ORIGINAL RESEARCH

A Systematic Review and Meta-Analysis of Food Insecurity and Dyslipidemia

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Purpose: **There is considerable interest in the association between food insecurity (FIS) and various cardiovascular risk factors such as dyslipidemia. Although the association between FIS and dyslipidemia has been studied across various methodologies and populations, there is no comprehensive systematic review and meta-analysis of these data.**

Methods: **A systematic literature search was conducted. Cross-sectional peer-review studies assessing the association between FIS and dyslipidemia were identified. Data extracted included population characteristics, study sizes, covariates explored, and laboratory assessments of dyslipidemia. Effect sizes were extracted or calculated, then synthesized across studies using a random effect model, and the heterogeneity, publication bias, and subgroup dependence for each meta-analysis were assessed.**

Results: **For adults, meta-analysis demonstrated no significantly elevated odds for FIS individuals to have a concomitant abnormal lipid measurement. Covariate-unadjusted analysis of standardized mean differences showed no significant differences in lipid measurements between food-insecure and food-secure individuals. In contrast to quantitative laboratory results, food-insecure patients were more likely to self-report previous diagnoses of dyslipidemia.**

Conclusions: **Although current data do not suggest an association between FIS and dyslipidemia, more longitudinal studies and studies targeting women, children, the elderly, and patients with chronic diseases such as diabetes are needed to further address this issue. (J Am Board Fam Med 2022;35:656–667.)**

Keywords: **Cholesterol, Chronic Disease, Cross-Sectional Studies, Dyslipidemias, Food Insecurity, Hunger, LDL Triglyceride, Risk Factors, Social Determinants of Health**

Background

Food insecurity (FIS) is a complex phenomenon that generally refers to inadequate access to food of sufficient nutritional quality to promote health.[1] FIS can be due to a wide range of factors including poverty, access to public resources like transportation, and the presence of food deserts.[2–5] It is for this reason FIS has been linked to other important and well-established social determinants of health such as race, income level, housing, disability, and citizenship status.[6–10]

In addition to its relevance to various social determinants of health, multiple mechanisms have been proposed for a link between FIS and cardiovascular disease.[11–14] One possible link is mediated through cardiovascular risk factors such as high blood pressure, diabetes, and dyslipidemia.[12,14] For dyslipidemia, there are at least 2 potentially offsetting effects of FIS on patients' lipid measurements.

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The first is that FIS leads to nutritionally poor diets (ie, increased intake of foods high in saturated or trans fats and/or low in fiber) that may be further complicated or exacerbated by cultural and socioeconomic factors.[15–17] In contrast, a subset of severely food-insecure patients may consume overall fewer calories than their food-secure counterparts, which may lead to improved lipid measurements.[18,19] It remains unclear if the strength of such associations (effect sizes such as odds ratios [ORs] or standardized mean differences [SMDs]) is either measurable or clinically significant.

As both FIS and dyslipidemia each have high prevalence[5,20–27] and well-documented deleterious health effects,[28–38] identifying an association between the 2 factors could have relevance to clinicians. As a result, there has been considerable effort in the literature to measure the possible association between FIS and dyslipidemia in a number of cross-sectional studies spanning diverse populations and various lipid markers such as total cholesterol (TC), low-density lipoprotein (LDL), triglycerides (TG), and high-density lipoproteins (HDL).[39] However, there has yet to be a comprehensive systematic review and meta-analysis to synthesize these results.

Methods

Data Sources

This systematic review and meta-analysis is the result of an initially broad, systematic literature search investigating the link between FIS and cardiometabolic risk factors. The initial search was registered in Prospero as of January 28, 2020 (registration CRD42020149560) and included all peer-reviewed human studies involving any population, any methodology, and any publication year in 4 databases: PubMed, Scopus, Embase, and Web of Science. The initial search took place on September 9, 2019 and involved the Medical Subject Headings of FIS with hypertension, diabetes, metabolic syndrome, and dyslipidemia.

Study Selection

Every abstract obtained in the initial search described above was randomized and screened using Abstrackr[40,41]; 4 authors inspected for relevance. Relevance was defined as: (1) the study investigated FIS or a comparable concept, (2) the study also investigated hypertension, diabetes, metabolic syndrome, or dyslipidemia, (3) the study reported quantitative primary data, and (4) the study was peer reviewed and available in English. Articles that were excluded by all 4 authors were discarded; those with approval from at least 1 author were further discussed and reviewed by an additional author. Interrater reliability was assessed for the entire group and permutations of reviewer pairs.[42] Studies that satisfied the above conditions were then screened by at least 2 authors to identify those that contained primary data exploring direct associations between FIS and dyslipidemia; studies that contained data only through a third variable were discarded. Disagreements were revisited by an additional author. Included studies were then assessed through the AXIS tool for quality assessment of cross-sectional studies[43] to assess for individual-study biases.

Data Extraction

Every study identified that met the above inclusion criteria underwent manual extraction of study population characteristics, sample size, study design, measurements, and all outcomes related to FIS and dyslipidemia. Extracted data were grouped by the measured outcomes available from each study in its relationship to FIS: LDL, HDL, TC, and TG. Based on the available primary data, meta-analyses were possible on ORs and SMDs (specifically Hedges' g). Effect sizes were extracted by 1 author and, when not reported in a study, were calculated manually using the study's reported primary data. Regarding studies that separated outcomes by FIS categories (ie, mild vs severe FIS), the primary data were either pooled to calculate 1 effect size or, if applicable, reported effect sizes were combined using the random effects (RE) model. More information on how studies were grouped can be found in the Online Appendix figures and tables.

Data Synthesis and Meta-Analysis

Meta-analyses were conducted only when 3 or more effect sizes were available from separate studies on a specific outcome measure. Analysis was conducted using the metafor package in R based on the RE size model, which does not assume sampled populations have identical probability distributions.[44] Meta-analysis results were calculated using the DerSimonian-Laird estimator.[45] For OR meta-analysis, the logarithm was used as the effect size.

For each meta-analysis, study heterogeneity was calculated via the total variance (Q), the degrees of freedom (*df*), and the I^2 statistic.[46] Publication bias was evaluated by the Begg and Mazumdar rank correlation test for funnel plot asymmetry as well as Kendall's τ in Egger's regression test.[47,48]

Results

Study Characteristics

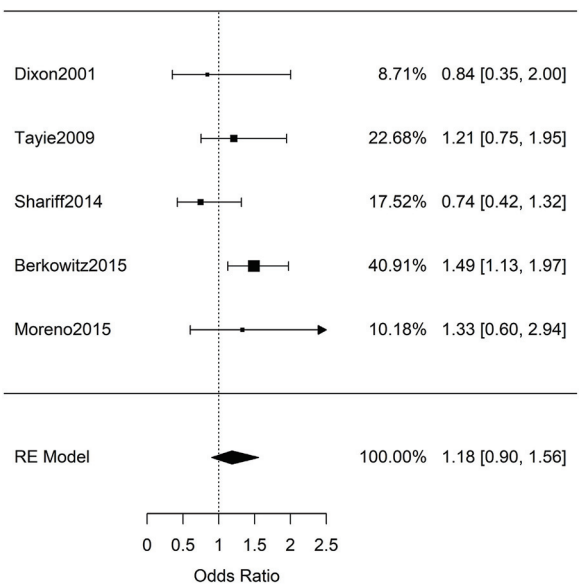
A total of 787 abstracts were reviewed by 4 authors, with significant group interrater agreement: Fleiss kappa = 0.68 [95% CI, 0.66, 0.71, n = 4] with each user having permutated interrater agreements above 0.6. One hundred ninety-six abstracts were then full-text evaluated, and 32 manuscripts were found to have primary data exploring the association between dyslipidemia and FIS (Online Appendix Figure 1). All studies identified in a previous 2017 preliminary nonmeta-analysis review were also discovered on this review.[39] All studies had either a cross-sectional design or contained data specific to FIS that corresponded to baseline characteristics from a cohort study. Most studies were from the US, which had the highest number of patients; Malaysia and Iran were the other most represented countries.

Twenty-five studies presented data on adults,[12,19,49–71] 5 presented data on children,[72–76] and 2 studies had data on both.[64,77] Twenty-six studies presented lab measurements for 1 (or a combination) of LDL, TG, TC, or HDL; 5 studies exclusively used only self-reports of previous diagnoses of dyslipidemia; 1 study used general nonspecific diagnosis of hyperlipidemia from chart review.[75] The characteristics of each study are presented in Online Appendix Tables 1–11. These tables divide studies based on child/adult status, dyslipidemia measurements, and choice of effect size (OR, SMD). Each table indicates where in the manuscript the original information was located and whether we calculated the effect sizes ourselves by extracting primary data. We noted manuscripts with overlapping patient data and those for which we could not extract nor calculate effect sizes.

For children, the few identified studies (Online Appendix Tables 9 and 10) did not have sufficient overlap to perform any meta-analysis. In short, the data from some studies suggested associations between FIS and specific dyslipidemia measurements,[72] while others did not.[64,74,76] One study presented data on both children and adults but was not analyzed due to inability to separate the data from the 2 groups.[77]

In adults, the available literature data allowed for 8 meta-analyses to explore the association of FIS with dyslipidemia: by 4 lab measurements (LDL, HDL, TC, TG) and with 2 different effect sizes

Figure 1. Meta-analysis of adult studies investigating increased odds of elevated low-density lipoprotein (LDL) for food-insecure patients. Synthesis of the 5 studies resulted in a nonsignificant combined odds ratio of 1.18 [95% CI, 0.90-1.56, n = 22,746, Q(*df* = 4) = 5.5, I^2 = 27%].



(OR and SMD). As some studies had partially overlapping data (depending on population and/or measurement modality and reporting), the total number of manuscripts and sample size used for each meta-analysis will be discussed in the subsections below.

Results of Individual Studies and Synthesis of Results by Dyslipidemia Measurement

LDL

We first analyzed studies that explored the association between food insecurity and elevated LDL measurements. The 5 studies (n = 22,746) that reported the adjusted ORs were combined for meta-analysis in Figure 1. Synthesis of the results revealed no significant association between FIS and elevated LDL: OR_{LDL} = 1.18 [95% CI, 0.90–1.56, n = 22,746, Q(df = 4) = 5.5, I^2 = 27%]. All of these studies adjusted for various covariates such as age, sex, gender, and, in some cases, body mass index (BMI) or adiposity (Online Appendix Table 1). One study was excluded from the meta-analysis above as it involved overlapping National Health and Nutrition Examination Survey data (Online Appendix Table 1).[51]

Five additional studies (n = 1,143) reported sufficient data to calculate the SMD in LDL levels between food-insecure and food-secure adults (Online Appendix Table 2). Although these data were not adjusted for covariates, synthesis also resulted in no significant difference in LDL levels between food-secure and food-insecure patients: g_{LDL} = −0.02 [95% CI, −0.28, 0.25, n = 1143, Q (df = 4) = 17, I^2 = 76%] (Figure 2). Lastly, the study on veterans with diabetes by Smalls et al also did not show a significant association between LDL and FIS,[58] but it was not added to the meta-analysis due to lack of primary data for OR or Hedges g.

HDL

Synthesis by meta-analysis of the 6 nonoverlapping studies (n = 28,557) (Online Appendix Table 3) exploring FIS and low levels of HDL resulted in a nonsignificant result: OR_{HDL} = 1.02 [95% CI, 0.98, 1.06, n = 28,557, Q(df = 5) = 2.7, I^2 = 0%] (Figure 3). Not only was the synthesized OR close to 1, but the heterogeneity (I^2 = 0) was lower than that expected from random chance. Synthesis of the 6 HDL studies (Online Appendix Table 4) with standardized mean data resulted in a nonsignificant difference in HDL levels between food-secure and food-insecure adults: g_{HDL} = −0.01 [95% CI, -0.07, 0.04, n = 7,096, Q(df = 5) = 3.20, I^2 = 0%] (Figure 4).

Total Cholesterol

Meta-analysis of 6 studies (n = 28,225) (Online Appendix Table 5) showed similar odds for elevated

Figure 2. Meta-analysis of adult studies investigating food insecurity and low-density lipoprotein (LDL) measurement. Hedges' g, standardized mean differences with a small size correction, were calculated from the primary data of the 5 studies. Meta-analysis resulted in a nonsignificant effect: g_{LDL} = -0.02 [95% CI, -0.28, 0.25, n = 1,143, Q(df = 4) = 17, I^2 = 76%].

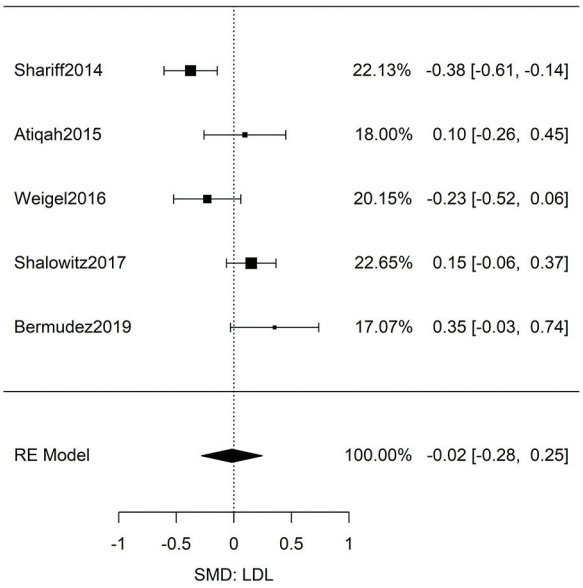
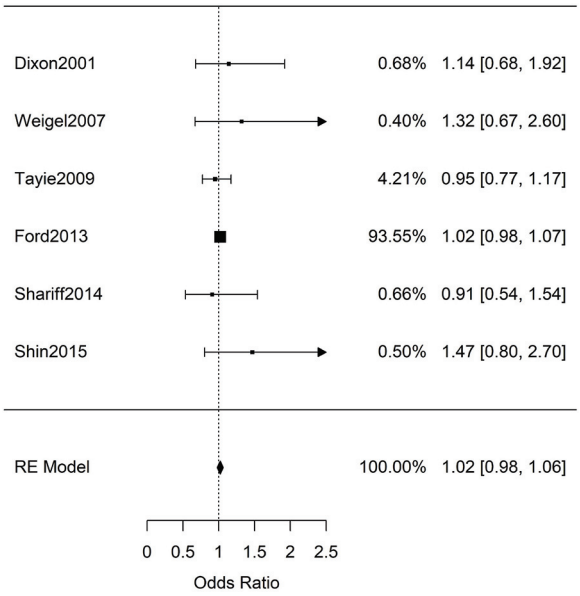


Figure 3. Meta-analysis of adult studies investigating increased odds of low high-density lipoprotein (HDL) for food-insecure patients. Synthesis of the 6 studies resulted in a nonsignificant combined odds ratio of OR_{HDL} = 1.02 [95% CI, 0.98, 1.06, n = 28,557, Q(*df* = 5) = 2.7, I^2 = 0%].



cholesterol between food-insecure and food-secure patients: OR_{TC} = 1.00 [95% CI, 0.95, 1.05, n = 28,225, Q(*df* = 5) = 4.3, I^2 = 0%]. The results (Figure 5) were homogeneous as evidenced by the calculated I^2. The study excluded from this meta-analysis, due to overlapping data, also reported no significant association.[61] Analysis of SMDs of 5 studies (Online Appendix Table 6) also showed no significant association in the TC levels between food-insecure and food-secure patients: g_{TC} = 0.02

Figure 4. Meta-analysis of adult studies investigating food insecurity and high-density lipoprotein (HDL) levels. Hedges' g, standardized mean differences with a small size correction, were calculated from the primary data of the 6 studies. Meta-analysis resulted in a nonsignificant effect: g_{HDL} = -0.01 [95% CI, -0.07, 0.04, n = 7,096, Q (*df* = 5) = 3.20, I^2 = 0%].

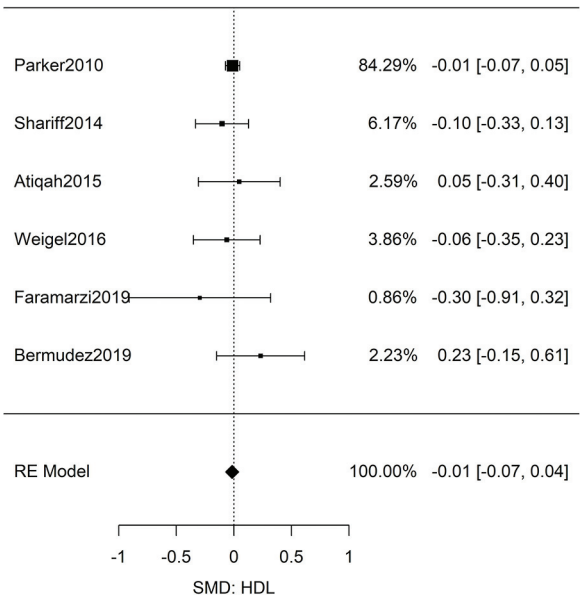
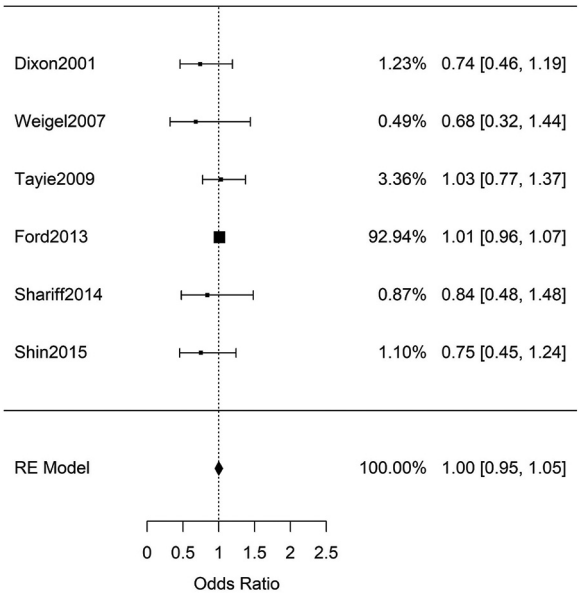


Figure 5. Meta-analysis of adult studies investigating increased odds of elevated total cholesterol for food-insecure patients. Synthesis of the 6 studies resulted in a nonsignificant combined odds ratio of OR_{TC} = 1.00 [95% CI, 0.95, 1.05, n = 28,225, Q(*df* = 5) = 4.3, I^2 = 0%].



[95% CI, -0.20, 0.24, n = 1,614, Q(*df* = 4) = 13, I^2 = 70%] (Figure 6).

Triglycerides

Meta-analysis of 5 studies (Online Appendix Table 7) with adjusted ORs for elevated TG in food-insecure versus food-secure patients yielded OR_{TG} = 1.13 [95% CI, 0.80, 1.61, n = 16,107, *Q*(*df* = 3) = 3.29, I^2 = 10%] (Figure 7). Similarly, analysis of SMDs for 5 studies (Online Appendix Table 8) showed no significant difference between food-secure and food-insecure patients: g_{TG} = 0.02 [95% CI, -0.22, 0.27, n = 958, Q(*df* = 4) = 10.2, I^2 = 61%] (Figure 8).

Self-Reports of Dyslipidemia Diagnosis

As previous meta-analyses studies have shown conflicting results between lab measurements and self-report of chronic conditions,[78] we a priori decided to separate these studies. We identified 5 studies (n = 12,888) that used self-reports of previous/current dyslipidemia diagnosis (Online Appendix Table 11). There was sufficient data to synthesize 3 of the studies; the result showed a significant association: $OR_{self\text{-}report}$ = 1.15 [95% CI, 1.08, 1.22, n = 9,212, Q(*df* = 2) =2.2, I^2 = 10%] (see Online Appendix Figure 2).

Risk of Bias within Studies and across Studies

Analysis with the AXIS tool did not identify any study warranted for exclusion. As for publication bias, none of the funnel plot asymmetry tests yielded positive results. However, it should be emphasized that for such a small number of studies the statistical power for these tests is very small.[79,80]

Subgroup Analyses

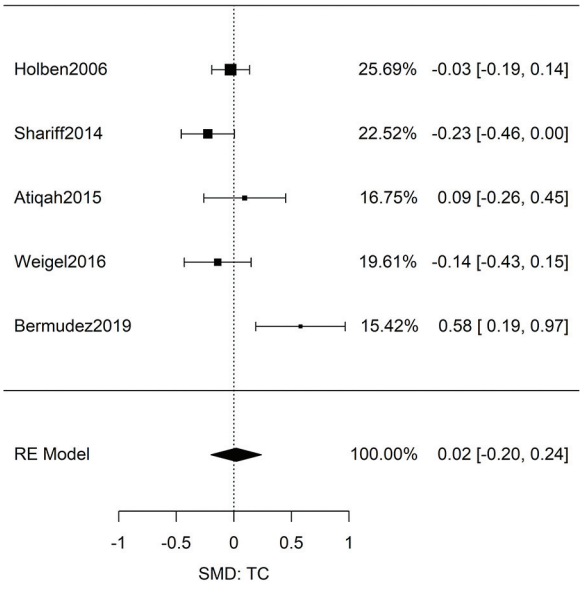
Diabetic Patients

One US study specific to the diabetes population reports a significant association between FIS and elevated LDL.[53] Another US study, specific to California and Hispanics, does not report an association between FIS and elevated LDL in their diabetic population.[52] These were the only 2 studies reporting adjusted ORs for the diabetic population and were considered too few for meta-analysis. We also calculated the association specific to this group by extracting primary data from 2 other US studies (at Hartford and Illinois)[56,57]; the analysis did not yield a significant association between FIS and elevated LDL.

Female Patients

There were mixed results on whether FIS was associated with higher odds of elevated LDL measurements in women.[49,50] The study on US women by Tayie and Zizza[49] showed significantly higher adjusted odds of elevated LDL in food-insecure compared with food-secure patients; combining

Figure 6. Meta-analysis of adult studies investigating food insecurity and total cholesterol levels. Hedges' g, standardized mean differences with a small size correction, were calculated from the primary data of the 5 studies. Meta-analysis resulted in a nonsignificant effect: g_{TC} = 0.02 [95% CI, -0.20, 0.24, n = 1,614, Q(*df* = 4) = 13, I^2 = 70%].



their results from different levels of FIS yielded AOR = 1.51 [95% CI, 1.02, 2.24, n = 2,977] (Online Appendix Table 1). In contrast, the study by Shariff et al on Malaysian women did not show a significant result: AOR = 0.75 [95% CI, 0.42, 1.31, n = 625].[50]

Three comparable studies (Online Appendix Table 2) were available for meta-analysis after calculating the

Figure 7. Meta-analysis of adult studies investigating increased odds of elevated triglycerides for food-insecure patients. Synthesis of the 4 studies resulted in a nonsignificant combined odds ratio of OR_{TG} = 1.13 [95% CI, 0.80, 1.61, n = 16,107, *Q*(*df* = 3) = 3.29, I^2 = 10%].

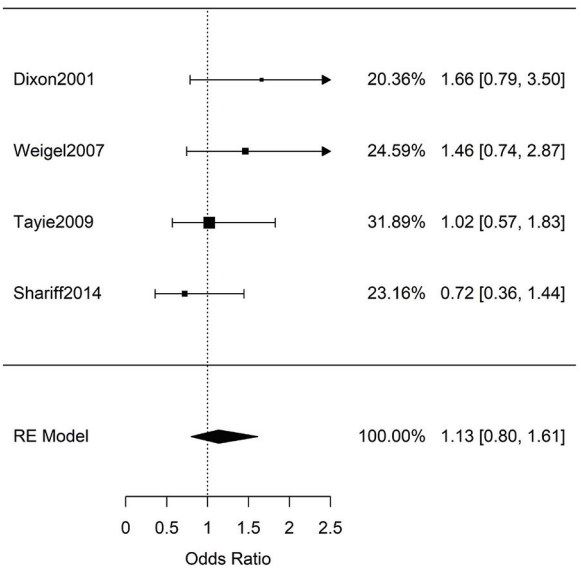
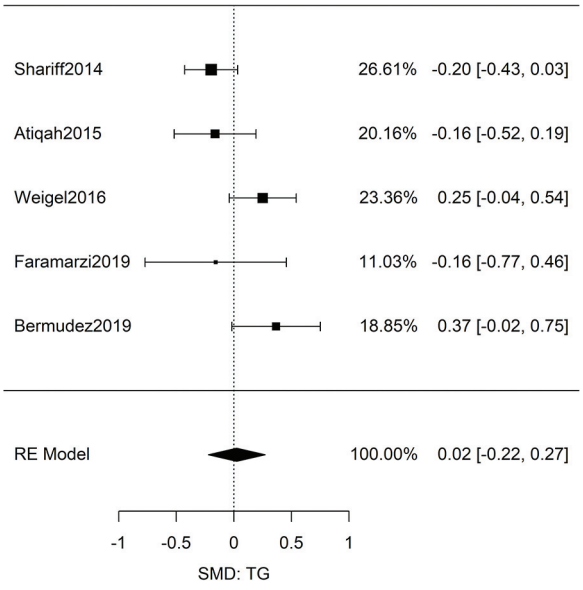


Figure 8. Meta-analysis of adult studies investigating food insecurity and triglycerides levels. Hedges' g, standardized mean differences with a small size correction, were calculated from the primary data of the 5 studies. Meta-analysis resulted in a nonsignificant effect: g_{TG} = 0.02 [95% CI, -0.22, 0.27, n = 958, Q(df = 4) = 10.2, I^2 = 61%].



SMD in LDL levels between the food-secure and food-insecure women[50,54,55]; synthesis of the results yielded significantly lower LDL levels in food-insecure patients compared with food-secure patients: g_{LDL_Women} = -0.24 [95% CI, -0.45, -0.02, n = 668, Q(df = 2) = 3.1, I^2 = 55%]. As this corresponds to unadjusted data, it is difficult to compare with the results from Tayie and Zizza and Shariff et al.[49,50]

Discussion

In this systematic review and meta-analysis, we found no association between FIS and dyslipidemia. Synthesis of the available literature showed that food-insecure adults did not have significantly elevated nor decreased odds of qualifying for a dyslipidemia diagnosis, whether by elevated LDL, TC, or TG, or a decreased HDL. There are several possible explanations for the nonassociation observed in the synthesis of the current data.

First, counterbalancing, opposing effects may be operating across the general population due to 2 major subsets of patients: 1 ingesting fewer calories[11–13] and another consuming a poor-quality diet with normal or increased calories.[14,15] Given its complexity, FIS may translate into differences in diet and calorie intake, effects that may vary significantly across different cultures, locations, and individuals. As these studies did not measure the calories or nutritional quality of the food ingested, it is currently not possible to assess the impact of these factors. Furthermore, there were very few studies outside of the USA, and few studies presenting data on socioeconomic, racial, or ethnic subgroups. Therefore, it remains possible that associations between FIS and lipid profiles might be detected in future studies focusing on specific subpopulations of patients.

Second, it is possible that the strengths (ie, effect sizes) of the intermediate associations (ie, FIS to diet quality, and diet quality to dyslipidemia) are small and do not lead to an appreciable effect size overall. The upper limits of the 95th confidence intervals from the meta-analyses provide convincing evidence that the overall effect size is most likely small. For example, the unadjusted effect size for TC was (g = 0.02 [95% CI, -0.20, 0.24]); and an effect size of 0.24 is small, especially when compared with other FIS associations.[31,81,82] Similarly, upper limits from the covariate-adjusted ORs (ie, OR_{TC} = 1.00 [95% CI, 0.95, 1.05]) suggest weak effects as well.

Finally, it is important to acknowledge that the effect of FIS on serum lipids may be time dependent

and thus may not have been captured in the currently available cross-sectional studies because the patients studied had not experienced FIS for a long enough duration to produce measurable changes in serum lipid levels. Furthermore, our review identified few studies that focused (or performed subpopulation analysis) on elderly populations, which may have demonstrated a larger response. Admittedly, our results may reflect a complex interplay of all of the processes described above.

Unlike dyslipidemia studies that used lab measurements, self-reports of previous diagnosis were significantly associated with FIS. This finding is similar to what has been previously reported by Beltrán et al for FIS and self-reported diabetes and hypertension.[78,83] It is currently unclear why food-insecure patients are more likely to report such chronic diagnoses, although 1 possibility is a complex interaction between FIS, anxiety/depression,[31] and the odds of self-reporting poor health.[84]

With respect to its clinical implications, our data do not indicate an association between FIS and dyslipidemia and thus do not support routine lipid screening of food-insecure individuals. However, as more FIS-dyslipidemia studies focusing on different countries, races, ethnicities, or socioeconomic groups emerge, such assessments may subsequently be determined to be warranted.

This study has several important limitations. First, the combined cross-sectional studies do not yield information on either causality or temporal relationships between FIS and lipid measurements. Second, our subgroup analyses were greatly limited by the availability of demographic-specific data on FIS and dyslipidemia. Not only were the studies limited to a few countries, there was very little data to explore by meta-analysis how the association occurs in children, across genders, across races/ethnicities, and for seniors. Third, the small number of studies do not allow satisfactory exploration of publication bias. Although no funnel asymmetry test was significant, it is important to note that the statistical power of these tests is small for the number of studies reviewed.

Conclusions

Currently, the available published data do not support an association between FIS and dyslipidemia. This literature, however, would be further strengthened by prospective and more higher-quality retrospective cohort studies; studies targeting important populations such as children, women, minorities, seniors, and patients with diabetes; investigations of populations beyond those of the USA, Malaysia, and Iran; and studies incorporating covariates such as calorie intake or diet quality as well as BMI.

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APPENDIX

Note: References cited below are those of the 32 studies that were the basis of this systematic review and meta-analysis. Please note that the numbering of these studies in the references for the appendix does not correspond to their numbering in the references for the main manuscript.

Figure 1. Flow chart displaying the study selection process.

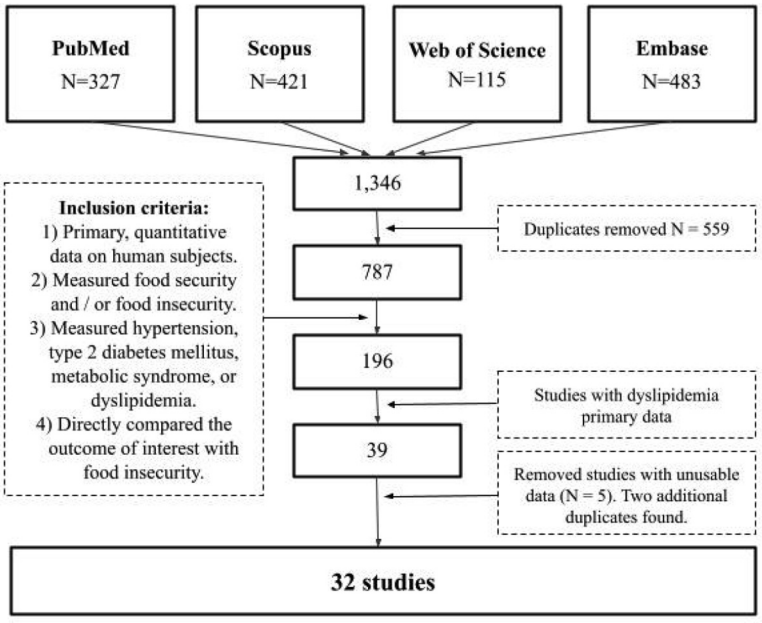

Figure 2. Meta-analysis of adult studies (n = 9,212) investigating increased odds of self-reported dyslipidemia for food insecure patients. Synthesis of the three studies resulted in a significant combined odds ratio of 1.15 [95%CI: 1.08–1.22, n = 9212, Q (df = 2) = 2.2, I2 = 10%].

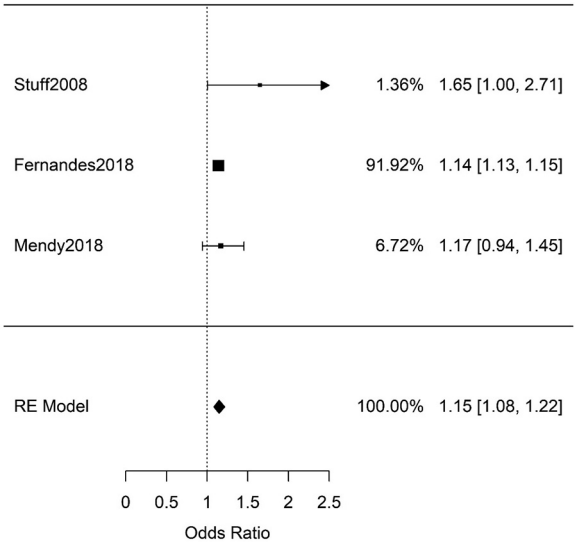

Table 1. Adult studies (n = 22,746) with sufficient data to retrieve or calculate the odds ratio for food insecurity and elevated LDL

Study	Patients	Study Size	Criteria	Results	Covariates
Dixon2001[1]	USA. NHANES 1988-1994. Adults. General population.	6,475	LDL > 160 mg/dL	AOR = 0.73 [0.23, 2.32]. Table 6.	Age, race, income, region of USA, smoking, alcohol.
	USA. NHANES 1988-1994. Seniors. General population.	3,690		AOR = 1.00 [0.27, 3.71]. Table 6.	
	Combined	10,165		AOR = 0.84 [0.35, 1.99].	
Tayie2009[2]	USA. NHANES 1999-2002. Women.	2,977	LDL > 130 mg/dL	AOR = 1.51 [1.02, 2.24]. *,$$: Table 4.	Age, education, income, physical activity, race/ethnicity, smoking.
	USA. NHANES 1999-2002. Men.	2,572		AOR = 0.93 [0.58, 1.51]. *,$$: Table 4.	
	Combined	5,549		AOR = 1.21 [0.75, 1.94].	
Shariff2014[3]	Malaysia. Low-income women.	625	LDL > 130 mg/dL	AOR = 0.745 [0.42, 1.32]. Table 4.	Adjusted for age, ethnicity, urban/rural strata, education, employment and income per capita.
Berkowitz2015[4]	USA. Boston. General population.	411	LDL > 100 mg/dL	AOR = 1.49 [1.13, 1.97]. Table 4.	Age, gender, race/ethnicity, education, insurance, health literacy, survey language, nativity, blood pressure medication use, and clustering by clinic.
Moreno2015[5]	USA. California. Hispanics with diabetes.	250	LDL > 100 mg/dL^	AOR = 1.33 [0.60, 2.94]. ^: Table 3	Age, gender, yearly household income, education, insurance coverage, general health status, number of doctor visits in the last 12 months, insulin use, and years with diabetes, **BMI**.

*: Calculated by authors from primary data
$$: Data from different FIS levels was combined with RE model
^: Inverted AOR from low LDL to high LDL

Excluded studies:

Berkowitz2013[6]	USA. NHANES 1999-2008. Diabetic patients.	2,557	LDL > 100 mg/dL	AOR = 1.86 [1.01, 3.44]. Table 2.	Age, gender, race/ethnicity, education, income, insurance, smoking, diabetes duration, statin use, **BMI**.

For studies with overlapping subjects, such as those from NHANES, we chose the study with the highest amount of subjects. The studies were still catalogued for their potential utility in subgroup analysis.
The study by Ford et al.[7] was not included in the meta-analyses due to unavailability of separate LDL measurement..

Table 2. Adult studies (n = 1,143) with sufficient data to retrieve or calculate the standardized mean difference (Hedges'g) in LDL levels between food secure and food insecure patients

Study	Patients	Study Size	Results
Shariff2014[3]	Malaysia. Low-income Women.	293	g = -0.38 [-0.61, -0.14]. * : Table 2.
Atiqah2015[8]	Malaysia. General Population. Women.	109	g = 0.02 [-0.36, 0.41]. *: Table 3.
	Malaysia. General Population. Men.	15	g = 0.22 [-1.05, 1.49]. *:Table 3.
	Combined	124	g = 0.10 [-0.26, 0.45]. *: Table 3.
Weigel2016[9]	Ecuador. Low-income women.	269	g = -0.23 [-0.52, 0.06]. *: Table 4.
Shalowitz2017[10]	USA. Illinois. Diabetic patients.	336**	g = 0.15 [-0.06, 0.37]. *: Table 1.
Bermudez2019[11]	USA. Hartford. Hispanics with diabetes.	121	g = 0.35 [-0.03, 0.74]. Table 1.

*: Calculated from primary data by the authors
**: Baseline data of the cohort

Excluded studies:

Dixon2001[1]	USA. NHANES 1988-1994. Adults.	6,475	Table 5.
	USA. NHANES 1988-1994. Seniors.	3,690	Table 5.
	Combined	10,165	
Smalls2015[12]	USA. Veterans with T2DM.	411	

The study by Dixon et al. was not included in the Hedges g meta analysis due to inability to obtain standard deviation for all groups. The study by Smalls et al. was not added due to lack of primary data to obtain an odds ratio with confidence intervals.

Table 3. Adult studies (n = 28,557) with sufficient data to retrieve or calculate the odds ratio for food insecurity and decreased HDL

Study	Patients	Study Size	Criteria	Results	Covariates
Dixon2001[1]	USA. NHANES 1988-1994. Adults. General population.	6,475	HDL < 35 mg/dL	AOR = 0.97 [0.49, 1.90]. Table 6.	Age, race, income, region of USA, smoking, alcohol.
	USA. NHANES 1988-1994. Seniors. General population.	3,690		AOR = 1.46 [0.64, 3.35]. Table 6.	
	Combined	10,165		AOR = 1.14 [0.68, 1.92].	
Weigel2007[13]	USA El Paso, TX. 2003.	100	HDL < 40 mg/dL (males); HDL < 50 mg/dL (females)	AOR = 1.32 [0.67, 2.60]. *,$$: Table 3.	Age, sex, education, US residence time, children living in household.
Tayie2009[2]	USA. NHANES 1999-2002. Women.	2,977	HDL < 50 mg/dL	AOR = 0.84 [0.61, 1.16]. *,$$: Table 4.	Age, education, income, physical activity, race/ethnicity, smoking
	USA. NHANES 1999-2002. Men.	2,572	HDL < 40 mg/dL	AOR = 1.04 [0.79, 1.38]. *,$$: Table 4.	
	Combined.	5,549	N/A	AOR = 0.95 [0.77, 1.17].	
Ford2013[7]	USA. NHANES 2003-2008. General population.	10,455	HDL < 40 (males); HDL < 50 (females)	ARR = 1.02 [0.97, 1.07]. *,$$: Table 2.	Age, sex, race, educational status, health insurance, alcohol use.
Shariff2014[3]	Malaysia. Low-income women.	625	HDL< 50 mg/dL	AOR = 0.91 [0.54, 1.55]. Table 4.	Adjusted for age, ethnicity, urban/rural strata, education, employment and income per capita.
Shin2015[14]	USA. Wisconsin. SHW 2008-2011. Men.	865	HDL < 40 mg/dL	AOR = 1.10 [0.68, 1.80]. Table 4.	Age, race, education, smoking, alcohol, obesity, **BMI**.
	USA. Wisconsin. SHW 2008-2011. Women.	798	HDL < 50 mg/dL	AOR = 2.04 [1.15, 3.64]. Table 4.	
	Combined	1,663	N/A	AOR = 1.47 [0.80, 2.69].	

*: Calculated by authors from primary data

$$: Results from different FIS levels combined by RE model

Excluded studies:

Shiue2016[15]	USA. NHANES 2003-2004.	4,924	HDL < 20 or > 85	AOR = 0.89 [0.61, 1.31]. Table 2.	Age, sex, education, ethnicity, family income.
Murillo2018[16]	Mexico. Women in fisheries communities.	116			
Vercammenn2019[17]	USA. NHANES 2007-2014.	13,518			
Weigel2019[18]	USA. El Paso, TX: 2015	75			

Shiue 2015 was not included in the meta-analysis due to overlapping data. For studies with overlapping subjects, such as those from NHANES, we chose the study with the highest number of subjects. The studies were still catalogued for their potential utility in subgroup analysis. The study by Murillo et al.[16] and Vercamenn et al.[17] were not added to the meta analyses due to lack of primary data to calculate either OR or Hedges g. The study by Weigel et al.[18] was not added due to inability to separate various lipid measurements.

Table 4. Adult studies (n = 7,096) with sufficient data to retrieve or calculate the standardized mean difference (Hedges'g) in HDL levels between food secure and food insecure patients

Study	Patients	Study Size	Results
Parker2010[19]	USA. NHANES 1999-2006. General population.	6,138	g = -0.01 [-0.07, 0.05] *,$$: Table 1.
Shariff2014[3]	Malaysia. Low-income Women.	293	g = -0.10 [-0.33, 0.13]. *: Table 2.
Atiqah2015[8]	Malaysia. General Population. Women.	109	g = 0.14 [-0.25, 0.53]. *: Table 3.
	Malaysia. General Population. Men.	15	g = -0.24 [-1.51, 1.03]. *: Table 3.
	Combined	124	g = 0.05 [-0.31, 0.40]. *: Table 3.
Weigel2016[9]	Ecuador. Low-income women.	269	g = -0.06 [-0.35, 0.23]. *:Table 4.
Faramarzi2019[20]	Iran. Azar cohort 2014-2017.	151	g = -0.30 [-0.91, 0.32]. *: Table 4.
Bermudez2019[11]	USA. Hartford. Hispanics with diabetes.	121	g = 0.23 [-0.15, 0.61]. *: Table 1.

*: Calculated by authors from the primary data
$$: FIS levels merged by means and pooled-SD

Excluded studies:

Dixon2001[1]	USA. NHANES 1988-1994. Adults.	6,475	Table 5.
	USA. NHANES 1988-1994. Seniors.	3,690	Table 5.
	Combined	10,165	

The study by Dixon et al. was not included in the Hedges g meta analysis due to inability to obtain standard deviation for all groups.

Table 5. Adult studies (n = 28,225) with sufficient data to retrieve or calculate the odds ratio for food insecurity and elevated total cholesterol

Study	Patients	Study Size	Criteria	Results	Covariates
Dixon2001[1]	USA. NHANES 1988-1994. Adults. General population.	6,475	TC >/= 6.21 mmol/L	AOR = 0.80 [0.42, 1.50]. Table 6.	Age, race, income, region of USA, smoking, alcohol.
	USA. NHANES 1988-1994. Seniors. General population.	3,690		AOR = 0.67 [0.33, 1.36]. Table 6.	
	Combined	10,165		AOR = 0.74 [0.46, 1.19].	
Weigel2007[13]	USA: El Paso, TX. 2003.	100	TC>200 mg/dL	AOR = 0.68 [0.32, 1.44] *,$$: Table 3.	Age, sex, education, US residence time, children living in household.
Tayie2009[2]	USA. NHANES 1999-2002. Women.	2,977	TC >/= 240 mg/dL	AOR = 1.02 [0.67, 1.57]. *,$$: Table 4.	Age, education, income, physical activity, race/ethnicity, smoking.
	USA. NHANES 1999-2002. Men.	2,572		AOR = 1.03 [0.70, 1.52]. *,$$: Table 4.	
	Combined	5,549		AOR = 1.03 [0.77, 1.37].	
Ford2013[7]	USA. NHANES 2003-2008. General population.	10,455	TC >/= 200 mg/dL or use of cholesterol -lowering meds	ARR = 1.01 [0.96, 1.07]. *,$$: Table 2.	Age, sex, race, educational status, health insurance, alcohol use.
Shariff2014[3]	Malaysia. Low-income women.	293	TC >/= 5.17 mmol/L	AOR = 0.84 [0.48, 1.49]. Table 4.	Adjusted for age, ethnicity, urban/rural strata, education, employment and income per capita.
Shin2015[14]	USA. Wisconsin. SHW 2008-2011. Men.	865	TC >/= 240 mg/dL	AOR = 0.95 [0.56, 1.62]. Table 4.	Age, race, education, smoking, alcohol, **BMI**.
	USA. Wisconsin. SHW 2008-2011. Women.	798		AOR = 0.57 [0.31, 1.02]. Table 4.	
	Combined	1,663		AOR = 0.75 [0.45, 1.24]	

*: Calculated by authors from primary data

$$: Results from different FIS levels combined by RE model

Excluded studies:

Shiue2016[15]	USA. NHANES 2003-2004.	4,924	TC < 140 or > 400	AOR = 1.26 [0.82, 1.93] Table 2	Age, sex, education, ethnicity,

For studies with overlapping subjects, such as those from NHANES, we chose the study with the highest amount of subjects. The studies were still catalogued for their potential utility in subgroup analysis.

Table 6. Adult studies (n = 1,614) with sufficient data to retrieve or calculate the standardized mean difference (Hedges'g) in total cholesterol levels between food secure and food insecure patients

Study	Patients	Study Size	Results
Holben2006[21]	USA Rural Ohio. Men.	285	g = -0.12 [-0.42, 0.17]. *: Table 5.
	USA Rural Ohio. Women.	522	g = -0.05 [-0.25, 0.14]. *: Table 5.
	Combined	807	g = -0.03 [-0.19, 0.14]. *: Table 5.
Shariff2014[3]	Malaysia. Low-income Women.	293	g = -0.23 [-0.46, 0.00]. *: Table 2.
Atiqah2015[8]	Malaysia. General Population. Women.	15	g = 0.06 [-0.33, 0.45]. * :Table 3.
	Malaysia. General Population. Men.	109	g = 0.14 [-1.13, 1.41]. *: Table 3.
	Combined	124	g = 0.09 [-0.26, 0.45]. *: Table 3.
Weigel2016[9]	Ecuador. Low-income women.	269	g = -0.14 [-0.43, 0.15]. *: Table 4.
Bermudez2019[11]	USA. Hartford. Hispanics with diabetes.	121	g = 0.58 [0.19, 0.97]. *: Table 1

*: Calculated by authors from the primary data

Excluded studies:

Dixon2001[1]	USA. NHANES 1988-1994. Adults.	6,475	Table 5.
	USA. NHANES 1988-1994. Seniors.	3,690	Table 5.
	Combined	10,165	

The study by Dixon et al. was not included in the Hedges g meta-analysis due to inability to obtain standard deviation for all groups.

Table 7. Adult studies (n = 16,107) with sufficient data to retrieve or calculate the odds ratio for food insecurity and elevated triglycerides

Study	Patients	Study Size	Criteria	Results	Covariates
Dixon2001[1]	USA. NHANES 1988-1994. Adults. General population.	6,475	TG>/= 2.26 mmol/L	AOR = 1.82 [0.80, 4.18]. Table 6.	Age, race, income, region of USA, smoking, alcohol.
	USA. NHANES 1988-1994. Seniors. General population.	3,690		AOR = 1.11 [0.19, 6.45]. Table 6.	
	Combined	10,165		AOR = 1.66 [0.79, 3.52].	
Weigel2007[13]	USA: El Paso, TX. 2003.	100	TG>150 mg/dL	AOR = 1.46 [0.74, 2.85]. *,$$: Table 3.	Age, sex, education, US residence time, children living in household.
Tayie2009[2]	USA. NHANES 1999-2002. Women.	2977	TG>= 150 mg/dL	AOR = 1.38 [0.88, 2.16]. *,$$: Table 4.	Age, education, income, physical activity, race/ethnicity, smoking
	USA. NHANES 1999-2002. Men.	2572		AOR = 0.76 [0.49, 1.18] *: *,$$: Table 4.	
	Combined	5,549		AOR = 1.02 [0.57, 1.83].	
Shariff2014[3]	Malaysia. Low-income women.	293	TG > 150 mg/dL	AOR = 0.72 [0.36, 1.45]. Table 4.	Adjusted for age, ethnicity, urban/rural strata, education, employment and income per capita.

*: Calculated by authors from primary data
$$: Results from different FIS levels combined by RE model

Table 8. Adult studies (n = 958) with sufficient data to retrieve or calculate the standardized mean difference (Hedges'g) in triglyceride levels between food secure and food insecure patients

Study	Patients	Study Size	Results
Shariff2014[3]	Malaysia. Low-income Women.	293	g = -0.20 [-0.43, 0.03]. *: Table 2.
Atiqah2015[8]	Malaysia. General Population. Women.	15	g = -0.28 [-0.67, 0.10]. *: Table 3.
	Malaysia. General Population. Men.	109	g = 0.35 [-0.92, 1.62]. *: Table 3.
	Combined	124	g = -0.16 [-0.52, 0.19]. *: Table 3.
Weigel2016[9]	Ecuador. Low-income women.	269	g = 0.25 [-0.04, 0.54]. *: Table 4.
Faramarzi2019[20]	Iran. Azar cohort 2014-2017	151	g = -0.16 [-0.77, 0.46]. *: Table 4.
Bermudez2019[11]	USA. Hartford. Hispanics with diabetes.	121	g = 0.37 [-0.02, 0.75]. *: Table 1.

Excluded studies:

Dixon2001[1]	USA. NHANES 1988-1994. Adults.	6,475	Table 5.
	USA. NHANES 1988-1994. Seniors.	3,690	Table 5.
	Combined	10,165	

The study by Dixon et al. was not included in the Hedges g meta-analysis due to inability to obtain standard deviation for all groups.

Parker2010[19]	USA. NHANES 1999-2006. General population.	6,138	Table 1

The study by Parker et al was not included due to a likely typo in Table 1 for the triglyceride levels. The values in the table [1.18 (1.1) mg/dL for food-secure and ≈ 120 (4.4) mg/dL for food insecure], and the t-test statistics in the text, are not compatible.

Table 9. Pediatric studies with sufficient data to retrieve or calculate the standardized mean difference (Hedges'g) in lipid levels between food secure and food insecure patients

Lipid	Study	Patients	Study Size	Results
LDL	Landry2018[22]	USA. Los Angeles, CA. Hispanics.	99	g = 0.16 [-0.24, 0.56]. *: Table3
HDL	Landry2018[22]	USA. Los Angeles, CA. Hispanics.	99	g = 0.22 [-0.18, 0.62]. *: Table3
	Parker2010[19]	USA. NHANES 1999-2006. General population.	3,126	g = -0.02 [-0.09, 0.06]. *,$$: Table 1
TC	Landry2018[22]	USA. Los Angeles, CA. Hispanics.	99	g = 0.29 [-0.12, 0.69]. *: Table3
TG	Landry2018[22]	USA. Los Angeles, CA. Hispanics.	99	g = 0.31 [-0.09, 0.72]. *,$$: Table1
	Parker2010[19]	USA. NHANES 1999-2006. General population.	3,126	g = 0.31 [-0.09, 0.72]. *: Table 3

*: Calculated by authors from primary data
$$: FIS levels combined by mean and pooled-SD

Excluded studies:

The study by Mahmoodi et al.[23] did not separate pediatric and adult data. The study by Lee et al.[24] contained overlapping NHANES data.

Table 10. Pediatric studies with sufficient data to retrieve or calculate the odds ratio for dyslipidemias between food secure and food insecure patients. There were not sufficient data to synthesize for a specific dyslipidemia (i.e. high LDL, or low HDL)

Lipids	Study	Patients	Study Size	Criteria	Results	Covariates
LDL	Tester2016[25]	USA. NHANES 2003-2010.	1,072	LDL > 110 mg/dL	AOR = 0.84 [0.58, 1.20]. *,$$: Table 3	Age, sex, race, marital status, education, adiposity.
HDL	Tester2016[25]	USA. NHANES 2003-2010. Females.	514	HDL < 40 mg/dL	AOR = 0.84 [0.58, 1.20]. *, $$: Table 3	Age, sex, race, marital status, education, adiposity.
		USA. NHANES 2003-2010. Males.	558		AOR = 0.88 [0.50, 1.54]. *,$$ Table 3	
		Combined	1,072		AOR = 0.85 [0.63, 1.16]	
	Holben2015[26]	USA. NHANES 1999-2006.	7,435	HDL < 40 mg/dL	AOR = 1.35 [1.15, 1.58.] *,$$: Table 3	Age, race/ethnicity, sex.
TC	Tester2016[25]	USA. NHANES 2003-2010. Females.	1,072	TC > 170 mg/dL	AOR = 0.79 [0.59, 1.06]. *,$$: Table 3	Age, sex, race, marital status, education, adiposity.
TG	Tester2016[25]	USA. NHANES 2003-2010.	1,072	TG > 90 mg/dL	AOR = 1.50 [1.11, 2.04]. *,$$: Table 3	Age, sex, race, marital status, education, adiposity.
	Holben2015[26]	USA. NHANES 1999-2006.	7,435	TG > 150 mg/dL	AOR = 1.33 [0.98, 1.80]. *,$$: Table 3	Age, race/ethnicity, sex.

*: Calculated by authors from primary data
$$: FIS levels combined by RE model
#: Combined by RE model

Table 11. Adult studies with self-reported or chart review methodology

Study	Patients	Methodology	Study Size
Gibson 2019[27]	Adults with diabetes.	Self-reported	3433
Sattler 2014[28]	GA senior adults w D2M.	Self-reported	243
Stuff2008[29]	Mississippi Adults.	Self-reported	1457
Fernandes2018[30]	Portugal Seniors > 65 yrs old.	Self-reported	1,885
Mendy2018[31]	Mississippi Adults.	Self-reported	5870
Bahadur2018[32]	USA. New Jersey. Children	Chart review	486

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