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Food insecurity and depression among low-income adults in the USA: does diet diversity play a role? Findings from the 2013–2014 National Health and Nutrition Examination Survey

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Abstract

Objective: Food insecurity is associated with a greater risk of depression among low-income adults in the USA. Members of food-insecure households have lower diet diversity than their food-secure counterparts. This study examined whether diet diversity moderates the association between food insecurity and depression.
Design: Multiple logistic regression was conducted to examine independent associations between food insecurity and depression, between diet diversity and depression, and the moderating effect of diet diversity in the food insecurity–depression link.
Setting: Cross-sectional data from the National Health and Nutrition Examination Survey (2013–2014).
Participants: 2636 low-income adults aged 18 years and older.
Results: There was a positive association between food insecurity and depression among low-income adults. Diet diversity was not associated with depression. Diet diversity had a moderating effect on the association between food insecurity and depression among low-income adults.
Conclusions: Food insecurity is independently associated with depression among low-income adults in the USA. However, this association differs across levels of diet diversity. Longitudinal studies are needed to confirm the role diet diversity may play in the pathway between food insecurity and depression.

Keywords
Food insecurity
Diet diversity
Depression
National Health and Nutrition Examination Survey
Adults
Low income
United States

Food insecurity is associated with adverse outcomes for the psychological and somatic health of adults and children across the world[1–5]. Food insecurity is associated with a wide range of chronic diseases influenced by diet, including hypertension, diabetes and hyperlipidaemia[6,7].

Poor diet quality found in food insecurity has a well-established relationship with depression[5,8–10]. Although the association between food insecurity and depression is well documented[5,8,11–18], the mechanisms of this association are not well understood[19]. A meta-analysis by Li and colleagues reports that high consumption of processed and refined foods and low intake of fruits and vegetables are associated with an increased risk of depression[20].

Diet diversity, as defined by Vadiveloo and colleagues' Healthy Food Diversity Index, includes dietary variety, quality and proportionality (i.e. distribution of food groups in the diet)[21]. Diet diversity is positively associated with improved nutritional intake in adults and children[22,23] and negatively associated with obesity and fat mass in adults[24], although previous research is limited to low-to-middle-income countries[23,25–27]. Members of food-insecure households often skip meals, reduce energetic intake, avoid food waste and make cost/satiety trade-offs to address inadequate food supply[28–30]. These compensatory strategies negatively impact diet diversity. Research has shown that individuals who are food-insecure have lower diet quality and diet diversity than their food-secure counterparts[31–33] and tend to have a suboptimal intake of micronutrients[29,34–38].

The relationship between diet quality and depression has been primarily limited to analysing Healthy Eating Index (HEI) scores[39] and dietary patterns[40]. The HEI is a tool for measuring diet quality as it relates to the

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Dietary Guidelines for Americans (DGA)[41,42]. HEI scores have been associated with depression incidence and severity of depressive symptoms[17,43], but HEI scores do not account for the proportions of types of foods consumed or diet variety beyond the thirteen DGA food groups[44]. Dietary pattern analysis examines the overall combinations of foods consumed and groups the patterns into recognised categories[45]. Dietary patterns have been associated with depression risk[46], but dietary pattern analyses are limited to explicitly defined diets, such as the Mediterranean or Western diets[19,20]. This study uses the Healthy Food Diversity Index (US HFD), which goes beyond the HEI's measure of diet quality; it provides scoring on diet diversity across twenty-six food groups and incorporates proportions of the food categories consumed[21].

Conceptual framework

Defining Diet Diversity

Several authors have called for new healthy diet diversity indices[25,47–50] as existing indicators do not consider measures of dietary quality and proportionality in their assessments. Consequently, Vadiveloo and colleagues developed the US HFD index that considers three key aspects of a varied diet simultaneously, namely, dietary variety, quality and proportionality of foods[51]. To construct the US HFD index, the authors adapted the validated German HFD index to the 2010 DGA[52]. The German HFD is a modification of the Berry Index, a measure used in economic studies to assess diversity in terms of the number and distribution of different food items[53]. The German HFD adapted the Berry Index so that the highest index value corresponds to individuals consuming the recommended food group shares. The index increases if the distribution of foods moves in favour of healthier foods and reflects the health value of consumed foods. The US HFD index incorporates weights which capture proportionality by penalising consumption of a single high-quality food group or equal consumption of all food groups. This ensures that neither a high health value nor a high Berry Index can independently generate a high US HFD index. The US HFD scores increase by consuming a higher proportion of foods from more healthful food groups, whereas scores decrease when less healthful food groups are consumed in higher proportions. From a public health standpoint, this scoring method brings about a wider assortment of healthy foods which promotes a diverse diet favourably associated with good health[24,54,55].

The role of diet diversity in the food insecurity–depression link

Associations between household food insecurity and depression are well established; however, there is less literature regarding the mechanisms by which food insecurity affects depression. To help fill this gap, two potential mechanisms were considered: First, food insecurity could have an adverse impact on depression through a direct effect of nutritional shortfalls[56–58]. For example, in an experimental study of 1081 healthy men, Heseker and colleagues found that reduced intake of vitamins over 2 months was associated with increased feelings of fear, irritability, nervousness, depression, decreased memory and well-being. These adverse symptoms were reversed as soon as the participants resumed vitamin intake[59]. However, this direct effect could be *mediated* by diet diversity. In their study on 330 multi-ethnic, low-income women, Dressler and Smith (2015) found that food-insecure women had a higher energetic intake and consumed more servings of discretionary foods, such as fat and sugar, which appeared to be partially mediated through the increased emotional eating among depressed participants[37]. This approach suggests that some of the mechanisms by which food insecurity adversely affects mental health outcomes are indirect. Food-insecure adults may consume more highly palatable but poorer quality foods, leading to poorer diet diversity and increased risks of depression. However, this approach would suppose a chronicity of effects that would need to be captured over time.

Another potential mechanism is that diet diversity could have a potential *moderating* effect in the association between food insecurity and depression. Vadiveloo proposed the Adapted Sensory-Specific Satiety model of eating behaviour, which postulates that diet diversity is driven by a greater satisfaction associated with consuming a variety of food items rather than consuming a single food item. This model is supported by research that has shown that diet diversity promotes enjoyment and satisfaction[38,60]. In contrast, a less diverse diet may decrease satisfaction and affect depression. In terms of a moderating effect, our goal was to examine the association between food insecurity and depression at differing levels of diet diversity.

Research objectives

The purpose of this study was to understand the role of diet diversity in the association between food insecurity and depression among low-income adults in the USA. The three specific aims of the study were to: examine the association between food insecurity and depression; examine the association between diet diversity and depression; and examine whether diet diversity moderates the association between food insecurity and depression.

Figure 1 details the conceptual framework with relationships among food insecurity (independent variable), diet diversity (moderating variable) and depression (dependent variable) in low-income adults. Our hypotheses are: first, there is a positive association between food insecurity and depression; second, there is a positive association between a lack of diet diversity and depression; third, there is a moderating effect of a lack of diet diversity in the association between food insecurity and depression.

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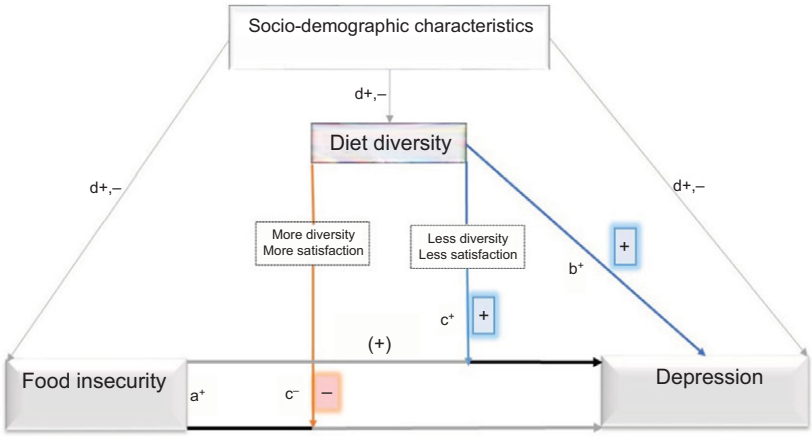

Hypotheses:

Main independent effects: a^+ Food insecurity is positively associated with depression. b^+ a lack of diet diversity is positively associated with depression.

Moderation effects: c^+ A lack of diet diversity exerts a reinforcing effect on the link food insecurity-depression.
c^- More diet diversity exerts an inhibiting effect on the link food insecurity-depression.

Confounding effects: Sex, age, race/ethnicity, body mass index (BMI), marital status, citizenship status, education attainment, household income, employment status, homeownership, and Vitamin D are negatively/positively ($d^{+,-}$) associated with food insecurity, diet diversity, and depression.

Fig. 1 (colour online) Proposed association between food insecurity, diet diversity and depression. (–) Inhibiting effect; (+) reinforcing effect

Materials and methods

Data source

National Health and Nutrition Examination Survey

This study used data from the 2013–2014 National Health and Nutrition Examination Survey (NHANES), the most recent version of NHANES that gathered data on food security at the time this study was conducted. The survey is conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention. The NHANES is a nationally representative, population-based survey that assesses the health and nutritional status of adults and children in the USA. NHANES dietary data are used to describe the intake of foods, nutrients, food groups and dietary patterns by the US population. The nutritional assessment component of the NHANES includes a 24-h dietary recall interview of participants of all ages. A second dietary interview of all participants who complete the in-person recall was collected by telephone and is scheduled 3–10 d later[61].

Food Patterns Equivalents Database

The NHANES analytic file was combined with the 2013–2014 Food Patterns Equivalents Database. The Food Patterns Equivalents Database, created by the US Department of Agriculture, translates individual food files from the 2013–2014 NHANES dietary data into their equivalent food group amounts. Foods in the NHANES food files are converted into cup equivalents of fruit, vegetables and dairy; ounce equivalents of grains and protein foods; teaspoon equivalents of added sugars and gram equivalents of solid fats and oils[62].

Study population

For the 2013–2014 survey, the National Center for Health Statistics included 10 175 individuals (unweighted response rate of 71 %) using a multistage, area cluster design with differential selection probabilities for designated demographic groups[63].

The analytic sample for the present study was constructed using combined data from the NHANES demographics, dietary, examination, laboratory and questionnaire files. We restricted our analysis to a sample of adults from households where there was a reasonable chance of having high food insecurity. We selected individuals below 300 % of the Federal poverty line (FPL) to obtain a sufficient sample size and variation in food insecurity status as applied in other research[64]. Furthermore, we wanted to focus on lower-income adults as they are the most-at-risk group to experience food insecurity[65] and depression[33,66] and determine whether diet diversity would mitigate the influence of food insecurity on depression in this high-risk group; respondents over 18 years of age, with energy intakes ≥400–<7000 kcal/d and 2 days of dietary recall data were included[21], and pregnant and lactating women were not considered because their nutrient needs differ from those of non-pregnant and non-lactating women[18,67]. The final analytic sample included 2636 adults, representing noninstitutionalised low-income civilian adults aged 18 years and older residing in the fifty states and the District of Columbia. Because we selected participants with completed 2-d dietary recall data, we applied sampling weights that adjust for nonresponse to the dietary component and incorporated the day of the week of recall.

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Additional details of NHANES sampling design and interviewing procedures are described elsewhere[61,68,69].

Measures

The measures used to characterise participants are shown in Table 1.

Depression

Depression was the dependent variable. The NHANES used the Patient Health Questionnaire-9 (PHQ-9)[70,71], a self-reported nine-item screening instrument, to determine the frequency of depression symptoms (i.e. sadness, trouble sleeping, fatigue, problems concentrating) over the past 2 weeks among participants. The PHQ-9 is a well-validated instrument with moderate concordance with clinical psychiatric interviews[70,72]. Each item was assessed on a four-point Likert scale ranging from 0 'Not at all' to 3 'Nearly every day.' Before summing the PHQ-9 items, we conducted a factor analysis to assess the unidimensionality of the items and computed a scale reliability coefficient to assess their internal consistency. Cronbach's alpha ($\alpha = 0{\cdot}99$) indicated very high internal consistency. We dichotomised the summative 0–27 quasi-interval scale into a binary indicator with 0 = PHQ-9 score < 10 or 1 = PHQ-9 score ≥ 10 (elevated depressive symptoms), as applied in other research[70].

Food insecurity

Food insecurity status was the primary independent variable. An adult in the NHANES-sampled household was administered the ten-item food security instrument. A food security score (0–10) was created to represent the number of affirmative responses to the food security items. Following procedures used by CDC and US Department of Agriculture, answers of 'Often true', 'Sometimes true' and 'Yes' were considered affirmative responses to being food-insecure. Responses to items 5 and 10 regarding the frequency of occurrence in the past 30 d were considered affirmative to being food-insecure if the respondent's answer was ≥3 d[73].

Diet diversity

In the study, diet diversity was analysed as an independent and as a moderating variable. Diet diversity was measured with Vadiveloo *et al.*'s (2014) US HFD[21,24]. This index captures dietary variety (number of foods), quality (concordance with the 2010 DGA) and proportionality (distribution of food groups in the diet). The index ranges between 0 (a diet with a single food) and nearly 1 (a diet with many types of food). To generate the US HFD, Vadiveloo *et al.* used the following equation:

$$\text{US HFD} = \left(1 - \sum s_i^2\right) \times hv$$

where s_i is the share or proportion of each individual food or food group i based on the volume of the total diet.

$$hv = \sum hf_i \times s_i$$

where hf_i are 'health factors', or weights, developed by Vadiveloo *et al.* for each food group using qualitative and quantitative recommendations for daily food group intakes based on the 2000-kcal US Department of Agriculture Food Pattern in the 2010 DGA (See Vadiveloo *et al.*, 2014, Table 1, p.1565[21]). Health values were obtained by multiplying the reported share by the volume of each food by its respective health factors and summing them to capture diet quality and proportionality. The methodology to build the US HFD is detailed elsewhere[21].

Because the focus of the study is on a *lack* of diet diversity, we reversed the obtained diet diversity score (1-US HFD) so that a higher score indicates less diet diversity.

Covariates

From previous studies, we included several covariates that could confound the association between food insecurity and depression: sex, age, race/ethnicity, BMI, marital status, citizenship status, education attainment, household income, employment status, homeownership and serum vitamin D[7,14,33,74–76].

Statistical analysis

Descriptive analysis

Stata/se 16[77] *svy* procedures were used to estimate parameters and adjust for NHANES complex stratified multistage-area-probability sampling. Rather than excluding participants, we created a study subpopulation for the estimation. STATA/se 16 has features for design-based analysis of subpopulation analysis for complex sample survey data[78]. Since 2013–2014 NHANES and 2013–2014 Food Patterns Equivalents Database are public and de-identified files, the University of Arkansas for Medical Science's IRB exempted the study.

We did not detect any multicollinearity among the independent variables in our study (all variance inflator factors were < 1·50, with an overall variance inflator factor mean of 1·20).

We computed weighted percentages for all categorical socio-demographic and health variables across levels of food insecurity and depression. The Rao–Scott χ^2 test of independence, which adjusts for sampling design, was used to determine statistically significant unadjusted associations[79]. For the variable lack of diet diversity (1-US HFD), we computed weighted means. The *t* test was used to determine statistically significant differences in lack of diet diversity means across socio-demographic and health measures. We further computed weighted means over 2 d of each food group across levels of food insecurity and depression (see Supplemental materials).

Regression analysis

We conducted logistic regression to determine the association between food insecurity and lack of diet diversity (main independent effects) on depression. In model 1,

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Table 1 Describing depression, food insecurity and lack of diet diversity among low-income adults in the USA

		Weighted percentages					Weighted percentages					Weighted means		
		Non-depressed (PHQ-9 < 10)*		Depressed (PHQ-9 ≥ 10)			Food secure (Score 0–2)		Food insecure (Score 3–10)			Lack of diet diversity† (1-US HFD)		
	Unweighted sample sizes‡	%	95 % CI	%	95 % CI	Statistical significance§	%	95 % CI	%	95 % CI	Statistical significance§	Mean	SE	Statistical significance§
	Total *n* 2636‖	88·2	86·2, 89·9	11·8	10·1, 13·8		73·5	69·1, 77·4	26·5	22·6, 30·9		0·673	0 003	
Mean age: 18–80 years¶	2636					*t*-statistic = –3·66; *P* = 0·002					*t*-statistic = 6·49; *P* < 0·001	44·9		*t*-statistic = –2·43; *P* = 0·028
Mean		44·3		50·1			46·3		41·3					
SE		0·80		1·33			0·68		0·85					
Sex						$F_{(1,15)} = 11·80$; *P* = 0·004					$F_{(1,\ 15)} = 1·93$; *P* = 0·185			*t*-statistic = 2·42; *P* = 0·028
Males	1193	90·8	87·9, 93·0		7·0, 12·1		75·8	69·5, 81·1	24·2	18·9, 30·5		0·678	0·003	
Females	1443	85·9	83·6, 87·9	14·1	12·1, 16·4		71·4	66·3, 76·0	28·6	24·0, 33·7		0·668	0·003	
Race/ethnicity						$F_{(3·35,50·31)} = 3·69$; *P* = 0·015					$F_{(3·49,52·40)} = 3·01$; *P* = 0·031			*t*-statistic = 3·39; *P* = 0·004
Mexican American	438	92·5	90·2, 94·3	7·5	5·7, 9·8		64·4	55·5, 72·3	35·6	27·7, 44·5		0·669	0·003	
Other Hispanic	267	87·3	81·2, 91·6	12·7	8·4, 18·8		66·1	54·6, 75·9	33·9	24·1, 45·4		0·672	0·008	
Non-Hispanic White	1088	87·1	84·1, 89·7	12·9	10·3, 15·9		76·3	69·6, 82·0	23·7	18·0, 30·4		0·667	0·004	
Non-Hispanic Black	595	88·9	86·3, 91·0	11·1	9·0, 13·7		72·4	66·5, 77·6	27·6	22·4, 33·5		0·695	0·003	
Non-Hispanic Asian	158	95·6	86·9, 98·6	4·4	1·4, 13·1		87·3	73·7, 94·3	12·7	5·7, 26·3		0·686	0·004	
Other Race – including multi-racial	158	79·9	65·2, 89·4	20·1	10·6, 34·8		68·4	52·3, 81·0	31·6	19·0, 47·7		0·669	0·009	
BMI						$F_{(3·16,47·42)} = 5·45$; *P* = 0·002					$F_{(3·44,\ 51·58)} = 2·64$; *P* = 0·050			*t*-statistic = 1·68; *P* = 0·114
Underweight (BMI < 18·5 kg/m^2)	56	93·2	81·3, 97·7	6·8	2·3, 18·7		73·9	54·7, 86·9	26·1	13·1, 45·3		0·649	0·014	
Healthy weight (BMI 18·5 ≤ 24·9 kg/m^2)	692	89·9	86·3, 92·7	10·1	7·3, 13·7		72·0	65·3, 77·8	28·0	22·2, 34·7		0·674	0·004	
Overweight (BMI 25·0 ≤ 29·9 kg/m^2)	778	92·0	88·1, 94·8	8·0	5·2, 11·9		77·9	71·8, 82·9	22·1	17·1, 28·2		0·666	0·002	
Obese (BMI 30·0 ≤ 34·9 kg/m^2)	541	83·2	78·8, 86·9	16·8	13·1, 21·2		74·8	68·5, 80·2	25·2	19·8, 31·5		0·678	0·005	
Obese class 2,3 (BMI ≥ 35·0 kg/m^2)	559	84·9	80·5, 88·5	15·1	11·5, 19·5		67·6	60·5, 74·0	32·4	26·0, 39·5		0·677	0·003	
Marital status						$F_{(1,15)} = 1·76$; *P* = 0·205					$F_{(1,\ 15)} = 3·47$; *P* = 0·082			*t*-statistic = 0·70; *P* = 0·496
Married/partnership	1257	89·3	85·4, 92·2	10·7	7·8, 14·6		75·6	69·3, 81·0	24·4	19·0, 30·7		0·671	0·002	
Other	1186	86·0	82·5, 88·8	14·0	11·2, 17·5		70·8	67·6, 73·8	29·2	26·2, 32·4		0·674	0·004	
Citizenship status						$F_{(1,15)} = 16·58$; *P* = 0·001					$F_{(1,\ 15)} = 0·89$; *P* = 0·359			*t*-statistic = –0·16; *P* = 0·878
Citizen by birth or naturalisation	2280	87·5	85·3, 89·3	12·5	10·7, 14·7		74·1	68·8, 78·7	25·9	21·3, 31·2		0·673	0·003	
Not a citizen of the USA	351	94·3	91·5, 96·2	5·7	3·8, 8·5		68·4	57·2, 77·8	31·6	22·2, 42·8		0·674	0·006	

Table 1 *Continued*

		Weighted percentages					Weighted percentages					Weighted means		
		Non-depressed (PHQ-9 < 10)*		Depressed (PHQ-9 ≥ 10)			Food secure (Score 0–2)		Food insecure (Score 3–10)			Lack of diet diversity† (1-US HFD)		
	Unweighted sample sizes‡	%	95 % CI	%	95 % CI	Statistical significance§	%	95 % CI	%	95 % CI	Statistical significance§	Mean	SE	Statistical significance§
Education**						$F_{(1·68,25·15)} = 1·27$; $P = 0·294$					$F_{(1·80,\ 27·05)} = 4·86$; $P = 0·018$			*t*-statistic = –1·75; $P = 0·101$
Less than HS/GED	663	85·4	79·9, 89·6	14·6	10·4, 20·1		64·4	55·7, 72·1	35·6	27·9, 44·3		0·677	0·005	
HS/GED	682	87·1	82·9, 90·3	12·9	9·7, 17·1		74·6	67·5, 80·5	25·4	19·5, 32·5		0·679	0·004	
More than HS/GED	1096	89·0	86·3, 91·3	11·0	8·7, 13·7		76·5	71·8, 80·6	23·5	19·4, 28·2		0·667	0·004	
Household income						$F_{(1,15)} = 4·09$; $P = 0·061$					$F_{(1,\ 15)} = 8·23$; $P = 0·012$			*t*-statistic = 0·21; $P = 0·838$
<$20 000 year	804	85·6	82·5, 88·2	14·4	11·8, 17·5		65·5	61·6, 69·2	34·5	30·8, 38·4		0·672	0·004	
$20 000 or more year	1767	89·2	86·6, 91·3	10·8	8·7, 13·4		76·1	69·5, 81·5	23·9	18·5, 30·5		0·673	0·003	
Employment status						$F_{(1,15)} = 29·52$; $P < 0·001$					$F_{(1,\ 15)} = 0·28$; $P = 0·605$			*t*-statistic = –0·32; $P = 0·752$
Working at a job or business/with a job or business but not at work	1229	93·8	90·8, 95·8	6·2	4·2, 9·2		74·6	68·7, 79·7	25·4	20·3, 31·3		0·673	0·003	
Looking for work/not working at a job or business	1403	81·9	79·0, 84·5	18·1	15·5, 21·0		72·3	64·9, 78·7	27·7	21·3, 35·1		0·672	0·004	
Homeownership						$F_{(1,15)} = 0·78$; $P = 0·392$					$F_{(1,15)} = 38·55$; $P < 0·001$			*t*-statistic = 0·18; $P = 0·862$
Rented other arrangement	1318	88·9	86·7, 90·8	11·1	9·2, 13·3		62·9	56·8, 68·6	37·1	31·4, 43·2		0·672	0·004	
Owned or being bought	1315	87·6	84·5, 90·1	12·4	9·9, 15·5		83·5	77·6, 88·0	16·5	12·0, 22·4		0·673	0·004	
Nutritional status of participants														
Vitamin D††						$F_{(1·55,23·18)} = 0·95$; $P = 0·380$					$F_{(1·85,\ 27·81)} = 9·15$; $P = 0·001$			*t*-statistic = –4·41; $P = 0·001$
25OHD2 + 25OHD3 < 50 nmol/l (VDD)	890	90·0	87·5, 92·1	10·0	7·9, 12·5		67·2	62·0, 72·0	32·8	28·0, 38·0		0·682	0·003	
25OHD2 + 25OHD3 ≥ 50 and <75 nmol/l (VDI)	969	86·8	83·8, 89·3	13·2	10·7, 16·2		73·4	67·9, 78·2	26·6	21·8, 32·1		0·671	0·004	
25OHD2 + 25OHD3 ≥ 75 nmol/l	777	88·1	82·5, 92·0	11·9	8·0, 17·5		79·7	73·2, 85·0	20·3	15·0, 26·8		0·665	0·003	

*Patient Health Questionnaire (PHQ-9).
†Lack of diet diversity ranges from 0·510 (more diversity) to (0·985) less diversity. It was calculated as 1-USHFS. Significance for US HFD (not shown here) are the same as those of the reversed scores (1-US HFD) presented in Table 1.
‡Cell sample sizes are not weighted. Estimates (percentages and means) are weighted. Thus, the weighted estimates would not correspond to the underweight '*n*' in the cells. Estimates do not account for missing data.
§Statistically significant unadjusted associations between categorical variables (e.g. sex and education) and depression or food insecurity were determined with the Rao–Chi-Square test of independence. Associations between continuous variables (continuous age) and depression or food diversity were determined with *t* test statistic.
‖The analytic unweighted sample size *n* 2636 represents non-pregnant, non-lactating, low income (≤300 % Federal Poverty level) adults noninstitutionalised civilian adults who have completed 2 d of dietary recall (weighted population *N* 112 328 599).
¶Respondents aged greater than 80 years are set with an age of 80 years in NHANES data for confidentiality reasons.
**HS/GED: High school/General Education Development.
††Vitamin D Serum 25-hydroxyvitamin D(25(OH)D) (25OHD2 + 25OHD3) using thresholds recommended by the Endocrine Society[102] as vitamin D deficiency (VDD) defined as 25(OH)D < 50 nmol/l and vitamin D insufficiency (VDI) as 50 ≤ 25(OH)D < 75nmol/l.

depression was regressed on food insecurity. In model 2, depression was regressed on lack of diet diversity (1-US HFD). In model 3, depression was regressed on both independent variables controlling for all potential confounders. Unadjusted and adjusted associations were presented as OR, with corresponding standard errors (SE). We computed the Archer–Lemeshow global goodness-of-fit test statistic – which takes the survey sampling design into account – to examine the adequacy of the logistic models[80].

To assess moderation, model 4 included all variables in model 3 and an interactive product term between food security and diet diversity. However, the interpretation of interaction terms in nonlinear models is challenging: in a logit model without interaction, the interpretation of a coefficient is the natural logarithm of the OR. The coefficient of the interaction terms is thus the natural logarithm of the ratio of two OR[81]. Furthermore, the sign of this coefficient is also not easily interpretable: when the focal and the moderator variables are both measured on a continuous scale, the marginal effect of one variable on the conditional probability that the outcome = 1 can have a positive or negative sign over the range of the other variable. A significant interaction would indicate that the effect of the food security is not the same for different values of diet diversity, but neither the value nor the sign of the estimates for the main effects and interaction terms would give clear information about the nature of the interactions. Hence, marginal effects were computed and then plotted to probe the interaction effect of food security and diet diversity on the predicted probability of depression[82].

Complete case analysis was conducted for all models, and statistical significance was set at a two-tailed alpha level of 0·05.

Results

Describing the relation between socio-demographic factors and food insecurity

Table 1 describes the study population of adults living in households with income <300 % FPL by socio-demographic characteristics as well as unadjusted associations.

On a range of 0–10, the mean food insecurity score was 1·55 (SE 0·09). Food-insecure adults were on average younger than non-food-insecure adults (mean age 41 years *v.* 46 years, $t = 6{\cdot}49$; $P < 0{\cdot}001$). Significant differences were seen across race/ethnicity groups ($F_{(3{\cdot}49,52{\cdot}40)} = 3{\cdot}01$; $P < 0{\cdot}001$). Mexican Americans and other Hispanic adults had a high prevalence of food insecurity (35·6 and 33·9 %), whereas Asians had a low prevalence of food insecurity (12·7 %). Significant differences were found by BMI categories ($F_{(3{\cdot}44,51{\cdot}58)} = 2{\cdot}64$; $P = 0{\cdot}05$): about a third of very obese people (32·4 %) were food-insecure compared with 28·0 % of healthy weight adults. Food insecurity was also significantly negatively associated with socio-economic characteristics – education ($F_{(1{\cdot}80,27{\cdot}05)} = 4{\cdot}86$; $P = 0{\cdot}018$); household income ($F_{(1,15)} = 8{\cdot}23$; $P = 0{\cdot}012$) and homeownership ($P < 0{\cdot}001$) – none of which was associated with depression. Although the level of vitamin D was not significantly associated with depression in our study population, we did find a significant association between vitamin D level and food insecurity ($F_{(1{\cdot}85,27{\cdot}81)} = 9{\cdot}15$; $P < 0{\cdot}001$). A third of adults with deficient levels of vitamin D (25OHD2 + 25OHD3 < 50 nmol/l) were food-insecure.

Describing the relation between socio-demographic factors and depression

Overall, 11·8 % of adults living in households <300 % of the FPL were considered depressed (i.e. PHQ ≥ 10). Depressed adults were, on average, older than non-depressed adults (mean age 50 years *v.* 44 years; $t = -3{\cdot}66$; $P = 0{\cdot}002$). A higher proportion of women were depressed than men (14·1 % *v.* 9·2 %; $F_{(1,15)} = 11.80$; $P = 0{\cdot}004$). Significant differences were seen across race/ethnicity groups ($F_{(3{\cdot}35,50{\cdot}31)} = 3{\cdot}69$; $P = 0{\cdot}015$). Mexican Americans and Asians had a low prevalence of depression (7·5 and 4·4 %, respectively), and adults of other/multiple races had a high prevalence of depression (20·1 %). Significant disparities in depressive symptoms were found across levels of BMI ($F_{(3{\cdot}16,47{\cdot}42)} = 5{\cdot}45$; $P = 0{\cdot}002$). The prevalence of depression was higher among citizen adults than non-citizens (12·5 % *v.* 5·7 %, $F_{(1,15)} = 16{\cdot}58$; $P = 0{\cdot}001$). The prevalence of depression was also lower among employed individuals than non-employed ones (6·2 % *v.* 18·1 %, $F_{(1,15)} = 29{\cdot}52$; $P < 0{\cdot}001$). No significant associations were seen for marital status, education, household income, homeownership or level of vitamin D ($P > 0{\cdot}05$).

Describing the relation between socio-demographic factors and lack of diet diversity

For the overall US HFD, we found a weighted mean of 0·33 (SE 0·003) over the 2-d recall period. Inversely, lack of diet diversity (1-US HFD) had a mean of 0·67 (SE 0·002) and ranged from 0·510 (more diversity) to 0·985 (less diversity). The difference between the US HFD mean for low-income adults with depression *v.* those without depression was not statistically significant (mean 0·67 (SE 0·002) *v.* mean 0·67 (SE 0·006); $t = -0{\cdot}03$, $P = 0{\cdot}975$).

Four factors were associated with a lack of diet diversity: age (inverse association, $P = 0{\cdot}028$); sex (females had more diverse diets than males: mean 0·0668 *v.* 0·678, $t = -2{\cdot}43$; $P = 0{\cdot}028$); race/ethnicity ($t = 3{\cdot}39$; $P = 0{\cdot}004$) with non-Hispanic Blacks having the least diverse diet and vitamin D level ($t = -4{\cdot}41$; $P = 0{\cdot}001$) with adults with deficient level 25OHD2 + 25OHD3 < 50 nmol/l having the highest score in lack of diet diversity. See Table 1.

Explaining the relation between food insecurity, lack of diet diversity and depression

The logistic regression (model 1) showed that food insecurity was positively associated with depression (OR 1·10, SE 0·03; $P = 0{\cdot}002$). For the association between lack of diet diversity and depression (model 2), the association was

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Table 2 Association between food insecurity, lack of diet diversity and depression among low-income adults in the USA: odds ratios (OR) and standard errors (SE)

	Model 1			Model 2			Model 3		
	Simple logistic regression unadjusted associations		*P*-values	Simple logistic regression unadjusted associations		*P*-values	Multiple logistic regression adjusted associations		*P*-values
Food Security (scores 0–10)	1·10	0·03	0·002				1·10	0·04	0·007
Lack of diet diversity	–			1·05	1·61	0·975	1·08	1·66	0·961
Archer–Lemeshow (*F*-adjusted statistic)	F-adjusted test statistic: $F_{(3,13)} = 6{\cdot}280$; $P = 0{\cdot}007$			F-adjusted test statistic: $F_{(9,7)} = 6{\cdot}749$; $P = 0{\cdot}010$			F-adjusted test statistic: $F_{(9,7)} = 1{\cdot}862$; $P = 0{\cdot}212$		

Model 3 is adjusted for sex, age, race/ethnicity, BMI, marital status, citizenship status, education attainment, household income, employment status, homeownership and vitamin D. Model 4 is not shown here. Archer–Lemeshow (F-adjusted statistic): Goodness-of-fit test for logistic regression model fitted using survey data. It tests the null hypothesis that the fitted model is correct. Higher values of *P*-values indicate a better fit.
Sources: Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). 2013–2014-National Health and Nutrition Examination Survey Data. Hyattsville, MD: US Department of Health and Human Services, Centers for Disease Control and Prevention. FPED: 2013–2014 Food Patterns Equivalents Database. US Department of Agriculture.

not significant (OR 1·05, SE 1·61; $P = 0{\cdot}975$). The Archer–Lemeshow goodness-of-fit test[80] indicated that the data did not fit these two simple models well: model 1: ($F_{(3,13)} = 6{\cdot}280$; $P = 0{\cdot}007$) and model 2 ($F_{(9,7)} = 0{\cdot}010$). In model 3 – in which depression was regressed on food insecurity and lack of diet diversity adjusting for confounders – multiple logistic regression showed that food insecurity was still positively and independently associated with depression (OR 1·10, SE 0·04; $P = 0{\cdot}007$). Lack of diet diversity was not associated with depression (OR 1·08, SE 1·66; $P = 0{\cdot}961$). The Archer–Lemeshow suggested no evidence of lack of fit ($F_{(9,7)} = 1{\cdot}862$; $P = 0{\cdot}212$) (Table 2).

The potential moderating effect of a lack of diet diversity was examined by including a product term (food insecurity × lack of diet diversity) (model 4). Since the estimate for interaction was significant at the 0·05 alpha level, and the Archer–Lemeshow (F-adjusted statistic) showed that model 4 provided the best fit of fitted models ($F_{(9,7)} = 0{\cdot}887$; $P = 0{\cdot}577$), we plotted the marginal effects of the interaction of food security and diet diversity to interpret the moderation effect in a meaningful way[83]. As shown in Fig. 2, at the intersection of a food security score of 2, the predicted probability of depression increases for all levels of diet diversity, but at differing gradient levels. For adults with the lowest level of diet diversity, the probability of depression increased more rapidly than for those who consume a more diverse diet.

Discussion

This study examined the association between food insecurity and depression; the association between a lack of diet diversity and depression; and the moderating effect of diet diversity in the association between food insecurity and depression among low-income adults in the USA in order to identify the mechanism through which food insecurity relates to depression.

This study found that 11·8 % of adults below 300 % of the poverty line were depressed and 26·6 % were food-insecure. After confounding risk factors were controlled for, food-insecure adults were twice as likely to report being depressed, compared with food-secure adults. This relation is consistent with previous analyses that have found associations between depression and food insecurity in adults[10,84,85], especially among adults in low-income households[67,86–92].

The mean US HFD score was 0·33 (SE 0·003), a mean score very similar to what Vadiveloo *et al.* (2014) found with analysis of 2003–2006 NHANES data and MyPyramid equivalents (mean 0·34 (SE 0·002))[21]. We did not find a significant association between a lack of diet diversity and depression in both unadjusted and adjusted models. This non-significance is contrary to our hypothesis, and contrary to a meta-analysis of twenty-one studies from ten countries that suggested a healthy diet pattern may decrease the risk of depression[20], and a systematic review and meta-analysis of observational studies using an array of dietary measures[93]. However, the primary focus of the study was on examining the mechanisms by which food security influences depression among low-income adults, and positing diet diversity as the measure used to investigate this mechanism through moderation rather than mediation.

The results demonstrated that diet diversity played a moderating role in the relation between food insecurity and depression. At lower levels of food insecurity (0–2), diet diversity does not seem to exert a moderating impact on the link food insecurity–depression. However, as hypothesised, the association between food insecurity and depression is magnified by diminishing levels of diet diversity. Although diet diversity is not independently

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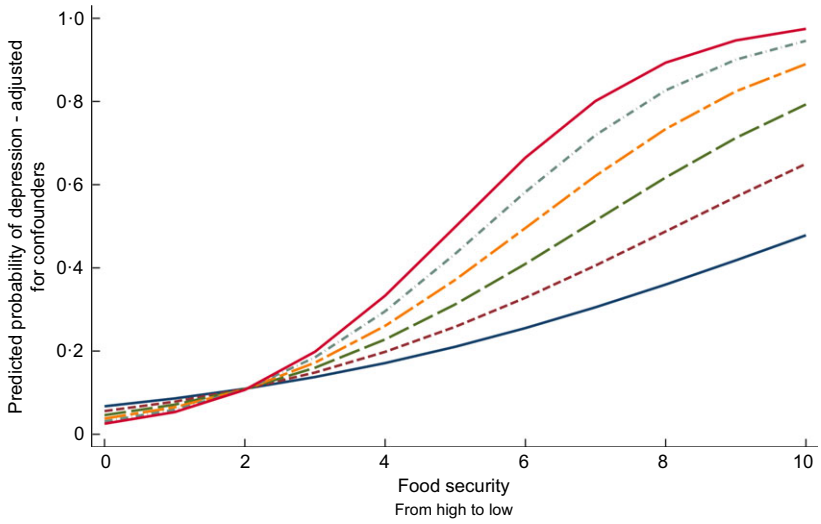

Fig. 2 (colour online) The moderating effect of food diversity in the association between food security and depression: plotting the predicted probabilities. —— 0·5; - - - 0·6; – – – 0·7; —·— 0·8; —··— 0·9; ——1
Source: Centers for Disease Control and Prevention (CDC). NationalCenter for Health Statistics (NCHS). 2013–2014-National Health and Nutrition Examination Survey Data. Hyattsville, MD: US Department of Health and Human Services, Centers for Disease Control and Prevention. FPED: 2013–2014 Food Patterns Equivalents Database. US Department of Agriculture. Note: This graph depicts the predicted probabilities obtained from calculating the marginal effects from Model 4. The estimate of the interaction was statistically significant $P < 0{\cdot}001$.

associated with depression, as could be deduced from the Adapted Sensory-Specific Satiety model of eating behaviour[94], our findings suggest that the consumption of diverse healthy food buffers the influence of food insecurity on the likelihood of depression, and conversely, lower levels of diet diversity may reinforce this impact. These findings are the first to show the moderating effect of diet diversity in the association between food insecurity and depression.

Limitations

Our findings should be interpreted in light of their limitations. Food insecurity, depression and dietary intake were self-reported. These self-report measures are subject to biases.

The 2013–2014 NHANES nonresponse rate of 29 % presents another limitation[95]. Without information on the non-respondents, it was not possible to gauge the extent of nonresponse bias.

Omitted control variables constitute another limitation of this study. Some variables found to be associated with both depression and food insecurity (e.g. inability to pay for medical bills[96], social support[10], domestic violence[89,97] or environmental factors[98], such as obesogenic, food access, rurality, neighbourhood safety and walkability) were not adjusted in regression models because they were not available.

This study posited food insecurity as leading to depression, that is, in regression models, depression was the dependent variable and food insecurity was one of the independent variables. In contrast, others have examined this association the other way around (i.e. reverse causality) treating food insecurity as the dependent variable and depression as one of the independent variables[86,99]. The cross-sectional design of this study limits the ability to ascertain causality and the bidirectional relationship between these two domains.

Future research

The scientific report of the 2015 Dietary Guidelines Advisory Committee concluded that current evidence on the association of dietary patterns with depression is limited[100]. Our study used a large population study of low-income adults to explore the moderating effect of diet diversity in the link between food insecurity and depression using a more comprehensive and more holistic diet diversity index. Future research may consider developing new measure of diet diversity.

As diet diversity changes with age[101], the association between food insecurity, diet diversity and depression in younger population also merits further examination. While a lack of diet diversity was analysed as a moderator, future longitudinal studies should investigate its role as a mediator.

Methodologically, because secondary data analysis poses the problem of omitted confounders, our research indicates the need for experimental interventions to examine the association between food insecurity and depression with diet diversity. The possible reverse causality between food insecurity and depression needs to be further elucidated with longitudinal studies as this bidirectionality may obscure other potential mechanistic effect of diet diversity in this association.

Additional research is also needed to identify other possible influences and mechanisms in the associations

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between food insecurity and depression, namely the mediating effect of diet diversity. Understanding the specific mechanism by which food insecurity exerts its impact on depression can aid in developing interventions to improve the mental health of individuals who are food-insecure. Furthermore, our focus was on a subpopulation of <300 % FPL. Therefore, the findings from this research cannot be extrapolated to the whole US population, but rather to the subpopulation of <300 % FPL. Future research may include the whole US population to determine if the findings from this study still hold among other income groups.

Conclusion

Food security is independently associated with depression among low-income adults in the USA. However, this association differs by differing levels of diet diversity. This is the first study that shows the moderating effect of diet diversity in the association between food insecurity and depression.

Longitudinal studies are needed to confirm the role diet diversity may play in the pathway between food insecurity and depression.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980020004644

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