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Review

Food insecurity and the risk of undernutrition complications among children and adolescents: A systematic review and meta-analysis

Sajjad Moradi [a], Atieh Mirzababaei [b], Hamed Mohammadi [c], Seyedeh Parisa Moosavian [d], Arman Arab [e], Behrooz Jannat [f], Khadijeh Mirzaei Ph.D. [b,*]

[a] Department of Community Nutrition, School of Nutrition and Food Science, Food Security Research Center, Isfahan University of Medical Sciences, Isfahan, Iran
[b] Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences (TUMS), Tehran, Iran
[c] Department of Clinical Nutrition, School of Nutrition and Food Science, Students Research Committee, Isfahan University of Medical Sciences, Isfahan, Iran
[d] Department of Clinical Nutrition, School of Nutrition and Food Science, Isfahan University of Medical Sciences, Isfahan, Iran
[e] Department of Community Nutrition, School of Nutrition and Food Science, Isfahan University of Medical Sciences, Isfahan, Iran
[f] Halal Research Center of IRI, FDA, Tehran, Iran

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ABSTRACT

Objectives: This systematic review and meta-analysis was performed to examine the association between household food insecurity and the risk of being underweight, stunting, and wasting in children and adolescents.
Methods: Pertinent studies were identified by searching PubMed, Web of Science, and Scopus databases up to June 2018. A total of 21 studies met the inclusion criteria to be included in the pooled analysis. The risk ratio of 55 173 individuals from 12 different countries were pooled in these studies for our meta-analysis.
Results: It was found that food insecurity increased the risk of stunting (odds ratio [OR] = 1.17; 95% confidence interval [CI]: 1.09–1.25) and underweight (OR = 1.17; 95% CI: 1.01–1.36) but not of wasting (OR = 1.04; 95% CI: 0.96–1.12). Subgroup analysis by age indicated that food insecurity increased the risk of stunting (OR = 1.20; 95% CI: 1.02–1.39) and underweight (OR = 1.34; 95% CI: 1.02–1.77) in children older than 5 y. This association was significant just for stunting risk (OR = 1.14; 95% CI: 1.05–1.23) in children younger than 5 y. Furthermore, among children and adolescents, risk of stunting or being underweight increased by the intensification of the level of food insecurity in food-insecure households. Furthermore, subgroup analysis by country development levels showed that children and adolescents living in developing countries had higher risk of stunting (OR = 1.16; 95% CI: 1.05–1.27).
Conclusions: Household food insecurity appears to be associated with higher risk of stunting and being underweight among children and adolescents. In addition, the intensification of the level of food insecurity and the increased age of children may increase the risk of stunting or being underweight in food-insecure households. Also, the level of economic development is an important factor in the effects of food insecurity on risk of stunting.

Introduction

Food insecurity is defined as the "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" [1]. Food insecurity affects health and well-being throughout life, from the prenatal period to old age, and has been associated with child dietary intake and weight status [2–4].

Food security is especially important for children because the nutritional content of their diets affects not only their current health, but also their physical, mental, and social development and thus their future health and well-being [5]. Childhood food insecurity has long-term adverse effects on the cognitive and socioemotional development of a child, ultimately impairing academic achievement even 3 y after transitioning out of food insecurity [6,7]. Household food insecurity (HFI) may be related to the protein energy malnutrition evident in stunting, wasting, and being underweight, which affects one-quarter of the world's children [8]. Globally the prevalence of stunting fell from 29.5% to 22.9% between 2005 and 2016, although 155 million children younger than 5 y old

* Corresponding author. Tel.: +98-21-88955569; fax: +98-21-88984861.
E-mail address: mirzaei_kh@tums.ac.ir (K. Mirzaei).

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across the world still suffer from stunted growth. In 2016 the number of chronically undernourished people in the world is estimated to have increased to 815 million, up from 777 million in 2015, although still down from about 900 million in 2000 [9].

Some studies have reported a positive association between household food insecurity and weight gain during childhood [10,11], but others have found no relationship [12–16]. Other studies find that household food insecurity is associated with overweight or obesity for preschool-aged children [17]. A few studies have found a negative association between household food insecurity and malnutrition among children [18–21]. Among adults, a few studies have found a significant association between household food insecurity and malnutrition. Tiwari et al. [22] found a strong association between household food insecurity and stunting and severe stunting among children aged 0 to 59 mo and 0 to 23 mo, respectively, which indicated that household food insecurity was significantly associated with stunting among preschool children.

In addition, socioeconomic status is a very important factor that affected food insecurity and undernutrition complications. In high-development countries, Martin et al. [23] reported that food insecurity did not increase the underweight risk in urban settings, whereas Metallinos-Katsaras et al. [24] found a strong association between household food insecurity and underweight among urban and rural settings. On the other hand, one study [12] in low-development areas indicated that food insecurity did not increase the underweight and stunting risk, but other studies have found a significant association between household food insecurity and malnutrition [25,26].

To date, observational studies have found inconsistent effects of food insecurity on children's weight status. In addition, the data from these individual studies might not be sufficient to identify a possible differential risk for growth problems. In addition, considerable controversy exists regarding the association between food insecurity and the risks of undernutrition complications in children and adolescents. Therefore a systematic review and meta-analysis was performed to examine the associations between food insecurity and the risks of undernutrition complications, including being underweight, stunting, and wasting in children and adolescents.

Methods

Literature search and selection

This meta-analysis was performed in accordance with the guidelines of the Meta-Analysis of Observational Studies in Epidemiology [27]. A systematic search of PubMed was performed on October 10, 2017, followed by a search of Scopus and Web of Science. The subsequent search was updated in June 2018. Search strategies used subject headings and keywords and did not use language and date restrictions. The following terms were used in the electronic search for associations between food insecurity and the risks of being underweight and growth disorders: ("Food Supply" [Mesh] or "Food Supply" [Title/Abstract] or "Food Supplies" [Title/Abstract] or "Food Insecurity" [Title/Abstract] or "Food Insecurities" [Title/Abstract] or "Food Insecurities" [Title/Abstract] or "Food Security" [Title/Abstract] or "Food insufficiency" [Title/Abstract]) AND ("Thinness" [Mesh] or "Thinness" [Title/Abstract] or "Leanness" [Title/Abstract] or "Under-weight " [Title/Abstract]) OR ("Growth Disorders" [Mesh] or "Growth Disorders" [Title/Abstract] or "Growth Disorder" [Mesh]or "Stunted Growth" [Title/Abstract] or "Stunting" [Title/Abstract] or "Stuntings" [Title/Abstract])) OR "Wasting Syndrome" [Mesh] or "Wasting Syndrome" [Title/Abstract] or "Wasting Syndromes" [Title/Abstract] or "Wasting Disease" [Title/Abstract] or "Wasting Diseases" [Title/Abstract]). A manual reference check was performed on pertinent studies to identify further relevant trials. Any disagreements during the study selection process were resolved through panel discussions.

Eligibility criteria

Studies were included in the final analysis if they met the following criteria: All observational studies that reported on the association between food insecurity and the risk of being underweight, stunting, or wasting in children and adolescents. Studies were excluded if a) they did not report the risks of being underweight, stunting, or wasting; b) they were reviews, case reports, conference reports, or letters; c) participants were >18 y old.

Study selection

The titles and abstracts of all articles retrieved in the initial search were evaluated independently by 2 reviewers. Articles not meeting the eligibility criteria were excluded using a screen form, with a hierarchical approach based on study design, population, or exposure and outcome. The reference lists of relevant review articles identified during this process were also examined to include additional studies. Full-text articles were retrieved if the citation was considered eligible and were subjected to a second evaluation for relevance by the same reviewers. Any disagreements were discussed and resolved by consensus.

Data collection

For the selected studies, two reviewers (S.M. and A.M.) extracted data separately using a standard data extraction form. They discussed any discrepancies in data extraction and sought the assessment of a third reviewer (Kh.-M.) for resolution. Extracted information included relevant study details (name of the first author, year, database, geographic area, study design, sample size), population characteristics (age range or mean age, male/female sex, and setting), exposure (criteria for being underweight, stunting or wasting status, level of food insecurity measurement, method of food insecurity assessment, most fully adjusted odds ratio [OR] estimate, and the adjusted covariates for calculating OR), main findings, and quality score.

Quality assessment for individual studies

Two reviewers (S.M. and A.M.) assessed the quality of each selected study using the Newcastle-Ottawa scale [28]. This scale awards a maximum of nine stars to each study: four stars for the adequate selection of cases and controls, two stars for the comparability of cases and controls on the basis of the design and analysis, and three stars for the adequate ascertainment of exposure in both the case and control groups. Studies of high quality were defined as those that scored the maximum nine stars on the Newcastle-Ottawa scale; studies of medium quality scored seven or eight stars.

Statistical analysis

To assess the associations between food insecurity and the risks of undernutrition complications among children and adolescents, the most fully adjusted risk estimates of being underweight, stunting, or wasting were pooled. To accurately examine the association between HFI and the risks of undernutrition complications in children and adolescents, the study populations were subgrouped based on age (≥5 y and <5 y), HFI levels (mild, moderate, and severe), and national economic development level (developed and developing). Pooled OR and 95% confidence interval (CI) were estimated using a weighted random-effect model (the DerSimonian-Laird approach). Heterogeneity among the studies was assessed by Cochran Q and I^2 statistics ($I^2 = (Q - df) / Q \times 100\%$; $I^2 < 25\%$, no heterogeneity; $I^2 = 25–50\%$, moderate heterogeneity; $I^2 = 50–75\%$, large heterogeneity, $I^2 > 75\%$, extreme heterogeneity). The heterogeneity was considered significant if either the Q statistic had $P < 0.1$ or $I^2 > 50\%$. To assess the statistical outcome validity, we detected overall outcome by sensitivity analysis. Visual inspection of asymmetry in funnel plots, Begg's test, and Egger's test were conducted to evaluate publication bias ($P < 0.05$ was considered representative of statistical significance). All statistical tests for this meta-analysis were performed with STATA (version 14.0; Stata Corp., College Station, TX, USA), and SPSS (version 23.0; IBM Corp., Armonk, NY, USA).

Results

Characteristics of the studies

The systematic literature search produced a total of 656 publications, after the exclusion of duplicates, from the different databases. After initial screening, 597 publications were excluded because they did not meet the study eligibility criteria, leaving 59 articles for full-text assessment (Fig. 1). A total of 22 studies met the criteria for the quantitative synthesis to be included in the systematic review [12,21–26,29–43]. Among these 22 studies, 21 used a cross-sectional design [12,21–23,25,26,29–43] and one study was longitudinal [24]. However, six studies [21,22,33,38,41,43] were not included in the quantitative synthesis because the criteria for assessment of underweight, stunting, and wasting or food insecurity measurement used local instruments and were not appropriate for meta-analysis. The risk ratio of 55 173 individuals was pooled in these studies for our meta-analysis. These studies were published between 2007 and 2018 and performed in the United States

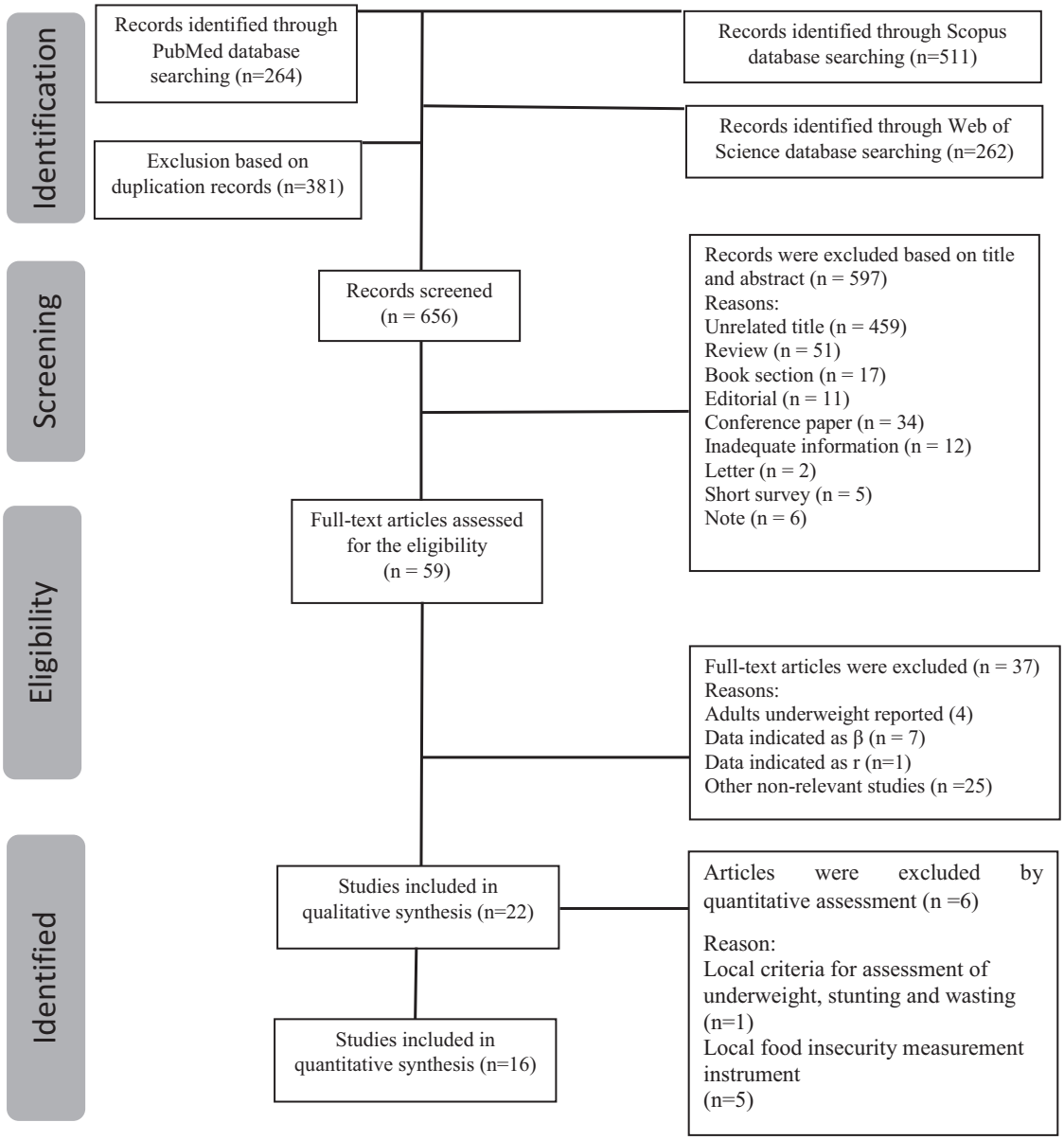

Fig. 1. PRISMA flowchart describing the study's systematic literature search and study selection.

[23,24,36], Brazil [38], Canada [31], Colombia [21, 29], Nepal [12,22,25], Malaysia [30], Ethiopia [34,37,39], Kenya [26,33], Iran [35], Mozambique [32], Mexico [41], Burundi [40], and Indonesia [42]. The studies included for assessment of food insecurity status used the US Department of Agriculture Scale [23,29,35], Household Food Security Survey Module [24], Household Food Insecurity Access Scale [12,25,31, 33,34,36,37,39,40,42], and Radimer/Cornell Scale [26,30]. These studies were conducted in different national economic development levels, including high and very high development [23,24,29–31,35,36], medium development [42], and low development [12,25,26,32–34,37,39,40]. Table 1 describes the main characteristics of included studies.

Quantitative synthesis

The study-specific, maximally adjusted OR results were pooled to examine the associations between food insecurity and the risk of being underweight, stunting, or wasting in children and adolescents. The results indicated that there was a significant overall association between food insecurity and the risks of undernutrition complications (OR = 1.15; 95% CI: 1.09–1.21) when all ORs were combined with the random-effects model. Heterogeneity existed among the studies ($P < 0.000$, $I^2 = 73.7\%$). These results revealed that food insecurity increased the risk of stunting (OR = 1.17; 95% CI: 1.09–1.25) and underweight (OR = 1.17; 95% CI: 1.01–1.36) but not of wasting (OR = 1.04; 95% CI: 0.96–1.12) (Fig. 2).

As shown in Table 2, food insecurity significantly increased the risk of being underweight among children and adolescents older than 5 y (OR = 1.34; 95% CI: 1.02–1.77) but not children younger than 5 y (OR = 0.97; 95% CI: 0.82–1.16). The results stratified by categorized food insecurity for being underweight in children and adolescents are shown in Table 2. These results indicated that HFI in two levels, including moderate food insecurity (OR = 1.30; 95% CI: 1.02–1.64) and severe food insecurity (OR = 1.69 95% CI:

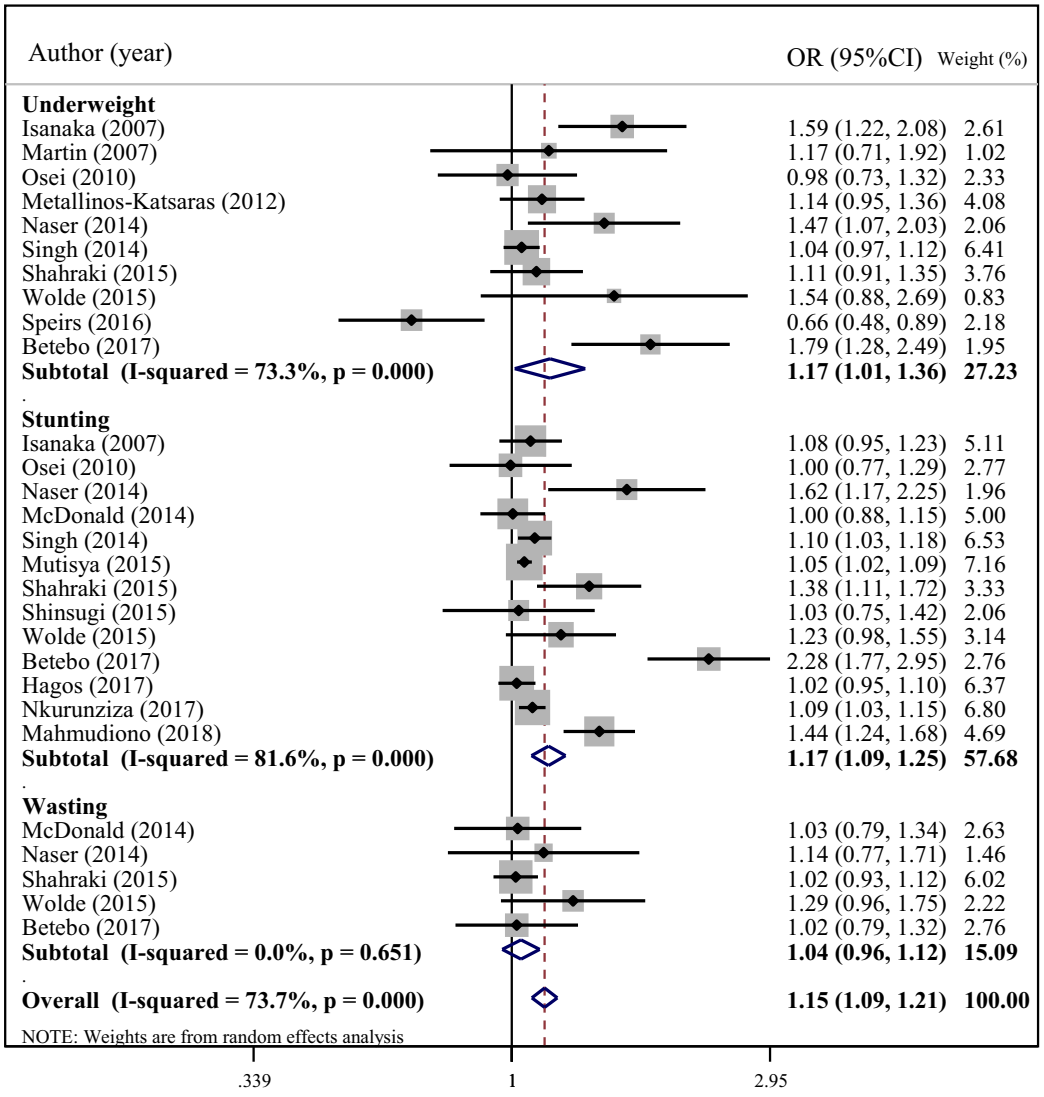

Fig. 2. Forest plots showing odds ratios (ORs) with 95% confidence intervals (CIs) of underweight, stunting, and wasting for children and adolescents.

1.16-2.44), increased the risks of being underweight, but not with mild food insecurity (OR = 1.03; 95% CI: 0.91–1.18).

For accurate evaluation of the associations between food insecurity and the risk of stunting, the study populations were grouped based on age (Table 2). The results suggested that food insecurity increased stunting risks in higher age groups (OR = 1.21 95% CI: 1.11-1.32). Age subgroup analysis revealed that food insecurity increased the stunting risk in both subgroups including children younger than 5 y (OR = 1.14; 95% CI: 1.05–1.23) and children and adolescents older than 5 y (OR = 1.20; 95% CI: 1.03–1.39). In addition, subgroup analysis by levels of food insecurity indicated that the risk of stunting increased in three levels of food insecurity, including mild (OR = 1.13; 95% CI: 1.02–1.25), moderate (OR = 1.15; 95% CI: 1.04–1.28), and severe (OR = 1.25; 95% CI: 1.11–1.40).

As shown in Table 2, there was no significant association between age subgroups and the risk of wasting among children and adolescents, although there was significant association between the risk of wasting increased in moderate level of food insecurity (OR = 1.15; 95% CI: 1.04–1.28).

Furthermore, subgroup analysis by country development levels suggested that children and adolescents living in developing countries had higher risk of stunting (OR = 1.16; 95% CI: 1.05–1.27), but not children and adolescent living in developed countries (OR = 1.36; 95% CI: 0.86–1.74). However, there was no association between country development levels and underweight or wasting risk (Table 2).

Sensitivity analysis

Sensitivity analysis was performed by omitting each of the studies included. The results indicated that the OR was not changed significantly by omitting any of the studies for stunting (Supplementary Fig. 1), underweight (Supplementary Fig. 2), and wasting (Supplementary Fig. 3). This indicated that the meta-analysis results were stable and not sensitive to any of the 16 studies ($P > 0.05$).

Publication bias

There was no evidence of publication bias for studies examining the association between food insecurity and stunting ($P = 0.24$, Begg's test; and $P = 0.06$, Egger's test), underweight ($P = 0.13$, Begg's test; and $P = 0.64$, Egger's test), and wasting ($P = 0.09$, Begg's test; and $P = 0.15$, Egger's test).

Table 1
Characteristics of the studies included in the systematic review and meta-analysis

First author (y)	Database/ country	Particpants: Age (y) Sex (female/male, %) Population size *(n)*	Criteria for underweight, stunting, or wasting	Measure of food insecurity level/ questionnaire	Reported OR	Main findings	Adjusted variables	Quality score
Isanaka et al. (2007)	—/Colombia	5–12 y *n* = 2526	WHO (1995)	H/USDA	Underweight and stunting risk	Food insecurity increased the underweight risk	Parental characteristics and socioeconomic status	High
Martin et al. (2007)	—/USA	2–12 y (50.9/49.1) *n* = 212	CDC (2006)	H/USDA	Underweight risk	Food insecurity did not increase the underweight risk	Age, sex, race/ethnicity, parent education greater than high school degree, and level of poverty	High
Hackett et al. (2009)	—/Colombia	<5 y (47.7/ 52.5) *n* = 1485	MANA (2006)	H/CHFSS	Underweight and stunting risk	Severe food insecurity increased the risk of underweight and stunting	Health and demographic factors, parental characteristics, and socioeconomic status	High
Osei et al. (2010)	AAMA/Nepal	<2 y (47.7/52.5) *n* = 368	WHO (2006)	H/HFIAS	Underweight and stunting risk	Food insecurity did not increase the underweight and stunting risk	Health and demographic factors, parental characteristics, and socioeconomic status	High
Metallinos-Katsaras et al. (2012)	—/USA	2–5 y (49/51) *n* = 28 353	CDC (2000)	H/HFSSM	Underweight risk	Food insecurity increase the underweight risk	Demographic factors and parental characteristics	High
Singh et al. (2014)	NDHS/Nepal	<5 y (49.3/50.7) *n* = 2335	WHO (2006)	H/HFIAS	Underweight and stunting risk	Severe food insecurity increased the risk of underweight and stunting	Health and demographic factors, parental characteristics, and socioeconomic status	High
Naser et al. (2014)	—/Malaysia	2–12 y (52.8/47.2) *n* = 233	WHO (1995)	Radimer/Cornell Scale	Underweight, stunting, and wasting risk	Food insecurity increased the underweight risk	Demographic factors and parental characteristics	High
Tiwari et al. (2014)	NDHS /Nepal	<5 y (49.3/50.7) *n* = 2830	WHO (2006)	H/NDHS	Stunting risk	Food insecurity increased the stunting risk	Demographic factors and parental characteristics	High
McDonald et al. (2014)	—/Canada	2.02 ± 1.25 y)46/54 (*n* = 900	WHO (2006)	H/HFIAS	Stunting and wasting risk	Food insecurity did not increase the risk of stunting or wasting	Health and demographic factors, parental characteristics, and socioeconomic status	High
Wolde et al. (2015(	—/Ethiopia	7–14 y)53/47(*n* = 450	WHO (2007)	H/ HFIAS	Underweight, stunting, and wasting risk	Food insecurity increased the stunting, underweight, and wasting risk	Health and demographic factors, parental characteristics, and socioeconomic status	High
Mutisya et al. (2015)	NUHDSS/ Kenya	<2 y (44/56) *n* = 6858	WHO (2007)	Radimer/Cornell Scale	Stunting risk	Food insecurity increased the stunting risk	Health and demographic factors, parental characteristics, and socioeconomic status	High
Shahraki et al. (2015)	—/Iran	7–11 y (48/51) *n* = 610	WHO (2007)	H/USDA	Underweight, stunting, and wasting risk	Severe food insecurity increased the risk of underweight, stunting, and wasting	Health and demographic factors, parental characteristics, and socioeconomic status	High
Rose et al. (2015)	—/Mozambique	<5 y *n* = 560	WHO (2006)	H /—	Underweight, stunting, and wasting risk	Food insecurity increased the wasting risk	Health and demographic factors and socioeconomic status	Medium
Shinsugi et al. (2015)	HDSS/ Kenya	<5 y (54/46) *n* = 404	WHO (2006)	H/HFIAS	Stunting risk	Food insecurity did not increase the underweight risk	Health and demographic factors and socioeconomic status	High
Speirs et al. (2016)	STRONG Kids/USA	2–5 y (51.1/48.9) *n* = 438	CDC (2000)	H/HFIAS	Underweight risk	Food insecurity did not increase the stunting risk	Health and demographic factors, parental characteristics, and socioeconomic status	High

(*continued on next page*)

Table 1 (*Continued*)

First author (y)	Database/ country	Particpants: Age (y) Sex (female/male, %) Population size *(n)*	Criteria for underweight, stunting, or wasting	Measure of food insecurity level/ questionnaire	Reported OR	Main findings	Adjusted variables	Quality score
Dorsey et al. (2017)	—/USA	<5 y *n* = 4853	WHO (2006))	H/FANTA	Stunting risk	Moderate food insecurity increased the stunting risk	Health and demographic factors and parental characteristics	Medium
Shamah-Levy et al. (2017)	ENSANUT/ Mexico	<5 y (49.8/50.2) *n* = 5087	WHO (2006)	H/ELCSA	Stunting risk	Food insecurity increased the stunting risk	Health and demographic factors, parental characteristics, and socioeconomic status	Medium
Betebo et al. (2017)	—/Ethiopia	<5 y (50.6/49.4) *n* = 508	WHO (2007)	H/HFIAS	Underweight, stunting, and wasting risk	Food insecurity increased the stunting and underweight risk	Health and demographic factors, parental characteristics, and socioeconomic status	High
Gubert et al. (2017)	DHS/Brazil	<5 y (47.8/52.2) *n* = 4299	WHO (2006)	H/EBIA	Stunting risk	Food insecurity did not increase the stunting risk	Health and demographic factors, parental characteristics, and socioeconomic status	Medium
Hagos et al. (2017)	—/Ethiopia	<5 y (49.6/50.4) *n* = 4094	WHO (2005)	H/HFIAS	Stunting risk	Food insecurity increased the stunting risk	Health and demographic factors, parental characteristics, and socioeconomic status	High
Nkurunziza et al. (2017)	PBF /Burundi	<2 y (51.1/48.8) *n* = 6199	WHO (2006)	H/HFIAS	Stunting risk	Severe food insecurity increased the stunting risk	Unadjusted	Medium
Mahmudiono et al. (2018)	—/Indonesia	2–5 y *n* = 685	WHO (2006)	H/HFIAS	Stunting risk	Severe and mild food insecurity increased the stunting risk	Health and demographic factors, parental characteristics, and socioeconomic status	High

AAMA, Action Against Malnutrition through Agriculture; CDC, Centers for Disease Control and Prevention; CHFSS, Colombian Household Food Security Scale; DHS, Demographic and Health Surveys; EBIA, Brazilian Food Insecurity Measurement Scale; ELCSA, Latin American and Caribbean Food Security Scale; ENSANUT, Mexican National Health and Nutrition Survey; FANTA, Food and Nutrition Technical Assistance; H, household; HDSS, Health and Demographic Surveillance System; HFI, household food insecurity; HFIAS, Household Food Insecurity Access Scale; HFSSM, Household Food Security Survey Module; MANA, Mejoramiento Alimentario y Nutricional de Antioquia; NDHS, Nepal Demographic and Health Survey; NUHDSS, Nairobi Urban Health and Demographic Surveillance System; OR, odds ratio; PBF, Study of Performance-Based Financing; USDA, United States Department of Agriculture; WHO, World Health Organization.

Table 2
Subgroup analysis to assess the association between food insecurity and undernutrition complications

Subgrouped by	No. of studies	OR*	95% CI	I^2 (%)	*P* for heterogeneity
Underweight					
Age (y)					
<5	4	0.97	0.82–1.16	68.8	0.02
≥5	3	**1.34**	**1.02–1.77**	60.0	0.08
Food insecurity degree					
Mild	4	1.03	0.91–1.18	30.3	0.23
Moderate	4	**1.30**	**1.02–1.64**	66.3	0.03
Severe	4	**1.69**	**1.16–2.44**	27.9	0.23
Country development level					
Developed countries	6	1.29	0.63–1.96	77.9	<0.001
Developing countries	4	1.20	0.68–1.72	36.6	0.192
Stunting					
Age (y)					
<5	9	**1.14**	**1.05–1.23**	85	<0.001
≥5	3	**1.20**	**1.03–1.39**	47.1	0.15
Degree of food insecurity					
Mild	8	**1.13**	**1.02–1.25**	57.1	0.02
Moderate	9	**1.15**	**1.04–1.28**	77.2	<0.001
Severe	9	**1.25**	**1.11–1.40**	80.6	<0.001
Country development level					
Developed countries	4	1.36	0.86–1.74	55.2	0.082
Developing countries	9	**1.16**	**1.05–1.27**	38.8	0.12
Wasting					
Age (y)					
<5	3	1.02	0.85–1.23	0.0	0.98
≥5	3	1.06	0.97–1.16	19.3	0.29
Food insecurity degree					
Mild	3	1.03	0.93–1.15	0.0	0.50
Moderate	**3**	**1.55**	**1.15–2.08**	53.7	0.11
Severe	3	1.31	0.83–2.07	76.2	0.01
Country development level					
Developed countries	3	1.15	0.85–1.25	0.0	0.91
Developing countries	2	1.30	0.60–2.00	27.1	0.24

CI, confidence interval; OR, odds ratio.
*Calculated by random-effects model.

Discussion

Food security as a growing concern worldwide causes an increased risk of several disease comprising behavioral problems [44], depression/anxiety and hyperactivity/inattention [45], diabetes mellitus [46], overweight/obesity [11,47], and undernutrition complications [22, 25,33,34] in children and adolescents. Research on the associations between food insecurity and undernutrition has produced mixed results [26]. Although some previous studies have found a direct association between food insecurity and the risks of undernutrition complications, such as being underweight, stunting, and wasting in childhood and adolescents [21,29,30], others have found no positive associations and even one negative association [12,23,24]. Hence this study, as a systematic review and meta-analysis of the literature, provides a quantitative estimate of the relationship between food insecurity and the risks of undernutrition complications (underweight, stunting, and wasting) in population-based studies of children and adolescents.

The overall results, based on the observational studies, indicated that there was a positive overall association between food insecurity and the risks of undernutrition complications. This association was especially significant for the risk of stunting. Previous studies conducted in the United States [23], Colombia [21], Ethiopia [34,37], Iran [35], Kenya [26], Malaysia [30], Mexico [41], Nepal [22,25], and Indonesia [42] reported similar results. Several reasons have been proposed for the higher stunting risk in food-insecure households, including delayed introduction of supplemental foods or introduction of high-starch and low-protein foods [18]; nutrient-poor foods, especially in vitamin A, iron, and zinc [48–50]; and lower intakes of animal protein and higher intakes of snack foods [51]. Moreover, our results indicated that children and adolescents living in developing countries had a higher risk of stunting, but not children and adolescents living in developed countries. The different food-insecurity outcome patterns between food-insecure households living in developed and developing countries could be explained by several factors, including differences in socioeconomic status, the availability and preferences of food, and physical activity level [52].

In addition, our results are in agreement with previous studies that indicated that food insecurity had a significant relationship with being underweight in children and adolescents [24,29,30,32,34,37,38,41]. Former studies, in addition to reasons mentioned for stunting, suggested that this relationship between food insecurity and the low nutritional status such as underweight may result from a reduction in portion size, dietary variety, and frequency of meals [30,37]. In contrast, other studies, including Martin and Ferris [23], Osei et al. [12], McDonald et al. [31], Shinsugi et al. [33], Speirs et al. [36], Rose et al. [32], and Gubert et al. [38], documented that there was no association between food insecurity and the risks of undernutrition complications.

To accurately assess the association between food insecurity and risk of undernutrition complications, the study populations were subgrouped based on age and the level of food insecurity. The age and level of food insecurity subgroup analysis suggested that the risks of stunted growth and being underweight increased with the intensification of food-insecurity level and with an increase in the age of children and adolescents in food-insecure households. Nevertheless, the mechanisms of association between household food insecurity and the risks of undernutrition complications with age and food insecurity levels in children and adolescents are still

not well understood. However, previous studies have suggested that poverty may modify the effect of food insecurity on nutrition [26,53]. Although food insecurity leads to decreased dietary intakes, poverty is closely linked with increased levels of food insecurity [26,53]. Also, at higher levels of food insecurity, more limited food resources and a rise in the price of food tends to exert more pressure on the amount of food each household member consumes and increases the risk of stunted growth and underweight in children [35]. Furthermore, regarding age, the results revealed that older children have a higher risk of undernutrition. These results may be due to older children missing meals to ensure that younger children have some food or due to children older than 5 y being at a critical growth stage and thus being at a higher risk of stunting and being underweight [26,54].

Although our results indicated that food insecurity did not have a significant relationship with wasting in children and adolescents, a recent study reported that age subgroup analysis did not have a major impact on wasting among children and adolescents [30,37]. However, there was a significant association between an increased risk of wasting and a moderate level of food insecurity. The existence of different methods and assumptions in food insecurity can alter the classification of food-insecure households and thus may potentially explain the lack of association between food insecurity and wasting risk [30,31,34,35,37]. Moreover, the small number of participants in the wasting category in some studies may have led to wide confidence intervals, which could have affected the overall results [55].

Some limitations of this meta-analysis should be discussed. First, a significant statistical heterogeneity was identified in the overall comparisons. However, we run a comprehensive subgroup analysis to find the potential sources of heterogeneity. Second, most included studies reported the risks of undernutrition complications for mixed-gender populations, and therefore it was not possible to perform a gender subgroup analysis. Third, there were only a small number of studies assessing household food security with reference to the risks of wasting in children and adolescents. It is suggested that in future studies, instead of mixed gender, more attention should be paid to the effects of food insecurity on specific genders. Lastly, the studies included used different tools for measurement of food insecurity and different criteria for child and adolescent status. Although the different measures of food insecurity and criteria of child and adolescent status in studies have validity and reliability, the comparability of these measures is an important gap that should be addressed.

Conclusion

In this systematic review and meta-analysis it was found that there was a positive association between HFI and the risks of stunting and underweight, but not for wasting. Furthermore, subgroup analysis suggested that the risks of stunted growth and being underweight increased with the intensification of the level of food insecurity and with the increased age of children and adolescents in food-insecure households. Further longitudinal and in-depth qualitative studies are warranted to confirm the possible association between household food security and the risk of undernutrition complications among children and adolescents.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2018.11.029.

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