across different studies a challenging task. Another inconsistency is noted with respect to the level at which food insecurity is measured – individual or household. A limited number of studies use food security measures at individual or child level (122, 207-208).

A crucial aspect regarding food security measurement is the *categorization scheme used for the experience-based food security indicator*, whether experiential food insecurity is measured as a continuous, dichotomous, or multinomial variable. This categorization is likely to affect results. For example, several studies (122, 158, 160) report that it was the milder but not the most severe levels of food insecurity where increased odds of obesity were found. Gubert *et al*. (30) reported child stunting to be associated with severe food insecurity but not with mild/moderate food insecurity. Such outcomes indicate that dichotomization of the experiential food insecurity to just two categories might conceal meaningful variations in results.

How *nutritional status is measured* – self-reported vs measured, continuous vs dichotomous – may also be relevant to explaining variations in outcomes on FI–malnutrition link. For example, Nettle *et al*. (6) found significantly stronger associations between FI and weight status when the outcome variable was obesity (BMI ≥ 30) than when the outcome was overweight (BMI ≥ 25). However, they found no significant differences in the strength of the association according to which predictor (FI measure) was used. According to Lyons, Park and Nelson (209), associations between obesity and FI are more pronounced when self-reported data on height and weight are used than when measured height and weight data are used.

Finally, how the relationship between FI and malnutrition is *empirically modelled* also serves to reconcile the contradictory evidence to a considerable extent. Empirical concerns that need to be addressed relate to problems such as omitted variable bias, selection bias or simultaneity bias. The same set of unobserved factors may affect both the dependent variable (malnutrition) and the explanatory variable (food insecurity). For example, 'ability' (a typical example of unobserved factor in labour economics) (210) of an individual can simultaneously affect his/her food security status and nutritional status by affecting productivity. Unless the researcher is able to control for these unobserved factors, a correlation between observed and unobserved factors can bias the estimated effect of FI on malnutrition. Additionally, sample "selection" problems arise when factors unobserved to the researchers drive selection of households to food-secure or food-insecure status (5). Furthermore, there is classification error in view of the fact that true food insecurity status is not observed. There may also be simultaneity bias in the relationship, as potentially the FI–malnutrition link is bi-directional. Just as FI can predict malnutrition, the latter can also be a risk factor for FI by affecting long-term productivity of individuals and further impoverishing them (10). These concerns create identification problems and consequently, estimating causal impact of FI on nutritional outcomes becomes challenging. Addressing these concerns is more problematic in cross-sectional data, while longitudinal data mitigate them to a considerable extent by taking care of unobserved factors which are time-invariant.

GAPS IN THE LITERATURE

Considerable gaps in knowledge exist in the literature examining the association of food insecurity and the nutritional status of children and adults.

The literature has focused on examining the correlation between FI and a range of nutritional outcomes rather than attempting to establish causality in the relationship (5). Improved analytical methods such as empirical models, which can address several biases in the relationship, are warranted. Significant gaps also exist in exploring the temporal dimension of food insecurity (173). The health consequences of temporary and persistent food insecurity might not be the same (211). For example, it is possible that those who experience persistent food insecurity have developed coping strategies to address the situation. As far as children are concerned, how the movement in and out of food insecurity can influence children's nutritional and developmental outcomes remains an important question. Pérez-Escamilla and Pinheiro de Toledo Vianna (212) observed that a key gap in the literature is that studies have not been designed to find out if there is a critical period of initial exposure to HFI in terms of child development outcomes.

It is therefore important to better understand the pathways from FI to poor nutritional outcomes. Few studies have investigated these mediating factors. For example, how dietary diversity mediates the relationship between HFI and nutritional outcomes is an important question and the limited available evidence is inconclusive (42). Theory-based designs and improved analytical frameworks are required to investigate how the mediators work (175). According to Jacknowitz and Morrissey (213), pathways can vary according to who is experiencing the insecurity in the household (adult or child), and with regards to child food insecurity, whether the child is directly affected by food insecurity or indirectly affected through the experience of adults or other children in their household. Pathways will also vary according to the outcome of interest such as undernutrition or overweight and obesity. Huge data gaps exist in the literature on this topic. It is impossible to answer the above concerns without access to longitudinal data. Data sets that follow children from birth are necessary in order to observe the effect of FI within a life course framework. Longitudinal studies can also improve our understanding of the temporality in food insecurity, such as the effects of chronic and transient food insecurity.

It is also important to have large-scale micro datasets to avoid problems of low statistical power for quantitative analysis (214). Moreover, data quality and survey design are often poor. Data collection processes must adhere to measurement protocols and the experience-based food security measure and the analytic protocols must be standardized (such as the FIES) to allow cross-cultural comparability of study results.

Finally, it is recommended that in order to understand the food insecurity–malnutrition link among children, further research be undertaken regarding how to measure food insecurity at the child level. The American Dietetic Association, in a note published in 2003, concluded that 'household food insecurity does not appear to be associated with overweight among children, a finding that may be due, in part, to the fact that a comprehensive measure of child food insecurity was not used in most studies' (cited in Eisenmann *et al*. (24). A recent review on FI–obesity link in the United States of America (22) finds only seven studies (out of twenty-five) reviewing HFI and weight status among children and adolescents, use child-specific measures of food insecurity.

Conclusion

This literature review reveals mixed evidence on the association between the experience of food insecurity (constrained access to adequate food) and malnutrition indicators. Results vary by income, settings, age, gender and study design, choice of indicators and empirical modelling techniques. Due to methodological differences, valid comparison of results is a challenging task, therefore addressing methodological discrepancies is essential to better understand this relationship. High quality longitudinal data is required to better understand the true nature of the relationship between food insecurity and malnutrition. Further research is also necessary to determine the mediators of experiential food insecurity and nutritional indicators with a view to informing policy.

In general, food insecurity is identified as a predictor of undernutrition as well as overweight and obesity. The policy implication of this result is that tackling food insecurity should simultaneously allow for addressing different nutritional challenges, especially the multiple burden of nutrition. However, malnutrition is not merely a food problem in that health is shaped by the broader societal and economic context in which the individual resides (12). Therefore, efforts to promote food security alone may not be adequate in combating malnutrition. Reverting to the conceptual bioecological framework described at the outset, malnutrition is likely to be driven by a complex array of risk factors interplaying at the individual, community and societal level. Therefore, cost-effective multisectoral interventions are needed. For example, subsidizing healthy food, taxing sugary food, providing incentives to production of traditional nutrition-rich staples, influencing food choice through nutrition labelling and nutrition education, and providing healthy meals at school might be some potential solutions.

Overall, these suggestions also underscore the importance of a nutrition-sensitive supply chain. It is important to identify the bottleneck at each point of the supply chain so that tailored actions can be implemented to target each distinct problem. Encouraging programs to promote physical activity is also a key potential intervention. Last but not the least, sustainable and inclusive economic growth, which aims to reduce income, educational, and gender inequality should be the key policy goal in a successful fight against food insecurity, hunger and malnutrition.

Tables

TABLE 1.
STUDIES ON THE ASSOCIATION BETWEEN FOOD INSECURITY AND CHILDHOOD STUNTING*

Country	Author (year)	Study population and sample size	Methods	Results on the association between food insecurity and childhood stunting or lower haz
BANGLADESH (28-29)	Hasan *et al.* (2013)	Children < 5 y of age (N = 5 904). Nationally representative sample.	Cross-sectional study using Bangladesh DHS 2011; food insecurity estimate was based on the HFIAS.	Positive association between food insecurity and stunting. The odds of being stunted were significantly higher for children in food-insecure HHs.
	Saha *et al.* (2009)	Children 0 to 24 months of age (N = 1 343). Matlab district.	Longitudinal study: children were followed from birth to 24 months of age; food insecurity estimate was based on the food security component questionnaire of the MINIMat study (scale developed specifically for Bangladesh).	Positive association. The proportion of stunted children was significantly higher among food-insecure HHs compared to food-secure HHs. Household food security was positively associated with higher gain in HAZ.
BRAZIL (2, 30, 32, 55)	Gubert *et al.* (2016)	Children <5 y of age (N = 4064). Nationally representative sample.	Cross-sectional study using Brazilian DHS 2006; food insecurity estimate was based on the Brazilian Food Insecurity Security Scale (EBIA).	Positive association between severe food insecurity and stunting.
	Lopes *et al.* (2013)	12–18 y old adolescents (N = 523). Low-income area of the municipality of Duque de Caxias, Rio de Janeiro.	Cross-sectional study; food insecurity estimate was based on the EBIA.	No association.

	Reis (2012)	Children <5 y of age (N = 4860). Nationally representative sample.	Cross-sectional study using Brazilian DHS 2006; food insecurity estimate was based on the EBIA.	Positive association between food insecurity and lower HAZ.
	Santos *et al*. (2013)	Children <5 y of age (N = 4817). Nationally representative sample.	Cross-sectional study using Brazilian DHS 2006; food insecurity estimate was based on the EBIA.	Positive association between food insecurity and lower HAZ.
CAMBODIA (50)	McDonald *et al*. (2015)	Children <5 y of age (N = 900 HHs). Four rural districts of Prey Veng province.	Cross-sectional study; food insecurity estimate based on an adapted version of HFIAS.	No association.
COLOMBIA (34, 53)	Hackett *et al*. (2009)	Preschool children receiving MANA food supplements (N = 2 784 low-income HHs**)**. Random sample representative of the 200 000 MANA participants. Department of Antioquia.	Cross-sectional study; food insecurity estimate was based on the 12-item Colombian Household Food Security Scale.	Positive association between food insecurity and stunting. The risk for child stunting increased in a dose-response way as food insecurity became more severe.
	Isanaka *et al*. (2007)	Children 5 to 12 y of age (N = 2 526). Primary public schools in Bogotá.	Cross-sectional study of school-age children's health and nutritional status; food insecurity estimate was based on a modified version of the Spanish-language US HFSSM (16 version) plus 5 child-specific questions used to measure child food security.	No association.

ETHIOPIA (33, 35, 47, 51)	Belachew *et al*. (2013)	Adolescents 13 to 17 y of age (N = 1 431). Jimma zone, Southwest Ethiopia.	Longitudinal Jimma Longitudinal Family Survey of Youth (JLFSY) study; participants were interviewed in three survey rounds one year apart; food insecurity estimate based on 4 of the 18 questions in US HFSSM and the coping strategies index.	Mixed. Negative association between food insecurity and linear growth in female adolescents but not in male adolescents. Food-insecure girls were shorter by nearly 1 cm (0.87 cm) compared with secure girls at baseline and catch up during follow up period was inadequate. The mean height of food-insecure males was not significantly different from food-secure males both at baseline and over the follow up period.
	Betebo *et al*. (2017)	Children 6 months to <5 y of age (N = 508). East Badawacho district, South Ethiopia.	Cross-sectional study using a community-based primary survey; food insecurity estimate based on the HFIAS.	Positive association between food insecurity and stunting. The odds of being stunted for children in food-insecure HHs were 6.7 times that of children in food-secure HHs.
	Jemal *et al*. (2016)	Children 6 months to <5 y of age (N = 284) Gambella town.	Cross-sectional study using a community-based survey; food insecurity estimate based on the HFIAS.	Positive association between food insecurity and stunting. The odds of being stunted were significantly higher for children in severe and moderately food-insecure HHs.
	Motbainor *et al*. (2015)	Children <5 y of age (N = 4110 HHs). East and West Gojjam Zones of Amhara Region.	Cross-sectional study using a community-based primary survey; food insecurity estimate based on the HFIAS.	No association.
GHANA (52)	Saaka *et al*. (2013)	Children 6 to 36 months old (N = 337). Tamale Metropolis of Northern Ghana.	Cross-sectional study, primary survey; food insecurity estimate based on the 30-day HFIAS.	No association.

GUATEMALA (25)	Chaparro (2012)	Children <5 y of age (N = 10100 nationally and 2477 in the Western Highlands region). Nationally representative sample.	Cross-sectional study using data from the National maternal–infant health survey (ENSMI); food insecurity estimate based on five questions adapted from the US HFSSM.	Mixed. Positive association between severe food insecurity and stunting at national level, but no significant association in the Western Highlands region.
HONDURAS (44)	Gray *et al*. (2006)	School-age children (N = 75). Five villages located on the East bank of Lago de Yojoa in the Department of Cortes in rural Central Honduras.	Cross-sectional study using a primary survey; food insecurity estimate was based on an adaptation of the US HSSM (8 items).	Positive (weak) association between severe food insecurity and stunting.
IRAN (ISLAMIC REPUBLIC OF) (43)	Shahraki *et al*. (2016)	Children aged 7–11 y (N = 610). Sistan and Baluchestan Provinces in South Eastern Iran (Islamic Republic of).	Cross-sectional study using a primary survey; food insecurity estimate based on the 18-item US HFSSM.	Positive association between food insecurity and stunting. The odds of being stunted for children in severely food-insecure HHs were 10.1 times that of children in food-secure HHs.
MALAYSIA (45)	Ali Naser *et al*. (2014)	Children 2–12 y of age (N = 223). Bachok district in Kelantan, rural area of North East Peninsular Malaysia.	Cross-sectional study, using a primary survey; food insecurity estimate was based on the Radimer/Cornell hunger and food security scale.	Positive association between food insecurity and stunting. Children in food-insecure HHs were three times more likely to be stunted than children in the food-secure HHs.

MEXICO (36-37)	Shamah-Levy *et al*. (2014)	Children <5 y of age (N not provided). Nationally representative sample.	Cross-sectional study using Mexican National Health and Nutrition Survey (ENSANUT) 2012; food insecurity estimate based on the ELCSA.	Positive association between food insecurity and stunting. The odds of being stunted for children in moderately and severely food-insecure HHs were 1.37 and 1.79, respectively, times that of children living in food-secure HHs.
	Shamah-Levy *et al*. (2017)	Preschool children (N = 5087) and schoolchildren (N = 7181). Nationally representative sample.	Cross-sectional study using Mexican National Health and Nutrition Survey (ENSANUT) 2012; food insecurity estimate based on the ELCSA.	The proportion of stunted children was significantly higher among severely and moderately food-insecure HHs (16.2% and 16.8%, respectively) compared to mildly food-insecure and food-secure HHs (13.2% and 10.7%, respectively). The interaction between HFI and maternal obesity had a significant impact on stunting.
NEPAL (38, 41, 49)	Osei *et al*. (2010)	Children 6 to 23 months of age (N = 368). Kailali District.	Cross-sectional study, using a community-based primary survey; food insecurity estimate was based on a short-adapted version of the HFIAS (5 questions).	No association.
	Singh *et al*. (2014)	Children <5 y of age (N = 2335). Nationally representative sample.	Cross sectional study using Nepal DHS 2011; food insecurity estimate based on an adapted version of HFIAS (7 items).	Positive association between food insecurity and stunting. The odds of being stunted for children in food-insecure HHs were 1.50 times that of children in food-secure HHs.
	Sreeramareddy *et al*. (2015)	Children <5 y of age (N = 2591). Nationally representative sample.	Cross-sectional study using Nepal DHS 2011; food insecurity estimate based on an adapted version of HFIAS (7 items).	Positive association between food insecurity and lower HAZ.
NICARAGUA (46)	Schmeer *et al*. (2017)	Children 3–11 y of age (N = 431 HHs). León, Nicaragua.	Cross-sectional study using a primary survey; food insecurity estimated based on ELCSA.	Positive association between food insecurity and lower HAZ.

PAKISTAN (39)	Baig-Ansari *et al*. (2006)	Children 6 to 18 months (N = 399). Squatter settlements of Karachi.	Cross-sectional study using a primary survey; food insecurity estimated based on the 18-item USHFSSM.	Positive association between food insecurity and stunting. Food-insecure HHs with hunger were three times more likely than other HHs to have a stunted child.
UNITED STATES OF AMERICA (54)	Kaiser *et al*. (2002)	Mexican–American children 3 to 6 y of age (N = 211). California.	Cross-sectional study using a primary survey; food insecurity estimate based on Radimer/Cornell scale.	No association.
BANGLADESH, ETHIOPIA, VIET NAM (42)	Ali *et al*. (2013)	Children 6 months to <5 y of age. Bangladesh (N = 2356), Ethiopia (N = 3422), Viet Nam (N = 3075).	Cross-sectional survey; food insecurity estimated based on the HFIAS.	Positive association between food insecurity and stunting across the three countries. The odds of being stunted were significantly higher for children in severely food-insecure HHs in Bangladesh and Ethiopia, and in moderately food-insecure HHs in Viet Nam.
BANGLADESH, BRAZIL, INDIA, NEPAL, PAKISTAN, PERU, SOUTH AFRICA, AND THE UNITED REPUBLIC OF TANZANIA (40)	Psaki *et al*. (2012)	Children aged 2 to 5 y (N = 800 total, 100 in each of the 8 countries**)**. Urban, rural and peri-urban areas.	Cross-sectional study using a primary survey; food insecurity estimate based on HFIAS.	Positive association between food insecurity and lower HAZ across countries.

INDIA, PERU, ETHIOPIA, VIET NAM (48)	Humphries *et al*. (2015)	Children aged 1, 5, and 8 y (three rounds of data collection) in various countries. Ethiopia (N = 1757), India (N = 1 825), Peru (N = 1 844), and Viet Nam (N = 1 828).	Longitudinal study following the same children at ages 1, 5 and 8 y, using a primary survey; at age 5 y. food insecurity estimate was based on a modified version of the US HFSSM, at age 8 y, the estimate was based on the HFIAS.	Mixed. Positive association between food insecurity and lower HAZ at age 5 y. However, the association attenuated after adjusting for other household factors and anthropometry at age 5 y and remained significant only for Viet Nam. Food insecurity was not significantly associated with HAZ at age 8 y.

Notes.

* Stunting refers to a height-for-age z score (HAZ) < -2

TABLE 2.

STUDIES ON THE ASSOCIATION BETWEEN FOOD INSECURITY AND CHILDHOOD WASTING*

Country	Author (Year)	Study population and sample size	Methods	Results on the association between food insecurity and childhood wasting
BANGLADESH (28)	Hasan *et al.* (2013)	Children < 5 y of age (N = 5 904). Nationally representative sample.	Cross-sectional study using Bangladesh DHS 2011; food insecurity estimate was based on the HFIAS.	Positive significant association between food insecurity and wasting.
BRAZIL (2, 30)	Gubert *et al.* (2016)	Children <5 y of age (N = 4 064). Nationally representative sample.	Cross-sectional study using Brazilian DHS 2006; food insecurity estimate was based on the Brazilian Food Insecurity Security Scale (EBIA).	No association.
	Reis (2012)	Children <5 y of age (N = 4 860). Nationally representative sample.	Cross-sectional study using Brazilian DHS 2006; food insecurity estimate was based on EBIA	No association.
CAMBODIA (50)	McDonald *et al.* (2015)	Children <5 y of age (N = 900 HHs). Four rural districts of Prey Veng province.	Cross-sectional study; food insecurity estimate based on an adapted version of HFIAS.	No association.
ETHIOPIA (33, 35, 51, 57)	Abdurahman *et al.* (2015)	Children 2 to <5 y. of age (N = 453 children). Haromaya District.	Cross sectional study using a community-based primary survey; food insecurity estimated based on HFIAS.	No association.
	Betebo *et al.* (2017)	Children 6 months to <5 y of age (N = 508). East Badawacho district, South Ethiopia.	Cross-sectional study using a community-based survey; food insecurity estimate based on the HFIAS.	No association.

	Jemal *et al*. (2016)	Children 6 months to <5 y of age (N = 284). Gambella town.	Cross-sectional study using a community-based survey; food insecurity estimate based on the HFIAS.	No association.
	Motbainor *et al*. (2015)	Children <5 y of age (N = 4 110 HHs). East and West Gojjam Zones of Amhara Region.	Cross-sectional study using a community-based primary survey; food insecurity estimate based on the HFIAS.	Positive significant association between food insecurity and wasting.
GHANA (52)	Saaka *et al*. (2013)	Children 6 to 36 months old (N = 337). Tamale Metropolis of Northern Ghana.	Cross-sectional study, primary survey; food insecurity estimate based on the 30-day HFIAS.	No association.
MALAYSIA (45)	Ali Naser *et al*. (2014)	Children 2–12 y of age (N = 223). Bachok district in Kelantan, rural area of North East Peninsular Malaysia.	Cross-sectional study, using a primary survey; food insecurity estimate was based on the Radimer/Cornell hunger and food security scale.	No association.
NEPAL (38, 41)	Sreeramareddy *et al*. (2015)	Children <5 y. of age (N = 2 591). Nationally representative sample.	Cross-sectional study using Nepal DHS 2011; food insecurity estimated based on an adapted version of HFIAS (7 items).	No association.
	Singh *et al*. (2014)	Children <5 y. of age (N = 2 335). Nationally representative survey.	Cross-sectional study using Nepal DHS 2011; food insecurity estimated based on an adapted version of HFIAS (7 items).	No association.
NIGERIA (56)	Ajao *et al*. (2010)	Children <5 y. of age (N = 423). lle-lle region in SouthWestern Nigeria.	Cross-sectional study using a primary survey; food insecurity estimate was based on the 18-item US HFSSM.	Positive association between food insecurity and wasting. The odds of wasting for children living in food-insecure HHs were 5.7 times that of children living in food-secure HHs.

BANGLADESH, ETHIOPIA, VIET NAM (42)	Ali *et al*. (2013)	Children 6 months to <5 y of age. Bangladesh (N = 2 356), Ethiopia (N = 3422), Viet Nam (N = 3 075).	Cross-sectional survey (baseline data); food insecurity estimate based on the HFIAS.	Mixed. Significant positive association between food insecurity and wasting in Bangladesh. No association in Ethiopia and Viet Nam.
BANGLADESH, BRAZIL, INDIA, NEPAL, PAKISTAN, PERU, SOUTH AFRICA AND UNITED REPUBLIC OF TANZANIA (40)	Psaki *et al*. (2012)	Children aged 2 to 5 y (N = 800 total, 100 in each of the 8 countries**)**. Urban, rural and peri-urban areas.	Cross-sectional study using a primary survey; food insecurity estimate based on HFIAS.	No association.

Notes.

* Wasting refers to a weight-for-height z score (WHZ) < -2.

TABLE 3.
STUDIES ON THE ASSOCIATION BETWEEN FOOD INSECURITY AND LOW BIRTH WEIGHT

Country	Author (Yer)	Study population and sample size	Methods	Results on the association between food insecurity and low birth weight
BANGLADESH (60)	Chowdhury *et al*. (2018)	Households with a live birth between 2006 and 2011 (N=8 753). Nationally representative sample.	Cross sectional survey: 2011 Bangladesh Demographic and Health Survey (DHS); food security measured by five questions aimed at capturing "the availability of food and a person's access to it."	Positive association between food insecurity and small size infants.
UNITED STATES OF AMERICA (58-59)	Borders *et al.* (2007)	Women receiving welfare in nine Illinois counties (N=1 363).	Illinois Family Study, a longitudinal cohort study; food security measured using US HFSSM.	Positive association between food insecurity and low birth weight.
	Grilo *et al.* (2015)	Women and adolescents (aged 14–21) who attended prenatal care at one of the 14 participating clinical sites in New York City (N=881).	Longitudinal study, primary survey; food security measured using a single question: "Do you ever run out of money or food stamps to buy food?"	Positive association between food insecurity and low birth weight.

TABLE 4.
STUDIES ON THE ASSOCIATION BETWEEN FOOD INSECURITY AND ANAEMIA IN WOMEN

Country	Author (Year)	Study population and sample size	Methods	Results on the association between food insecurity and anaemia in women
BANGLADESH (62)	Ghose *et al.* (2016)	Married women aged between 13 and 40 y (N=5 666). Nationally representative sample.	Cross-sectional study using Bangladesh Demographic and Health Survey (BDHS 2011) data; food security measured using HFIAS.	Positive association between food insecurity and anaemia. The odds of being anaemic were significantly higher for women in food-insecure HHs.
CAMBODIA (50)	McDonald *et al.* (2015)	Mothers with a child under five y old (N=900 HHs with such mothers). Prey Veng province.	Cross sectional study using data from a baseline survey conducted before the implementation of an intervention study; food security measured using an adapted version of HFIAS.	Positive association between food insecurity and anaemia. HFI increased the odds of maternal anaemia in a dose-response manner.
ECUADOR (61)	Weigel *et al.* (2016)	Adult women living in HHs with children in low-income neighbourhoods in Quito, Ecuador (N=794).	Cross sectional study using primary survey data; food security measured using the Spanish version of USHFSSM.	Positive association between food insecurity and anaemia. The odds of being anaemic were significantly higher for women in food-insecure HHs.
GUATEMALA (25)	Chaparro (2012)	Females 15–49 ys of age (N= 16 819 nationally and 3762 in the Western Highlands region). Nationally representative sample.	Cross-sectional study using data from the National maternal–infant health survey (ENSMI); food insecurity estimate based on five questions adapted from the US HFSSM.	Using national-level data, HFI was associated with haemoglobin concentration of women of reproductive age. However, a significant association was not reported for Western Highlands.

MEXICO (63-64)	Fischer *et al*. (2014)	Women of reproductive age (12–49 y) (N= 16 944). Nationally representative sample.	Cross sectional study using data from ENSANUT 2012; food security measured using ELCSA.	The association between HFI and anaemia was not significant for adolescent women (12–20 y), whereas in adult women (21–49 y), the adjusted odds of having anaemia were higher among those living in mild to severely food-insecure HHs, compared to adult women residing in food-secure HHs.
	Jones *et al*. (2017)	Non-pregnant female adolescents (15–19 ys) and non-pregnant adult women of reproductive age (20–49 ys) (N=4,039 non-pregnant female adolescents and 10,760 non-pregnant adult women of reproductive age). Nationally representative sample.	Cross sectional study using data from the 2012 National Health and Nutrition Survey of Mexico; food security measured using ELCSA.	Women from mild to moderately food-insecure HHs had greater odds of anaemia. Severe HFI was not associated with anaemia among girls or women. No association between HFI and anaemia, obesity, or their co-occurrence among female adolescents
UNITED STATES OF AMERICA (65, 173)	Laraia *et al*. (2010)	Pregnant women in North Carolina with incomes ≤ 400% of the income/poverty ratio (N=810).	Longitudinal study using data from the Pregnancy, Infection and Nutrition prospective cohort study; food security measured using US HFSSM	No significant associations between HFI and anaemia.
	Park *et al*. (2014)	Pregnant females aged 13 to 54 y. Nationally representative sample.	Pooled analysis using data from National Health and Nutrition Examination Survey; food security measured using US HFSSM	Mixed results. The odds of ID, classified by ferritin status, were 2.90 times higher for food-insecure pregnant females compared with food-secure pregnant females. Other indicators of ID were not associated with food security status.

TABLE 5.
STUDIES ON THE ASSOCIATION BETWEEN FOOD INSECURITY AND EXCLUSIVE BREASTFEEDING

Country	Author (Year)	Study population and sample size	Methods	Results on the association between food insecurity and exclusive breastfeeding
BANGLADESH (70)	Saha *et al*. (2008)	Infants who were born between May 2002 and December 2003 were followed until December 2004 and beyond (N= 1 343). Matlab district.	Longitudinal study using data from the Maternal and Infant Nutrition Intervention in Matlab (MINIMat) study. Food security measured using scale based on eleven items (scale developed specifically for Bangladesh).	No significant association between HFI and EBF at any age.
BRAZIL (68)	Gomes and Gubert (2012)	Children <2 y of age (N=1 635).	Cross sectional study using data from Brazilian DHS. Food security measured using the Brazilian Food Insecurity Scale (EBIA).	No association between food insecurity and breastfeeding in the first year of life or early introduction of foods other than breastmilk.
CANADA (66)	Orr *et al*. (2018)	Women who had completed the Maternal Experiences Breastfeeding Module and the Household Food Security Survey Module of the Canadian Community Health Survey (2005–2014) and who had given birth in the year of or year before their interview (N=10 450). Nationally representative sample.	Cross-sectional study using pooled data from the 2005–2014 Canadian Community Health Survey (CCHS). Food security measured using the Household Food Security Survey Module of the CCHS.	Negative association. Mothers caring for infants in food-insecure HHs were less able than food-secure women to sustain exclusive breastfeeding. Relative to women with food security, those with marginal, moderate and severe food insecurity had significantly lower odds of exclusive breastfeeding to 4 months, but only women with moderate food insecurity had lower odds of EBF to 6 months.
ETHIOPIA (71)	Yeneabat, Belachew and Haile (2014)	Mothers of infants (N=592). Northwest region of Ethiopia.	Community-based cross-sectional study using both quantitative and qualitative methods. Food security status assessed using adapted version of questionnaire from 2005 Ethiopian Demographic and Health Survey.	No association. In adjusted multivariate models, cessation of EBF was not significantly associated with food insecurity.

KENYA (67, 135)	Macharia *et al*. (2018)	Children less than 12 months of age and their mothers aged between 12 and 49 y (N=1 110). Korogocho and Viwandani, Nairobi.	Longitudinal study using primary survey data collected on household food security at baseline and IYCF practices postpartum. Food security measured using HFIAS.	Negative association. Infants living in food-insecure HHs were significantly less likely to be exclusively breastfed up to 6 months of age compared with infants from HHs that were food secure .
	Webb-Girard *et al*. (2012)	75 HIV-affected and 75 HIV-status unknown, low-income women who were either pregnant or with a child ≤24 months and residing in Nakuru, Kenya (N=150).	Cross sectional study using mixed method–quantitative and qualitative data from focus group discussions and 9-item HFIAS.	Food insecurity negatively affects attitude and belief towards EBF. The experience of food insecurity reduces their capacity to implement EBF for 6 months.
UGANDA (72)	Young *et al*. (2014)	180 HIV-infected pregnant and breastfeeding (BF) women receiving combination antiretroviral therapy. Tororo, Uganda.	Longitudinal cohort study using data from the Pregnant Women and Infant Study, a National Institute of Child Health and Human Development (PROMOTE) trial. Food security measured using the Household Hunger Scale	Mixed results. No association between moderate or severe HH hunger and EBF at 6 months. However, among those women still practicing EBF at 4 months, those experiencing moderate or severe household hunger were significantly more likely to cease EBF between 4 and 6 months.
UNITED STATES OF AMERICA (69)	Gross *et al*. (2012)	English- or Spanish speaking mothers at least 18-y old with a singleton full-term (≥37 weeks gestational age) infant participating in the Special Supplemental Food Program for Women, Infants, and Children with infants aged between 2 weeks and 6 months (N= 201 mother–infant pairs). Large urban medical center.	Cross sectional study of WIC participants at a large urban medical center. 2-item food security module adapted from the US HFSSM core module: 'worried food would run out' and 'low cost food." Response options included often, sometimes, or never true in the last 12 months. Mothers who responded sometimes or often true to both of the questions, were classified as food-insecure.	No association between food insecurity and exclusive breastfeeding.

TABLE 6.

STUDIES ON THE ASSOCIATION BETWEEN FOOD INSECURITY AND OVERWEIGHT AND OBESITY

Country	Author (Year)	Study population and sample size	Methods	Results on the association between food insecurity and overweight and obesity
BRAZIL (30-31, 55, 77, 83, 91, 215-216)	Gubert *et al*. (2017)	Mothers aged 15–49 and their children under 5 y of age. (N = 4 299 mother–child pairs.) Nationally representative sample	Cross-sectional study using Brazilian DHS 2006; food insecurity estimate was based on the Brazilian Food Insecurity Security Scale (EBIA).	Positive association between HFI and overweight in women.
	Gubert *et al*. (2016)	Children < 5 y of age (N = 4 064) Nationally representative sample.	Cross-sectional study using Brazilian DHS 2006; food insecurity estimate was based on the Brazilian Food Insecurity Security Scale (EBIA).	No association between HFI and overweight in children < 5 y
	Kac, Schlüssel *et al.* (2012)	Children < 5 y of age (N = 3 433) Nationally representative sample.	Cross-sectional study using Brazilian DHS 2006; food insecurity estimate was based on the EBIA.	No association between HFI and overweight in children < 5 y
	Kac, Velásquez-Melendez *et al.* (2012)	Adolescent females 15-19 y of age (N = 1529). Nationally representative sample.	Cross-sectional study using Brazilian DHS 2006; food insecurity estimate was based on the EBIA.	Positive association between HFI and excessive weight in adolescent females. There was a higher prevalence of excessive weight for adolescent females living in severely food-insecure households compared to food-secure households.
	Lopes *et al*. (2013)	12–18 y old adolescents (N = 523). Low-income area of the municipality of Duque de Caxias, Rio de Janeiro.	Cross-sectional study; food insecurity estimate was based on the EBIA.	No association between HFI and overweight in adolescents.
	Oliveira, Lira, Veras *et al*. (2009)	Adolescents (N = 1 528) and adults (N=1 163) from two towns in the state of Pernambuco, in north-eastern Brazil.	Cross-sectional, primary survey; food insecurity estimate was based on the EBIA	No association between HFI and overweight or obesity among adolescents.

	Schlüssel *et al*. (2013)	Adolescent females (N = 1 502), adult women (N = 10 226) and children < 5 y of age (N = 3 433). Nationally representative sample.	Cross-sectional study using Brazilian DHS 2006; food insecurity estimate was based on the EBIA.	Positive association between HFI and obesity among adult women; Positive association between HFI and excess weight among female adolescents. No association between HFI and obesity among children (either boys or girls).
	Velásquez-Melendez *et al*. (2011)	Women aged 18 to 45 y (N = 10 226). Nationally representative sample.	Cross-sectional study using Brazilian DHS 2006; food insecurity estimate was based on the EBIA.	Positive association between HFI and overweight among adult women.
CANADA (73, 87)	Dubois *et al*. (2006)	Children aged 1.5–4.5 y (N = 2103 children, 49% girls) in Quebec.	Longitudinal Study of Child Development in Quebec Food security measured using a single food insufficiency question asked to mothers	Positive association between HFI and child overweight and obesity at 4.5 y of age.
	Mark *et al*. (2012)	Boys and girls aged 9–18 y (N = 8 938). Nationally representative sample.	Cross sectional study using the Canadian Community Health Survey (CCHS) Cycle 2.2; food insecurity estimate was based 10 adult-referenced questions and 8 child-referenced questions.	Mixed results. Positive association between HFI and overweight in boys 9–18 y of age. There was a higher prevalence of BMI ≥85th percentile in boys in low-income food-insecure HHs than among boys in food-secure low-income HHs.
COLOMBIA (53)	Isanaka *et al*. (2007)	Children 5–12 y of age and their mothers (N = 2 526). Children attending public schools in Bogota.	Cross-sectional study of school-age children's health and nutritional status; food insecurity estimate was based on a modified version of the Spanish-language US HFSSM (16 version) plus 5 child-specific questions used to measure child food security.	No association between HFI and child or maternal overweight.

JAMAICA (88)	Dubois *et al*. (2008)	Children 10–11 y of age (N = 1 674 in Jamaica; 1 190 in Quebec). Nationally representative samples.	Cross-sectional study using the Québec Longitudinal Study of Child Development (QLSCD) 2008 & Jamaica Youth Risk and Resiliency Behaviour Survey of 2007. Food insecurity was measured based on two questions asked to children about experiences of food insecurity.	Mixed results. Negative association between HFI and overweight among children aged 10–11 y in Jamaica. Positive association between HFI and overweight or obesity only in girls In Québec.
ECUADOR (61, 100)	Weigel *et al*. (2016)	Adult women living in HHs with children (N = 794) in low-income neighbourhoods in Quito, Ecuador.	Cross sectional, primary survey. food insecurity estimate was based on the Spanish version of the US HFSSM	No association between HFI and obesity in adult women.
	Weigel and Armijos (2015)	Women of reproductive age (N = 10 748). Nationally representative sample.	Cross-sectional study using the Encuesta Demografica de Salud Materna e Infantil 2004 survey. Food insecurity was measured based on two questions on food insufficiency.	No association between food insecurity and adult or adolescent female overweight/obesity.
FRANCE (97)	Martin-Fernandez *et al*. (2014)	Adult men and women (N = 2 967). Representative sample of Paris metropolitan area.	Cross-sectional study using the third wave of a longitudinal, cohort study, the Health, Inequalities and Social Ruptures (SIRS) survey; food insecurity estimate based on the US HFSSM.	Positive association between HFI and overweight (higher BMI) among women. No association for men.
GHANA (52)	Saaka and Osman (2013)	Women of reproductive age (15 to 45 y) (N = 337). Tamale Metropolis of Northern Ghana.	Cross-sectional study, primary survey; food insecurity estimate based on the 30-day HFIAS.	No association between HFI and women's BMI.
IRAN (Islamic Republic of) (78)	Jafari *et al*. (2017)	Children aged 9.30 ± 1.49 y (N = 587: 439 girls and 148 boys) in Isfahan.	Cross-sectional study, primary survey; food insecurity estimate based on the Radimer/Cornell Scale.	No association between HFI and obesity in children aged 7–12 y. HFI was associated with abdominal but not general obesity.
LEBANON (92, 104)	Jomaa *et al*. (2017)	Mothers who have children < 18 y of age (N = 378) in Beirut.	Cross-sectional study, primary survey; food insecurity was measured based a locally-validated, Arabic version of the HFIAS.	Positive association between HFI and obesity in women.

	Ghattas *et al*. (2017)	Children and adults (N = 474) from 84 HHs in two settlements in the Bekaa valley. Children <5 y of age (N = 66) Children 5–17 y of age (N =146) Adults >18 y of age (including 65 and above) (N = 302)	Cross-sectional study, primary survey; food insecurity was measured using an Arabic version of the US HFSSM adapted to the Lebanese context.	No association between HFI and overweight and obesity among adults.
MALAYSIA (45, 101-102)	Ali Naser *et al*. (2014)	Mothers aged 18–55 y who were non-lactating, non-pregnant, and had at least one child aged 2–12 y (N = 223). Bachok district in Kelantan, rural area of North East Peninsular Malaysia.	Cross-sectional study, using a primary survey; food insecurity estimate was based on the Radimer/Cornell food security scale.	No association between HFI and obesity/overweight in adult women.
	Mohamadpour *et al*. (2012)	Indian women (19–49 y of age, non-pregnant, and non-lactating) (N = 169) in palm-plantation HHs in Negeri Sembilan.	Cross-sectional study, using a primary survey; food insecurity estimate was based on the Radimer/Cornell food security scale.	No association between HFI and obesity in adult women. However, significant association observed between HFI and risk waist-circumference.
	Shariff *et al*. (2014)	Women of reproductive age (N = 625) in three states of Peninsular Malaysia.	Cross-sectional study, using a primary survey; food insecurity estimate was based on the Radimer/Cornell food security scale.	No association between HFI and obesity/overweight in adult women.
MEXICO (37)	Shamah-Levy *et al*. (2014)	Children <5 y of age and adults. (N not provided). Nationally representative samples.	Cross-sectional study using Mexican National Health and Nutrition Survey (ENSANUT) 2012; food insecurity estimate based on the ELCSA.	Positive association between HFI and overweight (higher BMI) among adults. HFI significant predictor of overweight/obesity in adults, especially women.
NEPAL (38, 41)	Singh and Ram (186)	Married women aged 15 to 49 y (N = 4581). Nationally representative sample.	Cross sectional study using Nepal DHS 2011; food insecurity estimate based on an adapted version of HFIAS (7 items).	No association between HFI overweight in women.
	Sreeramareddy *et al*. (2015)	Children <5 y of age (N = 2 591). Nationally representative sample.	Cross-sectional study using Nepal DHS 2011; food insecurity estimate based on an adapted version of HFIAS (7 items).	No association of HFI with child overweight (BMI-for-age z score).

UGANDA (105)	Chaput *et al*. (2007)	60 food-secure (30 male and 30 female) and 60 food-insecure (30 male and 30 female) individuals in urban Kampala.	Cross-sectional study, using a primary survey; food insecurity estimate was based on the Radimer/Cornell food security scale.	No association between HFI and overweight in women.
UNITED STATES OF AMERICA (3-4, 26, 74-76, 79-82, 84-86, 93-96, 98-99, 103, 207-208, 217-221)	Asfour *et al*. (2015)	Children 2 to 5 y of age (N = 1 211) in twenty-eight subsidized childcare centres in Miami-Dade County, Florida.	Cross Sectional study using baseline data from a preschool intervention trial. Food insecurity measured using five survey questions from the US HFSSM.	No association between HFI and BMI percentile among children 2 to 5 y of age.
	Bhargava *et al*. (2008)	Children > 5 y of age (kindergarten to fifth grade) (N = 5 797 boys and 5 682 girls). Nationally representative sample.	Longitudinal study based on the Early Childhood Kindergarten Cohort Study; food insecurity measured using the US HFSSM.	No association between HFI and overweight in children > 5 y of age.
	Bronte-Tinkew *et al*. (2007)	Children 2 y of age (N = 8 693 children). Nationally representative sample.	Longitudinal study based on the Early Childhood Longitudinal Survey-Birth Cohort; food insecurity measured using the US HFSSM.	No direct association. HFI influences overweight via parenting practices and infant feeding practices.
	Buscemi *et al*. (2011)	Latino children 2–17 y of age (N = 63, 30 girls and 33 boys) from immigrant and non-immigrant families attending a primary health care clinic serving low income families in Memphis.	Cross-sectional study, using a primary survey; food insecurity measured using the US HFSSM.	Negative association between HFI and overweight in children 2–17 y of age. Acculturation is a significant moderating variable.
	Casey *et al*. (2006)	Children 3–17 y of age (N = 3 553 boys and 3442 girls). Nationally representative sample.	Cross sectional study using NHANES data; food insecurity measured using the US HFSSM (8 child-referenced items).	Mixed results. Positive association between HFI and overweight for the following demographic groups: children 12 to 17 y of age; white girls; children living in HHs with income < 1 and > 4 times the federal poverty level. Child food insecurity associated with risk for overweight for: above groups, and ages 3–5, Mexican American, and white.

	Gundersen *et al*. (2009)	Children 8–17 y of age (N = 2 516). Nationally representative sample.	Cross-sectional study using pooled NHANES data; food insecurity was measure using the US HFSSM.	No association between HFI and overweight in children 8–17 y of age.
	Gundersen *et al*. (2008a)	Children 10–15 y of age (N = 1 031). Boston, Chicago, and San Antonio.	Cross-sectional study using data from the Welfare, Children, and Families Three-City Study; food insecurity measured using three questions from the US HFSSM.	No association between HFI and overweight in children 10–15 y of age.
	Gundersen *et al*. (2008b)	Children 3–17 y of age (N = 841) and their mothers. Nationally representative sample.	Pooled time series-cross section data from the NHANES; food insecurity measured using the US HFSSM (8-item child scale).	No direct association between HFI and overweight among children 3–17 y of age.
	Kaur *et al*. (2015)	Children 2 to 11 y of age (N =9 701). Nationally representative sample.	Longitudinal study using NHANES data. Child-level food insecurity was assessed with US HFSSM based on eight child-specific questions. Personal food insecurity was assessed with five additional questions.	Mixed results. Obesity significantly associated with personal food insecurity for children 6–11 y of age but not in children 2–5 y of age.
	Kuku *et al*. (2012)	Children (N = 959). Nationally representative sample.	Longitudinal study using the Second Child Development Supplement (CDS-II) of the Panel Study of Income Dynamics (PSID); food insecurity measured using the US HFSSM.	HFI positively associated with obesity in children. Moreover, this relationship differs across relevant subgroups including those defined by gender, race/ethnicity and income.
	Hanson *et al*. (2007)	Adult men and women ≥20 y of age (N = 4 338 men and 4 172 women). Nationally representative sample.	Cross sectional study using the NHANES; food insecurity measured using 18 item US HFSSM.	Positive association between HFI and obesity in women but not in men. Greater likelihood of obesity in food insecure: married, widowed, and partnered women (as opposed to food secure, never married). Men with low food security less likely to be overweight. Women with marginal food security more likely to be overweight. Women with low food security more likely to be obese.

	Hernandez *et al*. (2017)	Adults 18–59 y of age (N = 1 990). Nationally representative sample.	Cross sectional study using National Health Interview Survey data; food insecurity measured using the 10-item US HFSSM.	Food insecurity was associated with 41% and 29% higher odds of being overweight/obese among white and Hispanic women, respectively. Food insecurity was not related to overweight/obesity among black women nor among white, black, and Hispanic men.
	Jyoti *et al*. (2005)	ECLS_K cohort (N = 5 682 boys and 5498 girls) kindergarten through 8th grade.	Early Childhood Longitudinal Study-Kindergarten Cohort; food insecurity measured using the US HFSSM.	Mixed results. Positive association between HFI and overweight only among girls.
	Laraia *et al*. (2015)	Women >16 y of age (N = 526) in North Carolina.	Longitudinal study using data from the Pregnancy, Infection and Nutrition (PIN) Postpartum Study; food insecurity measured using the US HFSSM.	Positive association between HFI and higher BMI among post-partum women. Among overweight/obese women, food insecurity was associated with a higher BMI at 12 months postpartum compared to overweight/obese women from food-secure HHs. Food security status was associated with higher levels of perceived stress, disordered eating behaviour and dietary fat intake above the recommended amount at 3 and 12 months postpartum
	Laraia *et al*. (2013)	Pregnant women (N = 1 041) in North Carolina.	Longitudinal study based on the Pregnancy, Infection and Nutrition (PIN) Postpartum Study; food insecurity measured using the US HFSSM.	Positive association between mild food insecurity and risk of excessive weight gain among pregnant women.
	Lohman *et al*. (2009)	Children 10–15 y of age (N = 1 011) in Boston, Chicago, and San Antonio.	Cross sectional study using Welfare, Children, and Families Three-City Study (1999 Wave 1); food insecurity measured using a 3-item subscale of the US HFSSSM (child)	No direct association between HFI and overweight in children 10–15 y of age; positive interaction of food insecurity and maternal stress index

	Martin and Lippert (2012)	Adult men and women of child bearing age (N = 7 931). Nationally representative sample.	Longitudinal study using the PSID; food insecurity measured using the US HFSSM.	Positive association between HFI and overweight/obesity in women. Among women, food-insecure mothers were more likely than child-free women to be overweight or obese. The risks are greater for single mothers relative to mothers in married or cohabiting relationships.
	Martin and Ferris (2007)	Children 2–12 y of age. (N =212; 108 girls, 104 boys) in Hartford, Connecticut.	Cross sectional study using a community survey; food insecurity measured using the 18 item US HFSSM.	No association between HFI and overweight in children 2–12 y of age.
	Metallinos-Katsaras *et al*. (2012)	Children 2–5 y of age (N = 2 353) from low-income families participating in the Massachusetts Special Supplemental Nutrition Program for Women, Infants, and Children.	Longitudinal study based on a primary survey; food insecurity measured using the 18-item US HFSSM.	Positive association between HFI and obesity in children 2–5 y of age.
	Metallinos-Katsaras *et al*. (2009)	Children ≤ 5 y of age (N = 8 493) from low-income families participating in the Massachusetts Special Supplemental Nutrition Program for Women, Infants, and Children.	Cross sectional study on a primary survey; food insecurity measured using the 4-item subscale of US HFSSM.	Mixed results. Negative association between HFI and overweight in girls < 2 y of age. Positive association between HFI and overweight in girls 2–5 y of age.
	Millimet and Roy (2015)	Children (kindergarten through eighth grade) (ECLS-K cohort N = 6 470); Children from birth through kindergarten entry (ECLS-B cohort N = 4 100). Nationally representative sample.	Longitudinal study using data from the ECLS-K and ECLS-B; food insecurity measured using the US HFSSM.	No long-run causal relationship between food security and child obesity in the presence of measurement error. Only in the absence of measurement error there exists any suggestive evidence that food insecurity has a long-run (negative) causal effect on child obesity and overweight status of children.

	Olson and Strawderman (2008)	Adult childbearing women (N = 662) living in a 10-county rural area of upstate New York.	Longitudinal study using data from the Bassett Mothers Health Project, an observational cohort study of healthy adult women followed from early pregnancy until 2 y postpartum; HFI measured postpartum using a 3-item subscale of the US HFSSM.	Positive association between HFI and obesity in women at two years postpartum; association lost significance after controlling for covariates.
	Rose and Bodor (2006)	Children in their kindergarten year (N = 16 889). Nationally representative sample.	Longitudinal study using the Early Childhood Longitudinal Study-Kindergarten Cohort (ECLS-K); food insecurity measured using the 18-item US HFSSM	No association between HFI and overweight in children of kindergarten age.
	Speirs *et al*. (2016)	Children 2–5 y of age (N = 438) recruited from 30 licensed child care centres in five counties in central Illinois	Cross sectional based on the Synergistic Theory and Research on Obesity and Nutrition Group Kids (STRONG Kids) program; food insecurity measured using the 18 item US HFSSM. Both HH food insecurity and child food insecurity estimated	Mixed results. No association between either HFI or child food insecurity and BMI for the full sample. Positive association between HFI and BMI z-scores for girls only.
	Trapp *et al*. (2015)	Low-income children aged 2–4 y (N = 222)	Cross-sectional study using a primary survey related to an obesity prevention/reversal study (Steps to Growing Up Healthy); food insecurity measured using the US HFSSM	No association between HFI and child BMI percentile.
	Whitaker and Sarin (2007)	Mothers with preschool children (N = 1 707) from 20 large cities.	Longitudinal study based on the Fragile Families and Child Wellbeing Study (Baseline 2001–2003; follow-up 2003–2005); food insecurity measured using the US HFSSM adult items.	No association between HFI and obesity in women. Significance of association (at both periods) was lost after controlling for covariates.
	Widome *et al*. (2009)	Multiethnic middle and high school students (N = 4 746) from 31 primarily urban schools in Minneapolis–St. Paul, Minnesota area.	Cross-sectional study using a primary survey, part of Project EAT (Eating Among Teens); food insecurity measured using the 2 items from US HFSSM	Positive association between HFI and overweight in adolescents. Food-insecure youths were more likely to have a body mass index above the 95th percentile.

VIET NAM (106)	Vuong *et al*. (2015)	250 adults (N = 250) in District eight in Ho Chi Minh City	Cross sectional study using primary survey; food insecurity measured using the ELCSA.	No significant association between HFI and overweight/obesity in adults.
INDIA, PERU, ETHIOPIA, VIET NAM (48)	Humphries *et al*. (2015)	Children aged 1, 5, and 8 y (three rounds of data collection) in four countries. Ethiopia (N = 1 757), India (N = 1 825), Peru (N = 1 844), and Viet Nam (N = 1 828).	Longitudinal study following the same children at ages 1, 5 and 8 y, using a primary survey; at 5 y of age food insecurity estimate was based on a modified version of the US HFSSM, at 8 y of age, the estimate was based on the HFIAS.	Mixed results. No association between HFI and BMI-Z in any of the 4 countries in cross-sectional analysis at 5 y of age, and only in Peru and Viet Nam at 8 y of age.
UNITED STATES OF AMERICA AND MEXICO (89)	Rosas *et al*. (2011)	5-year-old children and their mothers. In California, mother–child pairs of whom all children were born in the US and all mothers born in Mexico, participants in the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) study (N = 287 mother–child pairs). In Mexico, mothers and their 5-year-old children who were beneficiaries of the social welfare program *Oportunidades* (N = 316 mother–child pairs)	A binational study using two cross-sectional samples of 5-year-old children and their mothers in California and Mexico; food insecurity was measured based on the US HFSSM - Spanish Version (Short Form)	Mixed results. Positive association between HFI and overweight or obesity among children in Mexico. No association of HFI with child weight status in California.

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