Review Article

The Relationship between Food Insecurity and Risk of Overweight or Obesity in under 18 Years Individuals: A Systematic Review and Meta-Analysis

Ali Pourmotabbed, Seyedeh Parisa Moosavian[1], Amir Hadi[2], Hamed Mohammadi[1], Alireza Dadfarma[3], Shahabeddin Rezaei[4], Atefeh Babaei, Sajjad Moradi[2,5], Khadijah Mirzaei[6]

Department of Physiology, School of Medicine, Kermanshah University of Medical Sciences, Kermanshah, Iran, [1]Department of Clinical Nutrition, School of Nutrition and Food Science, Food Security Research Center, Isfahan University of Medical Sciences, Isfahan, Iran, [2]Halal Research Center of IRI, FDA, Tehran, Iran, [3]Department of Cellular and Molecular Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran, [4]Department of Clinical Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran, [5]Department of Clinical Nutrition, School of Nutrition and Food Science, Isfahan University of Medical Sciences, Isfahan, Iran, [6]Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran

Abstract

Objective: Food insecurit (FI) has been considered as reason for childhood and adolescent overweight/obesity (OW/OB). Hence, this study was undertaken to assess these relationships. **Design:** Related articles were found by searching the Web of Science, Scopus, PubMed and Embase databases until October 2019. Odds ratio (OR) was analized by a random-effects model. Standard methods were used for assessment of heterogeneity and publication bias. Data were available from 32 studies. The risk ratios of 139,762 participants were pooled from these articles for the meta-analysis. **Results:** This study domenstrated that children and adolescents in food-insecure condition are not at risk of OW/OB (OR = 1.02 95% CI: 0.99, 1.05). However, subgroup analysis indicated that FI related with inhanced risk of OW/OB in adolescents living in developed countries (OR = 1.14; 95% CI: 1.02, 1.27). Other subgroup analysis indicated that severe FI increased the risk of OW/OB among adolescents (OR = 1.24 95% CI: 1.03-1.49). In addition, we found that lower economic development significantly decreased risk of OW/OB among under 6 year children (OR = 0.88; 95% CI: 0.84, 0.93). **Conclusions:** Our results showed that higher FI degrees were related with more risks of OW/OB among adolescents (12–18 years). Moreover, the country economic levels had effect on the association between FI and risk of OW/OB.

Keywords: *Adolescents, children, food insecurity, obesity risk, overweight risk*

Introduction

Obesity and overweight have placed a large load on the children population over the last three decade with steady increases noted in all around the world,[1] especially in many underdeveloped countries.[2,3] Children with obesity and overweight have an enhanced risk of becoming more weight gain in adulthood,[4] and the conditions are associated with risk factors for a several of prevalent disease namely heart disease, type 2 diabetes,[1] hypertension,[5] dyslipidemia,[6] asthma,[7] metabolic syndrome, liver disease,[8] cancer,[9] and premature death.[8] The variables considered as potential risk factors for childhood and adolescent obesity are: genetic predisposition, maternal smoking during pregnancy, sedentary behavior, socioeconomic status, sleep habits, ethnic origin, microbiota, iatrogenic, endocrine diseases, low resting metabolic rate, obesogenic food advertising, diet and related problems.[10-13]

Food security is described as the assured access to acquire nutritionally enough and safe food that meets cultural requirements and attained in a socially possible procedure.[14] In other hands, food insecurity (FI) happens as a consequence of restricted resources, and affects many households in all around the world, thereby causing malnutrition.[15] Recent studies have shown a link between FI, growth problems and diseases among under 18 years individuals, which will lead to increased risks of health complications in adulthood. Food insecure individuals have increased risks of: weight abnormality,[16] anemia,[17] growth problems,[18] mental disorders[19] and overweight/obesity (OW/OB).[20,21]

One factor which has been more consideration in obesity studies is the effect of FI in association to weight status.[22] Researches by Franklin *et al*.[23] and Eisenmann *et al*.[24] assessed the associations between FI and OW/OB risk. Franklin *et al*.[23] suggested that FI may increase the risk of obesity in females.

How to cite this article: Pourmotabbed A, Moosavian SP, Hadi A, Mohammadi H, Dadfarma A, Rezaei S, *et al*. The relationship between food insecurity and risk of overweight or obesity in under 18 years individuals: A systematic review and meta-analysis. Int J Prev Med 2020;11:158.

Access this article online

Website: www.ijpvmjournal.net/www.ijpm.ir

DOI: 10.4103/ijpvm.IJPVM_463_19

Quick Response Code:

Address for correspondence:
Dr. Sajjad Moradi,
Department of Community Nutrition, School of Nutrition and Food Science, Food Security Research Center, Isfahan University of Medical Sciences, Isfahan, Iran.
Email: sajadmoradi9096@gmail.com
Dr. Khadijeh Mirzaei,
Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences (TUMS), Tehran, Iran.
E-mail: mirzaei_kh@tums.ac.ir

However, Eisenmann *et al*.[24] revealed that, even though the percent of overweight was high in children living in FI condition, there was no association between FI and weight status in children. Also, recent studies on the association between FI and risk of obesity in children has led to different outcomes; some previous researches have shown an relationship between FI and the risk of OW/OB in under 18 years individuals[20-22,25-31]; others, have suggested that no relationship exists.[31-43] Moreover, recent studies is evaluating more factors such as abdominal obesity, which may more accurately explain the association between FI and childhood OW/OB risk.[20,43]

Although several studies exist which assess the relationship between FI and risk of OW/OB in under 18 years individuals, it is not clearly understood whether FI is related with higher OW/OB risks among under 18 years individuals. Thus, current study was conducted to evaluation the relationship between FI and OW/OB risks in under 18 years individuals.

Methods

Literature search and selection

This study was conducted based on the guidelines of the Meta-Analysis of Observational Studies in Epidemiology.[44] A systematic literature review was undertaken using the PubMed, Web of Science, Scopus and Embase databases, until October 2019. Search strategies used medical subject heading (Mesh) and keywords without date or language limitations. The below keywords were used in the systematic search for the association between FI and risk of OW/OB in under 18 year subjects: (((((weight OR Obesity OR "Body mass index" OR BMI OR Adiposity OR Overweight OR obese*)) AND (((((“Food Insecurity” OR “Food Insecurities” OR “Food security” OR “Food securities” OR “Food Supply”) AND (((((“Paediatric Obesity” OR child* OR Paediatric OR adolescent* OR infant*))))). The review articles references were also assessed manually.

Eligibility criteria

Articles were inhered in the statistical analysis if they met the below features: (1) Observational articles that showed on the relationship between FI and the risks of OW/OB in under 18-year-old individuals; (2) Articles that reported odds ratios (OR) with corresponding 95% confidence intervals (CI) of OW/OB risk for children and adolescents. Articles were excluded if: (a) the data could not be used; (b) they were editorials, conference reports, reviews, book chapter, case reports or letters; (c) they did not report the risk of OW/OB; (d) they included adult individuals.

Study selection

The titles and abstracts of all studies in the primary search were assessed separately by 2 investigator. Studies not meeting the eligibility criteria were excluded using a screening form, with a step by step procedure according to research setting, participants, or exposure and result. The reference of included studies recognized among this procedure were also assessed to obtain more articles. Full-text studies were regained, if the citation was recognized qualified, and subjected to a next assessment for relationship by the same investigator. Any discrepancy was negotiated and resolved by consensus.

Data collection

For the included articles, two investigators (SM and AD) extracted information independently via a standard information extraction tool. They discussed any disagreements in data extraction process and sought the evaluation of a third investigator (HM) for resolution. Extracted data included articles details, population characteristics, exposure, main findings, and quality score [Table 1].

Quality assessment

Two investigators (SM and HM) evaluated the quality of included articles by the Newcastle-Ottawa scale.[45]

Statistical analysis

To evaluate the relationship of FI and the risk of childhood and adolescent OW/OB, the risk estimates for OW/OB were pooled. Because for accurately evaluate the relationship among FI and the OW/OB risk in under 18-year-old individuals, the study people were categorized according to age, FI assessment and, economic development levels[46] (developing or developed). In addition, studies with age-specific subgroup populations (under 6, 6–12, and 12–18 years) were grouped based on gender (girls, boys, and mixed), degree of FI (mild, moderate, and sever FI),[47] race/ethnicity, economic development level (developing or developed) and FI assessment method (child or household).

Pooled OR [and 95% confidence interval (CI)] was assessed using a weighted random-effect model (the DerSimonian-Laird approach). Heterogeneity in the included articles was examined via Cochran Q and I2 statistics (I2= (Q-df)/Q × 100%; I2 <25%, no heterogeneity;

Table 1: Description of the studies included in present meta-analysis investigating the association between food security status and risk of childhood and adolescents' obesity (2001-2019)

First Author (year publication)	Database	Country	Study design (fallow up duration)	Subjects:	Criteria for overweight and obesity status (year)	Race/ ethnicity	Level of food insecurity measurement	Measure of food insecurity	OR (95%CI)	Main findings	Adjusted variables	Quality Score
Alaimo K (2001)	NHANES-III	USA	Cross-sectional	Age: 2-16 years *n*=9196	CDC growth charts (2000)	White, Black, Hispanic, Asian and other race	Household	Food insufficiency family questionnaire	Overweight risk	There were no differences in overweight risk by food sufficiency status	Child's height and birth weight, mother's height and weight, father's height and weight, age squared, poverty income ratio, household size, family head education status, family head employment status, family head martial status, metropolitan location, health insurance coverage, regular source of health care, smoke exposure during pregnancy, and birth complications	+10/10
Rose D (2006)	ECLS-K	USA	Longitudinal (3 year)	Ages: 6.16±0.06 years, *n*=16889 (%48.6 girls and %51.4 boys)	CDC growth charts (2000)	White, Black, Latino and Asian American	Household Child	USDA	Overweight risk	Household food insecurity, is not associated with overweight risk	Age, gender, birth weight, mother education, household economic status, region, urbanization, physical activity of children and family meal patterns	+10/10
Dubois L (2006)	LSCDQ	Canada	Longitudinal (5 year)	Age: 3.5-4.5 years *n*=1549 (%48.9 Girls and %51.1 boys)	CDC growth charts (2000) and Cole criteria (2000)	White	Household	Radimer/ Cornell questionnaire	Overweight risk	Children living in households experiencing food insufficiency were more likely at some time to be overweight	Gender, birth weight, mother's age, mother's immigrant status, mother's education, mother's BMI, mother's psychological distress, maternal smoking during pregnancy, family type, family income sufficiency level, number of working parents, breastfeeding	+10/10
Casey PH (2006)	NHANES	USA	Cross-sectional	Ages: 3-17 years *n*=6995 (%49.2 Girls and %50.8 boys)	CDC growth charts (2000)	White, Black, Hispanic, Mexican American and other	Child	HFSSM	Overweight risk	Household and child food insecurity are associated with being overweight	Ethnicity, gender, age, and family poverty index level	+9/10

Contd...

Table 1: Contd...

First Author (year publication)	Database	Country	Study design (fallow up duration)	Subjects:	Criteria for overweight and obesity status (year)	Race/ ethnicity	Level of food insecurity measurement	Measure of food insecurity	OR (95%CI)	Main findings	Adjusted variables	Quality Score
Whitaker RC (2006)	Fragile Families and Child Well-being Study	USA	Cross-sectional	Ages: 3.21±0.27 years *n*=2459	CDC growth charts (2000)	White, Black, Hispanic and other race	Household	HFSSM	Obesity risk	Food insecurity did not increase the odds of obesity among US urban children	Race/ethnicity, maternal education, income-to-poverty ratio, and for children's food security, fully food secure	+10/10
Isanaka S (2007)	Children's health and nutritional status in primary public schools of Bogota	Colombia	Cross-sectional	Ages: 5-12 years *n*=2526	Cole growth reference (2000)	Hispanic	Household	USDA	Overweight/ obesity risk	Food insecurity was not related to child stunting or child overweight	Mother's age, education level, parity, marital status, father's age and education level, household size, per capita daily, money spent on food per capita, type of dwelling, home ownership, household socioeconomic stratum, and the number of home assets owned	+10/10
Martin KS (2007)	Hartford Connecticut study	USA	Cross-sectional	Ages: 2-12 years *n*=212 (%50.9 Girls and % 49.1 boys)	CDC growth charts (2006)	White Hispanic Black West Indian	Household	USDA	Overweight risk	Food insecurity did not increase the odds of childhood overweight.	Age, sex, race/ethnicity, Parent over high school degree and level of poverty	+9/10
Gundersen C (2008)	The Three-City Study	USA	Longitudinal (6 year)	Ages: 10-15 years *n*=1031 (%51.7 girls and %48.3 boys)	CDC growth charts (2007)	White, Black, Hispanic and other race	Household	CFSM	Overweight risk	Bivariate analyses indicated that there were no significant differences in the prevalence of at risk of overweight and overweight	Age, race/ethnicity, household income: needs ratio, caregiver education and immigrant status, family eats breakfast together, family eats dinner together, household owns its residence, caregiver married, age of the caregiver, and household size	+10/10

Contd...

Table 1: Contd...

First Author (year publication)	Database	Country	Study design (fallow up duration)	Subjects:	Criteria for overweight and obesity status (year)	Race/ ethnicity	Level of food insecurity measurement	Measure of food insecurity	OR (95%CI)	Main findings	Adjusted variables	Quality Score
Gundersen C (2009)	NHANES	USA	Cross-sectional	Ages: 8 - 17 years *n*=2516 (%49.2 girls and %50.8 boys)	CDC growth charts (2000)	White, Black, Hispanic and other race	Households	CFSM	Obesity risk	Food insecure children were no more likely to be obese than their food-secure counterparts across all measures of obesity.	Age (y), race/ethnicity, gender, and annual household income divided by the poverty line	+9/10
Metallinos-Katsaras E (2009)	Special Supplemental Nutrition Program for Women, Infants, and Children	USA	Cross-sectional	Ages: under 5 years *n*=8493 (%48.6 girls and %51.4 boys)	CDC growth charts (2000)	White, Black and Hispanic	Households	HFSSM	Overweight/ obesity risk	Among girls younger than 2 years of age, household food insecurity was associated with reduced odds of overweight	Children's age, sex, parental/ caretaker report of child race/ethnicity, and maternal education	+9/10
Rosas LG (2011)	CHAMACOS	USA And Mexico	Longitudinal	Ages: 5-16 years *n*=603 (%47 Girls and%53 boys)	CDC growth charts (2000)	Mexican-American and Mexican	Household	USDA	Overweight/ obesity risk	In Mexico, male gender, high socioeconomic status and very low food insecurity were associated with being overweight or obese.	Age, gender, mother's weight status, mother education, mother's work status, household economic status, daily TV time, time spent playing outside and soda consumption	+10/10
DuboisL (2011)	QLSCD	Jamaica and Canada	Longitudinal	Ages: 10-11 years *n*=2864 (%52.5 girls and %47.5 boys)	Cole growth reference (2000)	Black White	Households	USDA	Overweight/ obesity risk	Food insecurity appears to be positively associated with childhood overweight/ obesity in children from the province of Québec, Canada.	Sex, level of physical activity, family type, family SES (by tertile: low, medium, high), and children's daily consumption of fruit, vegetables, and pastries	+10/10

Contd...

Table 1: Contd...

First Author (year publication)	Database	Country	Study design (fallow up duration)	Subjects:	Criteria for overweight and obesity status (year)	Race/ ethnicity	Level of food insecurity measurement	Measure of food insecurity	OR (95%CI)	Main findings	Adjusted variables	Quality Score
Metallinos-Katsaras E (2012)	WIC program	USA	Longitudinal	Ages: 2 - 5 years *n*=28353 (%49 girls and %51 boys)	CDC growth charts (2000)	White, Black, Hispanic and Asian	Household	HFSSM	Overweight/ obesity risk	Persistent household food insecurity without hunger was associated with 22% greater odds of child obesity	Child race/ethnicity, sex, child and household size, maternal age, education, and prepregnancy weight	+9/10
Kac G (2012)	DHS	Brazil	Cross-sectional	Ages: 15-19 years *n*=1529 (%100 girls)	WHO growth reference (2006)	Hispanic	Household	EBIA	Overweight/ obesity risk	Severe but not moderate or mild food insecurity, is independently associated with excessive weight among female adolescents	Self-reported skin color, years of schooling, area of residence, geographical region, per capita family income, smoking habit, marital status, number of people living in the household and age in years (continuous)	+10/10
Kaur J (2015)	NHANES	USA	Cross-sectional	Ages: 2 - 11 years *n*=9701 (%49.6 girls and %50.5 boys)	CDC growth charts (2014)	White, Black and Mexican-America	Child Individual	HFSSM	Obesity risk	An association between obesity and personal food insecurity was seen in children aged 6 to 11 years	Age, sex, race/ethnicity, and family poverty-to-income ratio and survey period	+10/10
Trappmann JL (2015)	CHILE	USA	Cross-sectional	Ages: 3-5 years *n*=374 (%48.6 girlsand %51.4 boys)	CDC growth charts (2013)	Hispanic and American Indian	Household	CHILE interview forms	Overweight/ obesity risk	No significant relationships emerged between food insecurity and child overweight/ obesity	Gender, plate cleaning encouragement, limiting of certain frequency, and receipt of federal assistance benefits (WIC, SNAP, WIC and/or SNAP, TANF, and Medicaid)	+10/10

Contd...

Table 1: Contd...

First Author (year publication)	Database	Country	Study design (fallow up duration)	Subjects:	Criteria for overweight and obesity status (year)	Race/ ethnicity	Level of food insecurity measurement	Measure of food insecurity	OR (95%CI)	Main findings	Adjusted variables	Quality Score
Holben DH (2015)	NHANES	USA	Cross-sectional	Ages: 12-18 years *n*=7435 (%48.5 girls and%51.5 boys)	CDC growth charts (2000)	White, Black, Hispanic and Mexican-American	Household	HFSSM	Overweight/ obesity risk	Household food insecurity was associated with an increased likelihood of being overweight and having central obesity.	Age, race/ethnicity, and sex	+9/10
Lohman BJ (2016)	IYFP	USA	Longitudinal	Ages: 13-16 years *n*=451 (%100 girls)	CDC growth charts (2000)	White	Household	CFSM	Overweight/ obesity risk	Those females who experienced only food insecurity in adolescence were not at risk of Overweight/ Obesity	Gender, respondent education level, parent education level, family of origin per capita income, adolescent and parent BMI	+10/10
Hernandez DC (2016)	"La Salud de Mamá y Niños" study	USA	Cross-sectional	Ages: 3-6 years *n*=96 (%51 girls and %49 boys)	CDC growth charts (2000)	Hispanic	Household	USDA	Overweight/ obesity risk	Maternal cumulative exposure to food insecurity does not impact children's body composition	Age, marital, education, years residing in the US. maternal BMI and weight status	+10/10
Papas MA (2016)	LCH	USA	Cross-sectional	Ages: 2.72±0.45 years *n*=74 (%56.7 girls and %43.3 boys)	CDC growth charts (2015)	Hispanic	Household	HFSSM	Overweight/ obesity risk	Food insecurity increased the odds of childhood obesity and overweight weight	Marital status, monthly household income, and number of children in household	+9/10

Contd...

Table 1: Contd...

First Author (year publication)	Database	Country	Study design (fallow up duration)	Subjects:	Criteria for overweight and obesity status (year)	Race/ ethnicity	Level of food insecurity measurement	Measure of food insecurity	OR (95%CI)	Main findings	Adjusted variables	Quality Score
Speirs KE (2016)	STRONG Kids	USA	Cross-sectional	Ages: 2-5 years *n*=438 (%51.1 girls and %48.9 boys)	CDC growth charts (2013)	White and African American	Household Child	HFSSM	Overweight/ obesity risk	There were no statistically significant associations between either household or child food insecurity and BMI for the full sample.	Ethnicity gender, age, maternal age, maternal BMI and family income level	+9/10
Gubert MB (2016)	2006 Brazilian Demographic and Health Survey	Brazil	Cross-sectional	Ages: under 5 year *n*=4064	WHO growth reference (2006)	Hispanic	Household	EBIA	Overweight risk	There was no association between Brazilian household food insecurity overweight.	Type of water for consumption, presence of adequate sanitation, maternal education level, maternal age, household location and geographic region	+10/10
Jones AD (2016)	National Health and Nutrition Survey of Mexico	Mexico	Cross-sectional	Ages: 15-19 years *n*=4039 (%100 girls)	WHO growth reference (2007)	Hispanic	Household	ELCSA	Obesity risk	Household food insecurity was not associated with the co-occurrence of overweight among female adolescents.	Age, parity, household size, the highest attained education level of the individual, household wealth status, urban city, and region	+10/10
Jafari F (2017)	Eementary schools, from three geographical areas (four educational destricts) of Isfahan, Iran	Iran	Cross-sectional	Ages: 7-12 years *n*=587 (439 girls and 148 boys)	WHO growth reference, (2007)	Middle East	Household, Individual Child	Radimer/ Cornell	Obesity risk	The slight levels of food insecurity might increase the likelihood of abdominal obesity	Age, gender, birth weight, birth order, multiple birth, exclusivity of breast feeding, complementary feeding, length of gestation, length of breastfeeding, maternal age at birth, mother education, father education, mother obesity, father obesity, household economic status, and physical activity of children	+10/10

Contd...

Table 1: Contd...

First Author (year publication)	Database	Country	Study design (fallow up duration)	Subjects:	Criteria for overweight and obesity status (year)	Race/ ethnicity	Level of food insecurity measurement	Measure of food insecurity	OR (95%CI)	Main findings	Adjusted variables	Quality Score
Bhawra J (2017)	APS	Canada	Cross-sectional	Ages: 6-17 years *n*=6900 (%48.9 girls and%51.1 boys)	Cole growth reference (2000)	White	Households	APS	Obesity risk	Children and youth who are in households with very low food security are indeed at higher risk for overweight and obesity	Demographic, household, school, geographic and cultural variables	+9/10
Shamah-Levy T (2017)	ENSANUT	Mexico	Cross-sectional	Ages: under 5 years *n*=5087 (%49.8 girls and %50.2 boys)	WHO growth standards (2016)	Hispanic	Household	ELCSA	Overweight/ obesity risk	There was an inverse relationship between household food security with overweight and obesity risk in schoolchildren	Sex, urbanicity, region of residence, maternal education and benefiting from a food assistance	+9/10
Swindle (2018)	FMI	USA	Cross-sectional	Ages: 10-15 years *n*=808 (%52 girls and %48 boys)	CDC growth charts (2016)	White, Black, Hispanic and other race	Household	HFSSM	Overweight risk	Children which parent had education beyond high school indicated a reversal with food insecurity odds of overweight less than food security odds.	Differences in food security group size	+8/10
Yeganeh (2018)	Mothers from 10 Health Service Centers in the city of Bushehr, Iran.	Iran	Cross-sectional	Ages: under 5 years *n*=400 (%53.8 girls and %46.3 boys)	WHO growth standards (2016)	Middle East	Household Child	Radimer/ Cornell	Overweight/ obesity risk	There was no relationship between household food security with overweight/ obesity risk	Non	+8/10

Contd...

Table 1: Contd...

First Author (year publication)	Database	Country	Study design (fallow up duration)	Subjects:	Criteria for overweight and obesity status (year)	Race/ ethnicity	Level of food insecurity measurement	Measure of food insecurity	OR (95%CI)	Main findings	Adjusted variables	Quality Score
Wu (2019)	TDCYP	Taiwan	Cross-sectional	Ages: 10-15 years *n*=1326 (%52 girls and %48 boys)	Chen & Chang, 2010	Asian	Household	USDA	Overweight/ obesity risk	There was a direct relationship between household food security with overweight/ obesity risk	Family structure, household income, and pocket money status	+9/10
Au (2019)	HCS	USA	Cross-sectional	Age: 4-15 Years *n*=5138 (50.9% girls and 49.1% boys)	CDC growth charts (2000)	White, Latino, Black and other race	Household	USDA	Overweight/ obesity risk	There was a direct relationship between household food security with overweight/ obesity risk	Maximum father education, and maximum maternal employment.	+9/10
Lee (2019)	NHANES	USA	Cross-sectional	Age: 12-19 Years *n*=2662 (46% girls and 54% boys)	CDC growth charts (2000)	White, Black, Hispanic	Household	USDA	Overweight/ obesity risk	There was no relationship between household food security with overweight/ obesity risk	Age, sex, race/ethnicity, and household income-to-poverty ratio.	+9/10
Gipson-Jones (2019)	large surveillance sample of low-income parents and children attending community-based primary care clinics in Memphis, Tennessee	USA	Cross-sectional	Age: 2-5 Years *n*=264 (51.9% girls and 48.1% boys)	CDC growth charts (2000)	Black, and other race	Household	USDA	Overweight/ obesity risk	There was no relationship between household food security with overweight/ obesity risk	Non	+8/10

APS: Aboriginal Peoples Survey, CFSM: Core Food Security Module, CHAMACOS: Center for the Health Assessment of Mothers and Children of Salinas, CHILE: Child Health Initiative for Lifelong Eating and Exercise, FMI: Family Map Inventory, DHS: Demographic and Health Survey, EBIA: Brazilian Food Insecurity Measurement Scale, ECLS-K: Early Childhood Longitudinal Study-Kindergarten Cohort. ELCSA: Latin American and Caribbean Food Security Scale, ENSANUT: Mexican National Health and Nutrition Survey, HCS: Healthy Communities Study, HFI: Household Food Insecurity, HFSSM: Household Food Security Survey Module, IYFP: Iowa Youth and Families Project, LCH: La Comunidad Hispana, LSCDQ: Longitudinal Study of Child Development in Québec, NHANES: National Health and Nutrition Examination Survey, OW/OB: Overweight/Obesity, TDCYP: Taiwan Database of Children and Youth in Poverty

I2 = 25-50%, moderate heterogeneity; I2 = 50-75%, large heterogeneity, I2 >75%, extreme heterogeneity). The heterogeneity was considered significant if either the Q statistic had $P < 0.1$ or I2 >50%. Visual inspection of asymmetry in funnel plots, Begg's test and Egger's test were carry out to assess publication bias ($P < 0.05$ was considered representative of statistical significance). All statistical tests were conducted with STATA (version 14.0) and SPSS (version 23.0) software.

Results

Features of the studies

The systematic literature search obtained a total of 3413 articles, after the remove of same results, from the mentioned search engines. After initial screening, all of undesired articles were omitted because they did not meet eligibility criteria, leaving 55 studies for full-text evaluation [Figure 1]. A total of 32 articles met the inclusion criteria to be included in the meta-analysis.[20-22,25-32,34-43,48-58] In these 32 articles, 26 used a cross-sectional setting,[20-22,27,29-33,35,36,38-43,48,50-58] whereas the other 6 were longitudinal studies.[25,26,28,34,37,49] The OR of 139.762 participants was analyzed among these articles for the present study. These articles were published during 2001 and 2019, and performed in the Canada,[22,25,27] United States,[20,21,26,28-30,32,34,36-40,42,49,50,52,55-58] Jamaica[27] Brazil,[41,48] Mexico,[26,31,51] Colombia,[35] Iran[43,54] and Taiwan.[53] Table 1 showed the feature of the articles included. The studies included assess weight status by CDC growth charts,[20,21,25,26,28-30,32,34,36-40,42,49,50,52,55-58] WHO growth standards,[31,41,43,48,51,54,59] Cole growth reference[22,27,35] or local criteria.[53] The articles included for evaluation of FI were USDA,[26,27,34-36,40,53,56-58] CFSM,[37,38,49] HHFSM,[20,21,28-30,42,50,52,55] HFIAS, Radimer/Cornell,[25,43,54] ELCSA,[31,51] EBIA[41,48] and valid local survey forms.[22,32,39] The quality evaluation of each included articles indicated that all articles were of appropriate quality [Supplementarys Table 1 and 2].

Quantitative synthesis

The extracted odds ratio was analyzed to assess the relationship between FI and the risk of childhood and adolescent OW/OB. As illustrated in Figure 2, there was no relationship between FI and risk of OW/OB in under 18 years individuals (OR = 1.02 95% CI: 0.99, 1.05) by using the random-effects model. Heterogeneity also existed in the articles ($P < 0.001$, $I^2 = 75.1\%$). Moreover, subgroup analysis according to type of FI assessment including household (OR = 1.03 95% CI: 0.99, 1.06) or child FI (OR = 1.04 95% CI: 0.97, 1.12) did not show

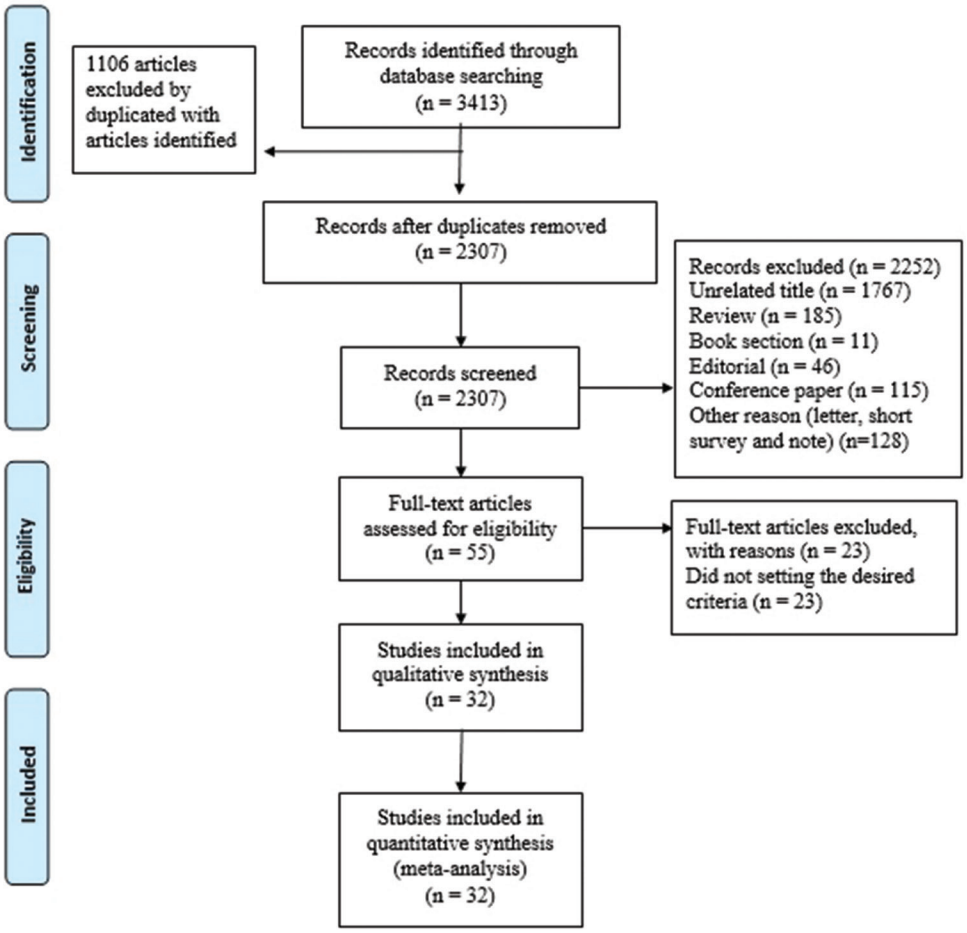

Figure 1: PRISMA flowchart describing the study's systematic literature search and study selection

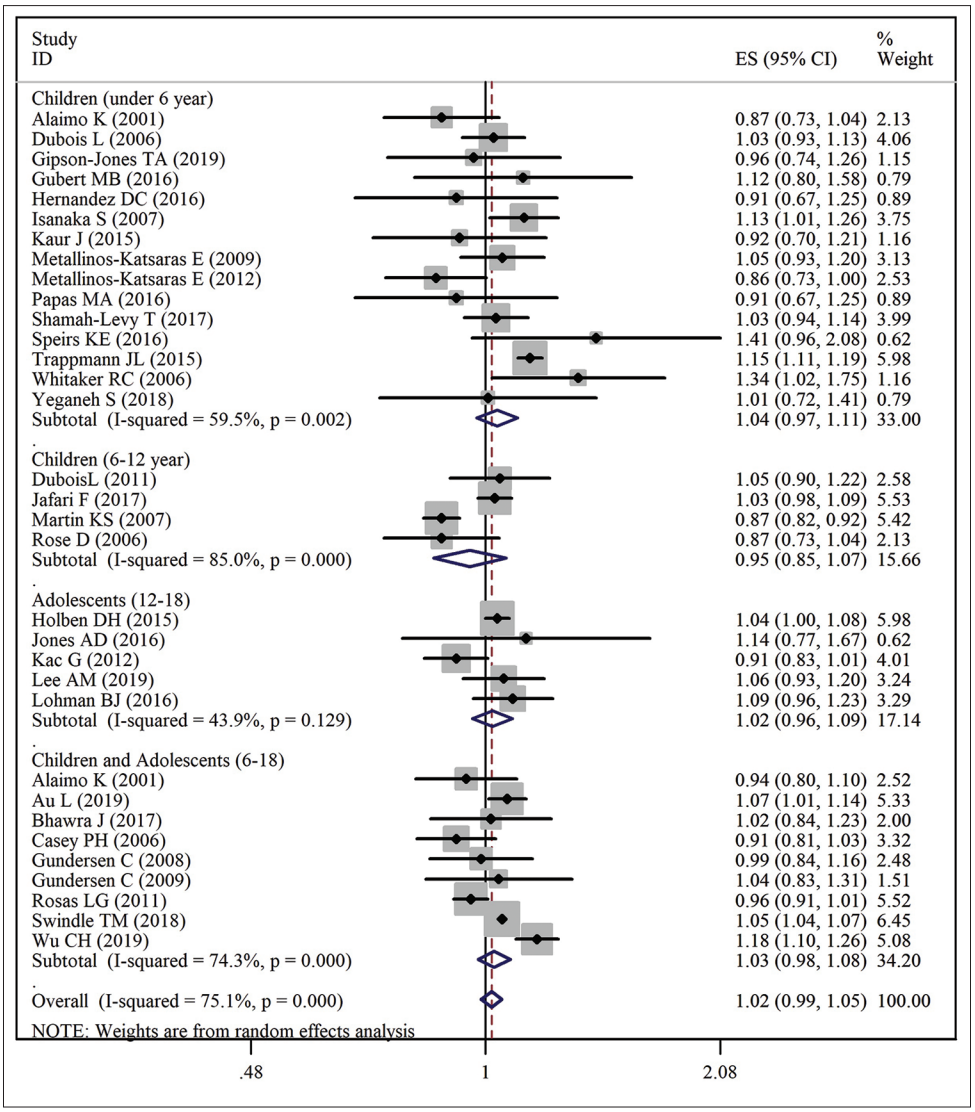

Figure 2: Forest plots investigating the association of food security status and risk of childhood overweight/obesity in all included studies (2001–2017) (OR with 95% CI). All comparison was conducted with food secure subjects (referent)

relationship between FI status and the risk of childhood OW/OB [Figure 3]. However, FI with enhanced risk of childhood OW/OB in developed countries (OR = 1.06; 95% CI: 1.02, 1.10), but not developing countries (OR = 0.96; 95% CI: 0.90, 1.03), [Figure 4].

Other subgroup based on examining the relationship between categorized FI and the risk of OW/OB is shown in Table 2. As shown in Table 2, Subgroup analysis by race/ethnicity and gender, level of FI and FI evaluation method in children showed no significant association [Table 2]. However subgroup by economic levels demonstrated that lower degree of national economic development significantly decreased risk of OW/OB among under 6 year children (OR = 0.88; 95% CI: 0.84, 0.93).

The specific outcomes by categorized FI for adolescents from 12 to 18 years old are shown in Table 2. These outcomes showed that sever FI associated with the increased risk of OW/OB (OR = 1.24 95% CI: 1.03-1.49); but mild or moderate FI also did not indicate any relationship with risk of OW/OB. Further subgroup by economic levels indicated that lower levels of economic development significantly increased risk of OW/OB among 12- to 18-year-old adolescents (OR = 1.14; 95% CI: 1.02, 1.27) living in developed countries.

Sensitivity analysis

Sensitivity analysis was conducted by removing each of the articles. The outcomes revealed that the OR was not changed sharply by removing each individual article. This showed the meta-analysis outcomes were constant and not sensitive to any one of the 32 articles [Figure 5].

Publication bias

No evidence of publication bias in articles relevant to FI and OW/OB risk in under 18 years individuals was observed,

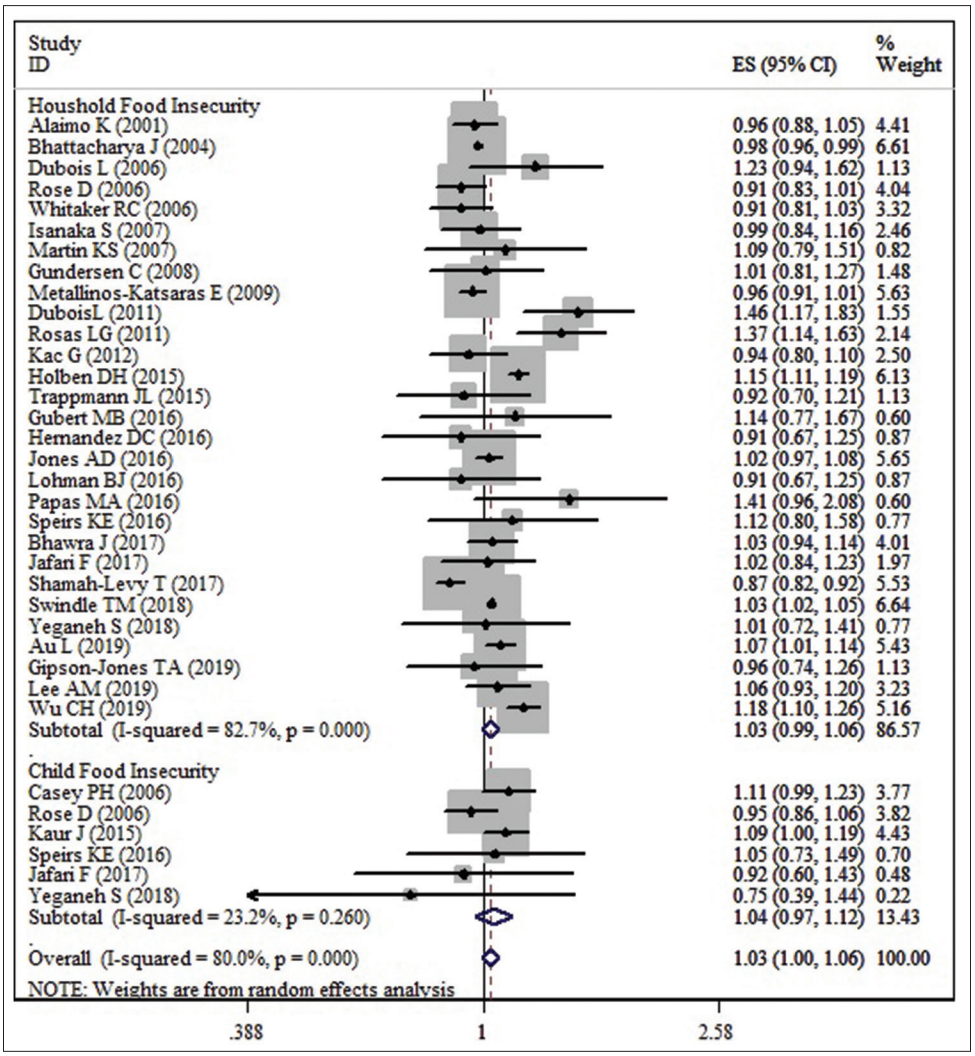

Figure 3: Forest plots showing investigating the association of food security status and risk of childhood overweight/obesity in different subgroups of food security assessment method (Childhood/household food insecurity assessment) (2001–2017) (OR with 95% CI). All comparison was conducted with food secure subjects (referent)

according to the outcome of Begg's test (P = 0.722) and Egger's test (P = 0.289). As illustrated in Figure 6, the funnel plot revealed to be symmetrical, which showed there was no obvious publication bias. Furthermore, the filled funnel plot showed that any study might not have been published [Figure 7].

Discussion

Currently, the relationship between FI status and OW/OB in youth populations is very important for researchers. Different results exist regarding the relationship between FI status with the childhood and adolescent OW/OB risk. Present research, as first study was performed of the quantitative estimates were made of the associations between IF and the risk of OW/OB among under 18 years individuals.

The results found no overall association between FI and OW/OB risk in under 18 years individuals. Currently, the FI-obesity paradox is considered as an obesity risk factor in food-insecure households. Nettel *et al*.,[60] according to the insurance hypothesis (IH), demonstrated that obesity in FI condition is originated in adaptive evolutionary thinking: the function of storing fat is to provide a buffer against shortfalls in the food supply. Thus, people may store higher adipose tissue when they receive cues that availability to food is unsure.[60] In addtion, Dhurandhar *et al*.,[61] according to hypothesis known as a "resource scarcity hypothesis," speculated that fattening is a physiologically regulated response to threatened food supply, which occurs specifically in low social status individuals. Nevertheless, in accordance with our findings the latest epidmiological study conducted by Eisenmann *et al*.[24] reported no difference between the association of FI and OW/OB risk anong children. Although, Eisenmann *et al*.[24] did suggest that sex and race may mediate the relationship between FI and rsik of OW/OB in children. However in present meta-analysis in category of children under 6 years, any significant association were not

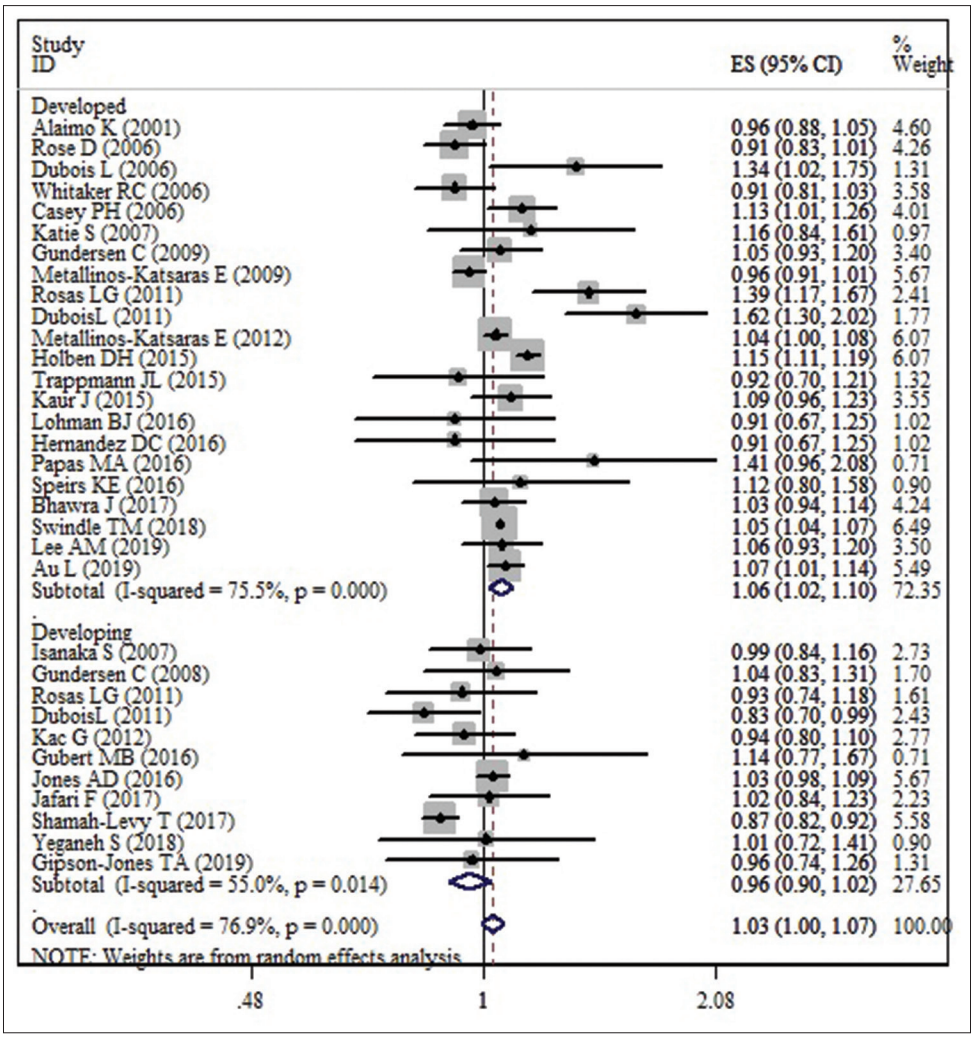

Figure 4: Forest plots showing investigating the association of food security status and risk of childhood overweight/obesity in different subgroups of economic development level (developed/developing countries) (2001–2017) (OR with 95% CI). All comparison was conducted with food secure subjects (referent)

found in all subgroups of sex and ethnicity. The mechanisms of association between FI with the OW/OB risk in children are still not well understood. One possibility is that mothers supply enough meals for their children by decreasing their own meals.[42] Children may also have availability to better quality intake than their family.[42] This opinion may be confirmed by the results of recent adult epidmiological studies. Moradi *et al*.[16] and Franklin *et al*.[23] reported that adults in FI condition, were at risk of obesity. Hence, maternal care for under 6 years children can be recognized as a main factor for the prevention of OW/OB in FI conditions. Even though, this maternal care and support led to lower food quality, and finally could associate to inhanced risks of obesity in women.

Other noteworthy results among children and adolescents (12–18 years) is that sever FI increased the risk of OW/OB, whereas lower levels of FI did not. Conversely to preschool and lower-aged children, it seems that among the 12- to 18-year-old population (with decreased maternal care and support), there is an increase in the OW/OB risk for sever FI level. Moreover, FI has an effect on adolescent OW/OB through mechanisms that have been proposed in previous studies, such as: calorie dense foods[26,43]; nutrient-poor meals[31]; lower intakes of high quality protein source and more intakes of snack meals[41]; higher eating when food is accessible and metabolic changes to ensure enough uses of energy[26,43]; parenting or feeding styles[62]; psychological or mental dioeders[38,62]; different standards for a healthy diet; and pregnancy FI.[43] Further rigorous evidence is yet required to understand the effects of FI on the risk of OW/OB in under 18 years individuals.

In addition, another main results of the current research indicated that according to national economic development degree there was association between FI and the risk of OW/OB in 18 years individuals. In similar results, recent meta-analysis[16] in adults showed that socioeconomic level was an important factor affecting weight status. The lower

Table 2: Subgroup analysis to assess the association between food security status and risk of childhood and adolescent overweight and obesity (2001-2019)

Subgrouped by*	No. of studies	Pooled OR[1]	95% CI	I^2 (%)	*P* for heterogeneity
Age					
Children (under 6 year)					
Food insecurity level					
Mild food insecurity	2	0.98	0.84, 1.13	87.6	0.04
Moderate food insecurity	3	0.99	0.84, 1.15	79.7	0.07
Sever food insecurity	3	1.09	0.80, 1.48	90.3	<0.001
Gender					
Girls	5	0.93	0.86, 1.00	0.0	0.56
Boys	4	0.98	0.90, 1.07	0.0	0.98
Both	10	1.02	0.93, 1.11	76.9	<0.001
Race/ethnicity					
Hispanic	5	0.96	0.84, 1.09	50.0	0.09
Mixed	8	0.99	0.93, 1.05	55.6	0.03
Assessment method					
Child Food Insecurity	2	0.95	0.70, 1.38	0.0	0.42
Household Food Insecurity	11	0.99	0.93, 1.06	63.2	0.001
Economic development level					
Developed	9	1.02	0.95, 1.09	56.8	0.01
Developing	4	0.88	0.84, 0.93	0.0	0.42
Children (6-12 year)					
Gender					
Girls	2	1.31	0.58, 2.99	94.1	<0.001
Boys	2	0.97	0.64, 1.49	69.7	0.06
Both	3	1.00	0.94, 1.07	47.4	0.07
Race/ethnicity					
Hispanic	2	1.01	0.87, 1.17	0.0	0.55
White	2	1.20	0.69, 2.11	95.3	<0.001
Mixed	3	1.03	0.90, 1.18	80.9	0.005
Assessment method					
Child Food Insecurity	3	1.01	0.90, 1.14	43.9	0.16
Household Food Insecurity	4	1.05	0.93, 1.18	76.5	<0.001
Economic development level					
Developed	3	1.06	0.94, 1.19	84.5	<0.001
Developing	3	0.94	0.80, 1.12	40.7	0.18
Adolescents (12-18 year)					
Food insecurity level					
Mild food insecurity	4	1.12	0.99, 1.26	81.50	0.001
Moderate food insecurity	4	1.13	0.99, 1.30	79.8	0.001
Sever food insecurity	4	1.24	1.03, 1.49	83.3	0.001
Race/ethnicity					
Hispanic	2	1.02	0.96, 1.08	10.5	0.29
Mixed	4	1.06	0.98, 1.15	90.4	0.0
Economic development level					
Developed	4	1.14	1.02, 1.27	72.2	0.006
Developing	5	0.97	0.88, 1.07	51.1	0.10

[1]Calculated by Random-effects model. *All comparison was conducted with food secure subjects (referent)

subjective socioeconomic level was associated with changes in several metabolic hormones, for example, increases in neuropeptide Y (NPY),[63] insulin[64,65] and cortisol,[66] which may lead to obesity. Furthermore, individuals who had a lower subjective socioeconomic level indicated an increase in active ghrelin, leading to lower feelings of fullness and satiety, compared with those at a higher socioeconomic level.[67] These associations may be amplified by obesogenic environments in developed countries (such as higher psychosocial stress and biological functioning, access to energy-dense and low-nutrient foods), leading to increased risks of OW/OB.[68]

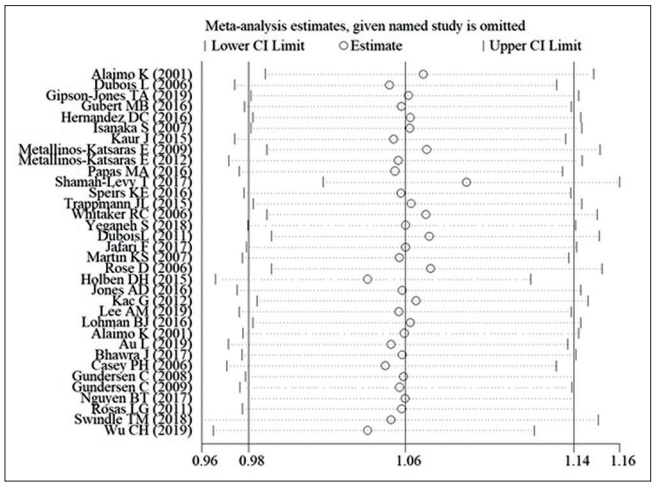

Figure 5: Forest plot of sensitivity analysis of all included studies

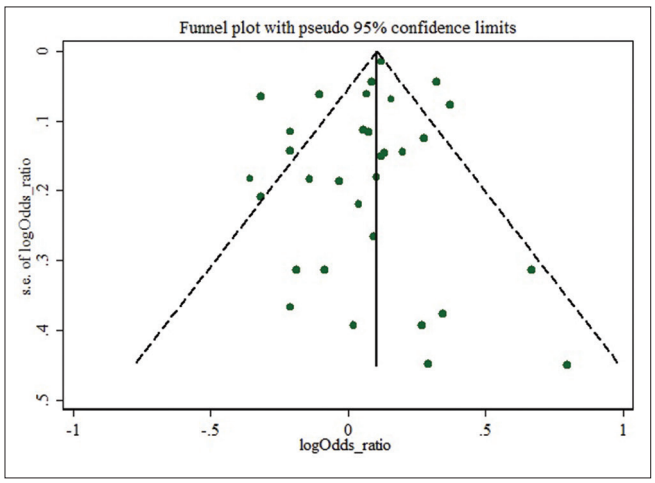

Figure 6: Funnel plot of food security status and risk of childhood and adolescents OW/OB

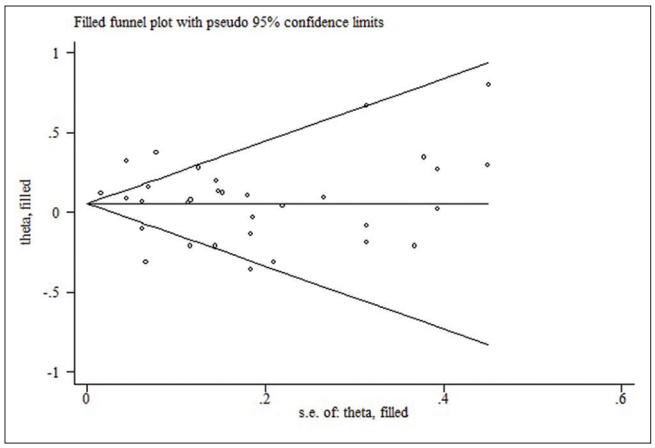

Figure 7: Filled funnel plot showing filled studies

Strengths and limitations

The important power of present meta-analysis is the high number of articles assessed. The high number of articles leads to a better and more accurate conclusion. Moreover, several subgroup analyses according to age, gender, FI level, national development level, and food security assessment tools, are important strengths and unique aspects of the present study. Several limitations of current study should be noted. (1) High heterogeneity was existed in the statistical analysis, even though several subgroups and sensitivity analyses were conducted. (2) Notwithstanding the several articles published relevant to the relationship between FI and the risk of OW/OB among children and adolescents, only some articles assessed FI with reference to the risk of abdominal obesity. (3) Although the scale of food security assessment did not affect the results, most studies used the household scale instead of a child food security scale. The use of household food security data in assessing the child's food security level may increase possible errors. (4) A number of studies[21,22,26,33,37,38] reported wide age-range (6–18) results. This reporting method led to a limitation in this paper's subgroup analyses. (5) Many of the studies included were conducted in developed countries[20-22,25-27,29,30,32,34,36-40,42,49,50,52] with only a relatively small number of studies being conducted in developing countries.[27,31,35,41,43,48,51]

Conclusions

In summarize, the current study demonstrated that there was no association between FI status and risk of OW/OB in under 18 year individuals. However, this analysis implied that sever FI level may be related with a significant OW/OB risk in adolescents. Moreover, the economic development status had positive association with the relationship between FI and increased the risk of OW/OB in under 18-year individuals. Performing program to decrease the OW/OB risks by facilitating the bioavailability of essential nutrients, fortified, and complementary foods and following dietary guidelines—as well as improving infant and young child feeding (IYCF) practices[69] —should be integrated into poverty rebate programs. Additional longitudinal research with adjusting main obesity related factor such as physical activity or energy intake are required to acceptance the possible association between FI and the OW/OB risk in under 18-year individuals. Additionally, it is proposed that in next researches, more consideration to the association between FI and central obesity.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Received: 10 Dec 19 **Accepted:** 23 Jan 20
Published: 22 Sep 20

References

1. Dias KA, Green DJ, Ingul CB, Pavey TG, Coombes JS. exercise and vascular function in child obesity: A meta-analysis. Pediatrics 2015;136:e648-59.

2. Lindsay AC, Sitthisongkram S, Greaney ML, Wallington SF, Ruengdej P. Non-responsive feeding practices, unhealthy eating behaviors, and risk of child overweight and obesity in Southeast Asia: A systematic review. Int J Environ Res Public Health 2017;14.
3. Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. Int Rev Psychiatry (Abingdon, England) 2012;24:176-88.
4. Singh AS, Mulder C, Twisk JW, van Mechelen W, Chinapaw MJ. Tracking of childhood overweight into adulthood: A systematic review of the literature. Obes Rev 2008;9:474-88.
5. Kline AM. Pediatric obesity in acute and critical care. AACN Adv Crit Care 2008;19:38-46.
6. Wyatt SB, Winters KP, Dubbert PM. Overweight and obesity: Prevalence, consequences, and causes of a growing public health problem. Am J Med Sci 2006;331:166-74.
7. Sybilski AJ, Raciborski F, Lipiec A, Tomaszewska A, Lusawa A, Furmanczyk K, *et al*. Obesity--A risk factor for asthma, but not for atopic dermatitis, allergic rhinitis and sensitization. Public Health Nutr 2015;18:530-6.
8. Bass R, Eneli I. Severe childhood obesity: An under-recognised and growing health problem. Postgrad Med J 2015;91:639-45.
9. Gonzalez-Muniesa P, Martinez-Gonzalez MA, Hu FB, Despres JP, Matsuzawa Y, Loos RJ, *et al*. Obesity. Nat Rev Dis Primers 2017;3:17034.
10. Trandafir LM, Temneanu OR. Pre and post-natal risk and determination of factors for child obesity. J Med Life 2016;9:386-91.
11. Oken E, Levitan EB, Gillman MW. Maternal smoking during pregnancy and child overweight: Systematic review and meta-analysis. Int J Obes 2008;32:201-10.
12. Moradi S, Mirzaei K, Abdurahman AA, Keshavarz SA, Hossein-Nezhad A. Mediatory effect of circulating vaspin on resting metabolic rate in obese individuals. Eur J Nutr 2016;55:1297-305.
13. Moradi S, Mirzaei K, Abdurahman AA, Keshavarz SA. Adipokines may mediate the relationship between resting metabolic rates and bone mineral densities in obese women. Osteoporos Int 2017;28:1619-29.
14. Anderson SA. Core indicators of nutritional state for difficult-to-sample populations. J Nutr (USA) 1990;120 (Suppl 11):1559-600.
15. Shen X, Gao X, Tang W, Mao X, Huang J, Cai W. Food insecurity and malnutrition in Chinese elementary school students. Br J Nutr 2015;114:952-8.
16. Moradi S, Mirzababaei A, Dadfarma A, Rezaei S, Mohammadi H, Jannat B, *et al*. Food insecurity and adult weight abnormality risk: A systematic review and meta-analysis. Eur J Nutr 2019;58:45-61.
17. Moradi S, Arghavani H, Issah A, Mohammadi H, Mirzaei K. Food insecurity and anaemia risk: A systematic review and meta-analysis. Public Health Nutr 2018;21:3067-79.
18. Moradi S, Mirzababaei A, Mohammadi H, Moosavian SP, Arab A, Jannat B, *et al*. Food insecurity and the risk of undernutrition complications among children and adolescents: A systematic review and meta-analysis. Nutrition 2019;62:52-60.
19. Melchior M, Chastang JF, Falissard B, Galéra C, Tremblay RE, Côté SM, *et al*. Food insecurity and children's mental health: A prospective birth cohort study. PLoS One 2012;7:e52615.
20. Holben DH, Taylor CA. Food insecurity and its association with central obesity and other markers of metabolic syndrome among persons aged 12 to 18 years in the United States. J Am Osteopath Assoc 2015;115:536-43.
21. Casey PH, Simpson PM, Gossett JM, Bogle ML, Champagne CM, Connell C, *et al*. The association of child and household food insecurity with childhood overweight status. Pediatrics 2006;118:e1406-13.
22. Bhawra J, Cooke MJ, Guo Y, Wilk P. The association of household food security, household characteristics and school environment with obesity status among off-reserve First Nations and Metis children and youth in Canada: Results from the 2012 Aboriginal Peoples Survey. Health Promot Chronic Dis Prev Can 2017;37:77-86.
23. Franklin B, Jones A, Love D, Puckett S, Macklin J, White-Means S. Exploring mediators of food insecurity and obesity: A review of recent literature. Journal of community health 2012;37:253-64.
24. Eisenmann JC, Gundersen C, Lohman BJ, Garasky S, Stewart SD. Is food insecurity related to overweight and obesity in children and adolescents? A summary of studies, 1995–2009. Obes Rev 2011;12:e73-83.
25. Dubois L, Farmer A, Girard M, Porcherie M. Family food insufficiency is related to overweight among preschoolers. Social Sci Med 2006;63:1503-16.
26. Rosas LG, Guendelman S, Harley K, Fernald LC, Neufeld L, Mejia F, *et al*. Factors associated with overweight and obesity among children of Mexican descent: Results of a binational study. J Immigr Minor Health 2011;13:169-80.
27. Dubois L, Francis D, Burnier D, Tatone-Tokuda F, Girard M, Gordon-Strachan G, *et al*. Household food insecurity and childhood overweight in Jamaica and Quebec: A gender-based analysis. BMC Public Health 2011;11:199.
28. Metallinos-Katsaras E, Must A, Gorman K. A longitudinal study of food insecurity on obesity in preschool children. J Acad Nutr Diet 2012;112:1949-58.
29. Kaur J, Lamb MM, Ogden CL. The association between food insecurity and obesity in children—The National Health and Nutrition Examination Survey. J Acad Nutr Diet 2015;115:751-8.
30. Papas MA, Trabulsi JC, Dahl A, Dominick G. Food insecurity increases the odds of obesity among young Hispanic children. J Immigr Minor Health 2016;18:1046-52.
31. Jones AD, Mundo-Rosas V, Cantoral A, Levy TS. Household food insecurity in Mexico is associated with the co-occurrence of overweight and anemia among women of reproductive age, but not female adolescents. Maternal and Child Nutrition 2017;13:e12396.
32. Alaimo K, Olson CM, Frongillo EA. Low family income and food insufficiency in relation to overweight in US children: Is there a paradox? Arch Pediatr Adolesc Med 2001;155:1161-7.
33. Jones SJ, Jahns L, Laraia BA, Haughton B. Lower risk of overweight in school-aged food insecure girls who participate in food assistance: Results from the panel study of income dynamics child development supplement. Arch Pediatr Adolesc Med 2003;157:780-4.
34. Rose D, Bodor JN. Household food insecurity and overweight status in young school children: Results from the Early Childhood Longitudinal Study. Pediatrics 2006;117:464-73.
35. Isanaka S, Mora-Plazas M, Lopez-Arana S, Baylin A, Villamor E. Food insecurity is highly prevalent and predicts underweight but not overweight in adults and school children from Bogota, Colombia. J Nutr 2007;137:2747-55.
36. Martin KS, Ferris AM. Food insecurity and gender are risk factors for obesity. J Nutr Educ Behav 2007;39:31-6.
37. Gundersen C, Lohman BJ, Eisenmann JC, Garasky S, Stewart SD. Child-specific food insecurity and overweight are not associated in a sample of 10-to 15-year-old low-income youth. J Nutr 2008;138:371-8.

38. Gundersen C, Garasky S, Lohman BJ. Food insecurity is not associated with childhood obesity as assessed using multiple measures of obesity. J Nutr 2009;139:1173-8.
39. Trappmann JL, Jimenez EY, Keane PC, Cohen DA, Davis SM. Cross-sectional relationships between household food insecurity and child BMI, feeding behaviors, and public assistance utilization among Head Start children from predominantly Hispanic and American Indian communities in the CHILE study. J Hunger Environ Nutr 2015;10:439-55.
40. Hernandez DC. Latino mothers' cumulative food insecurity exposure and child body composition. Am J Health Behav 2016;40:92-9.
41. Gubert MB, Spaniol AM, Bortolini GA, Pérez-Escamilla R. Household food insecurity, nutritional status and morbidity in Brazilian children. Public Health Nutr 2016;19:2240-5.
42. Speirs KE, Fiese BH, Team SKR. The relationship between food insecurity and BMI for preschool children. Matern Child Health J 2016;20:925-33.
43. Jafari F, Ehsani S, Nadjarzadeh A, Esmaillzadeh A, Noori-Shadkam M, Salehi-Abargouei A. Household food insecurity is associated with abdominal but not general obesity among Iranian children. BMC Public Health 2017;17:350.
44. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, *et al*. Meta-analysis of observational studies in epidemiology: A proposal for reporting. Meta-analysis of observational studies in epidemiology (MOOSE) group. JAMA 2000;283:2008-12.
45. Modesti PA, Reboldi G, Cappuccio FP, Agyemang C, Remuzzi G, Rapi S, *et al*. Panethnic differences in blood pressure in Europe: A systematic review and meta-analysis. PLoS One 2016;11:e0147601.
46. Sun J, Wang J, Pan X, Yuan H. A New treatment strategy for inactivating algae in ballast water based on multi-trial injections of chlorine. Int J Mol Sci 2015;16:13158-71.
47. Coates J, Swindale A, Bilinsky P. Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide. Washington, DC: Food and Nutrition Technical Assistance Project, Academy for Educational Development; 2007. p. 34.
48. Kac G, Velasquez-Melendez G, Schlüssel MM, Segall-Côrrea AM, Silva AA, Pérez-Escamilla R. Severe food insecurity is associated with obesity among Brazilian adolescent females. Public Health Nutr 2012;15:1854-60.
49. Lohman BJ, Gillette MT, Neppl TK. Harsh parenting and food insecurity in adolescence: The association with emerging adult obesity. J Adolesc Health 2016;59:123-7.
50. Metallinos-Katsaras E, Sherry B, Kallio J. Food insecurity is associated with overweight in children younger than 5 years of age. J Am Diet Assoc 2009;109:1790-4.
51. Shamah-Levy T, Mundo-Rosas V, Morales-Ruan C, Cuevas-Nasu L, Méndez-Gómez-Humarán I, Pérez-Escamilla R. Food insecurity and maternal-child nutritional status in Mexico: Cross-sectional analysis of the National Health and Nutrition Survey 2012. BMJ Open 2017;7:e014371.
52. Whitaker RC, Orzol SM. Obesity among US urban preschool children: Relationships to race, ethnicity, and socioeconomic status. Arch Pediatr Adolesc Med 2006;160:578-84.
53. Wu CH, Lin CY, Hsieh YP, Strong C, Meshki C, Lin YC, *et al*. Dietary behaviors mediate the association between food insecurity and obesity among socioeconomically disadvantaged youth. Appetite 2019;132:275-81.
54. Yeganeh S, Motamed N, Najafpour Boushehri S, Ravanipour M. Assessment of the knowledge and attitude of infants' mothers from Bushehr (Iran) on food security using anthropometric indicators in 2016: A cross-sectional study. BMC Public Health 2018;18:621.
55. Swindle T, Fitzgerald S, McKelvey LM, Whiteside-Mansell L. Application of noninferiority tests to examine the food insecurity–obesity relationship in children. J Hunger Environ Nutr 2018;13:228-39.
56. Lee AM, Scharf RJ, Filipp SL, Gurka MJ, DeBoer MD. Food insecurity is associated with prediabetes risk among US adolescents, NHANES 2003–2014. Metab Syndr Relat Disord 2019;17:347-54.
57. Gipson-Jones TL, O'Neal LJ, Sheats JL, Thorpe Jr RJ, Beech BM, Bruce MA. Food security status and overweight/Obesity among 2-to 5-year-old boys and girls in a community-based clinic. Fam Community Health 2019;42:117-22.
58. Au LE, Zhu SM, Nhan LA, Plank KR, Frongillo EA, Laraia BA, *et al*. Household food insecurity is associated with higher adiposity among US schoolchildren ages 10–15 years: The healthy communities study. J Nutr 2019;149:1642-50.
59. Cook JT, Frank DA, Casey PH, Rose-Jacobs R, Black MM, Chilton M, *et al*. A brief indicator of household energy security: Associations with food security, child health, and child development in US infants and toddlers. Pediatrics 2008;122:e867-75.
60. Nettle D, Andrews C, Bateson M. Food insecurity as a driver of obesity in humans: The insurance hypothesis. Behav Brain Sci 2017;40:e105.
61. Dhurandhar EJ. The food-insecurity obesity paradox: A resource scarcity hypothesis. Physiol Behav 2016;162:88-92.
62. Gross RS, Mendelsohn AL, Fierman AH, Racine AD, Messito MJ. Food insecurity and obesogenic maternal infant feeding styles and practices in low-income families. Pediatrics 2012;130:254-61.
63. Cavagnini F, Croci M, Putignano P, Petroni M, Invitti C. Glucocorticoids and neuroendocrine function. Int J Obesity 2000;24(S2):S77-9.
64. Dallman MF, la Fleur SE, Pecoraro NC, Gomez F, Houshyar H, Akana SF. Minireview: Glucocorticoids—food intake, abdominal obesity, and wealthy nations in 2004. Endocrinology 2004;145:2633-8.
65. Björntorp P. Do stress reactions cause abdominal obesity and comorbidities? Obes Rev 2001;2:73-86.
66. Gruenewald TL, Kemeny ME, Aziz N. Subjective social status moderates cortisol responses to social threat. Brain Behav Immun 2006;20:410-9.
67. Sim A, Lim E, Leow M, Cheon B. Low subjective socioeconomic status stimulates orexigenic hormone ghrelin–A randomised trial. Psychoneuroendocrinology 2018;89:103-12.
68. Ryan-Ibarra S, Sanchez-Vaznaugh EV, Leung C, Induni M. The relationship between food insecurity and overweight/obesity differs by birthplace and length of US residence. Public Health Nutr 2017;20:671-7.
69. Balarajan Y, Ramakrishnan U, Özaltin E, Shankar AH, Subramanian S. Anaemia in low-income and middle-income countries. Lancet 2011;378:2123-35.

Supplementary Table 1: Quality assessment of included cross-sectional studies using the Newcastle-Ottawa scale

First Author (year)	Selection	Comparability	Exposure	Quality Score
Alaimo K (2001)	*****	**	***	+10/10
Casey PH (2006)	****	**	***	+9/10
Whitaker RC (2006)	*****	**	***	+10/10
Isanaka S (2007)	*****	**	***	+10/10
Martin KS (2007)	****	**	***	+10/10
Gundersen C (2009)	****	**	***	+9/10
Metallinos-Katsaras E (2009)	****	**	***	+9/10
DuboisL (2011)	*****	**	***	+10/10
Kac G (2012)	*****	**	***	+10/10
Kaur J (2015)	*****	**	***	+10/10
Trappmann JL (2015)	*****	**	***	+10/10
Holben DH (2015)	****	**	***	+9/10
Hernandez DC (2016)	*****	**	***	+10/10
Papas MA (2016)	****	**	***	+9/10
Speirs KE (2016)	****	**	***	+9/10
Gubert MB (2016)	*****	**	***	+10/10
Jones AD (2016)	*****	**	***	+10/10
Jafari F (2017)	*****	**	***	+9/10
Bhawra J (2017)	****	**	***	+9/10
Shamah-Levy T (2017)	****	**	***	+10/10
Swindle (2018)	***	**	***	+8/10
Yeganeh (2018)	***	**	***	+8/10
Wu (2019)	****	**	***	+9/10
Au (2019)	****	**	***	+9/10
Lee (2019)	****	**	***	+9/10
Gipson-Jones (2019)	***	**	***	+8/10

Each star represents one point from Newcastle Ottawa score

Supplementary Table 2: Quality assessment of included longitudinal studies using the Newcastle-Ottawa scale

First Author (year)	Selection	Comparability	Features of outcome	Quality Score
Rose D (2006)	*****	**	***	+10/10
Dubois L (2006)	*****	**	***	+10/10
Gundersen C (2008)	*****	**	***	+10/10
Rosas LG (2011)	*****	**	***	+10/10
Metallinos-Katsaras E (2012)	****	**	***	+9/10
Lohman BJ (2016)	*****	**	***	+10/10

Each star represents one point from Newcastle Ottawa score