


# BMJ Open Association of food security with cardiometabolic health during young adulthood: cross-sectional comparison of American Indian adults with other racial/ethnic groups

Cassandra J Nikolaus <sup>1</sup>, Anna Zamora-Kapoor,<sup>2</sup> Luciana E Hebert,<sup>1</sup> Ka'imi Sinclair<sup>3</sup>

**To cite:** Nikolaus CJ, Zamora-Kapoor A, Hebert LE, *et al.* Association of food security with cardiometabolic health during young adulthood: cross-sectional comparison of American Indian adults with other racial/ethnic groups. *BMJ Open* 2022;**12**:e054162. doi:10.1136/bmjopen-2021-054162

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2021-054162>).

Received 08 June 2021  
Accepted 19 May 2022



© Author(s) (or their employer(s)) 2022. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

<sup>1</sup>Institute for Research and Education to Advance Community Health, Washington State University—Spokane, Seattle, Washington, USA

<sup>2</sup>Sociology, Washington State University, Pullman, Washington, USA

<sup>3</sup>Nursing, Washington State University—Spokane, Seattle, Washington, USA

## Correspondence to

Dr Cassandra J Nikolaus;  
[cassandra.nikolaus@wsu.edu](mailto:cassandra.nikolaus@wsu.edu)

## ABSTRACT

**Objectives** Our aim was to assess the cross-sectional associations between food insecurity and cardiometabolic health indicators in American Indian young adults compared with non-Hispanic white, black, Asian or Pacific Islander and Hispanic young adults.

**Design** Data from the fourth wave of the National Longitudinal Study of Adolescent to Adult Health (Add Health) were used. Variables included a self-assessed measure of risk of food insecurity, indicators of cardiometabolic health (body mass index, haemoglobin A1c, blood pressure) and sociodemographic characteristics. Multivariable regression models were used to assess the association of risk of food insecurity with cardiometabolic health, while controlling for sociodemographic variables. All analyses were weighted and accounted for the complex survey design.

**Participants** The analytical sample of n=12 799 included mostly non-Hispanic white respondents (n=7900), followed by n=2666 black, n=442 American Indian, n=848 Asian or Pacific Islander and n=943 Hispanic.

**Results** Risk of food insecurity was more common among respondents who were female, Black, American Indian, had lower educational attainment, and were classified as having obesity or diabetes. In unadjusted models, risk of food insecurity was significantly associated with greater odds of obesity (OR=1.39; 95% CI 1.20 to 1.60) and diabetes (OR=1.61; 95% CI 1.23 to 2.11). After adjusting for sociodemographic factors (age, sex, education, income, household size, tobacco smoking, alcohol intake and race/ethnicity), only the association between risk of food insecurity and obesity remained (OR=1.19; 95% CI 1.03 to 1.38). Relationships among risk of food insecurity, sociodemographic characteristics and diabetes varied across models stratified by race and ethnicity.

**Conclusions** Results suggest that elevated risk of food insecurity is present in young American Indian adults, but its relationship with cardiometabolic health is unclear. Future work should capitalise on longitudinal data and the US Department of Agriculture's Food Security Survey Modules.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ The current study is the first to characterise food insecurity in American Indian young adults.
- ⇒ The analyses are strengthened by the use of objective measures with anthropometric and blood assessments to characterise cardiometabolic health.
- ⇒ The single item measure of food insecurity required a cautious interpretation of respondents' as being at risk of food insecurity.
- ⇒ The analyses rely on one cross-sectional wave of data collection from the Add Health study, so causality cannot be inferred.

## BACKGROUND

Diet-sensitive cardiometabolic diseases are some of the leading causes of morbidity and mortality in the USA, with heart disease and diabetes accounting for over 25% of deaths in 2017.<sup>1</sup> Annual healthcare costs incurred by patients to treat and manage heart disease and diabetes are substantial.<sup>2,3</sup> Furthermore, both diseases are associated with an average loss of over 10 quality-adjusted life years.<sup>4</sup> Though heart disease and diabetes are a consequence of physiological and metabolic changes in the body, racial and ethnic disparities in the burden of these diseases<sup>5,6</sup> are a product of structural and intermediary social determinants of health.<sup>7</sup>

Social determinants of health comprise the 'complex circumstances in which individuals are born and live that impact their health'.<sup>8</sup> One such determinant is food insecurity, defined as insufficient financial resources to access enough nutritious foods for all members of a household.<sup>9</sup> In 2019, an estimated 11% of US households experienced food insecurity.<sup>9</sup> The COVID-19 pandemic has exacerbated food insecurity in the USA,<sup>10</sup> which rose to

15% prevalence in 2020.<sup>11</sup> It is theorised that food insecurity has a cyclic relationship with chronic diseases, wherein coping responses and stress experienced as a result of food insecurity increase chronic disease risk. Subsequent disease treatment costs then perpetuate financial hardships, further amplifying food insecurity risk.<sup>12</sup> Empirical evidence supports the relationship of food insecurity to chronic disease development,<sup>13</sup> poor disease self-management,<sup>14</sup> greater healthcare costs<sup>15 16</sup> and premature mortality.<sup>17 18</sup>

Disparities in food insecurity across racial and ethnic groups are not well characterised. Although the annual report on US food security consistently indicates that food insecurity is more prevalent in households led by Hispanic or black, non-Hispanic adults when compared with households led by white, non-Hispanic adults,<sup>9</sup> this report lacks detailed racial or ethnic disparity data, as American Indian, Alaska Native, Native Hawaiian, Pacific Islander and Asian respondents are grouped together under a single 'other, non-Hispanic' category. Moreover, recent research reports that known risk factors for cardiometabolic health, such as overweight and obesity, have different effects across racial/ethnic groups. Asian adults have been found to have a higher likelihood of disease and early death with lower levels of overweight and obesity than non-Hispanic white and non-Hispanic black adults.<sup>19 20</sup> Similarly, non-Hispanic black children are more likely to become hypertensive than their non-Hispanic white and Hispanic counterparts, even after adjusting for current and birth weight.<sup>21</sup> This research programme stresses the need to continue examining risk factors for cardiometabolic health using race-stratified models.

American Indian people face unique historic and sociocultural influences that impact their lived experiences and community prevalence of social determinants of health.<sup>22 23</sup> As an example, forced relocation away from traditional lands and reliance on highly processed government food commodity programmes have had irreversible ramifications on American Indian food systems.<sup>24</sup> Yet, data that capture how these forces might impact contemporary food insecurity is sparse. American Indian people continue to be regularly omitted or misclassified in federal, state and local data collection and reports.<sup>25</sup> A handful of independent researchers have characterised food insecurity prevalence among American Indian or Alaska Native-led households.<sup>26–29</sup> An even smaller subset of studies have assessed the relationship of food insecurity to chronic diseases in samples of American Indian respondents.<sup>30–32</sup> In a sample of American Indian adults in rural Oklahoma, adults reporting experiences of food insecurity were more likely to report height and weight values considered obese as well as that they had been told by a doctor, nurse or other health professional that they had diabetes or high blood pressure.<sup>31</sup> However, food insecurity was not related to obesity when assessed among American Indian or Alaska Native adults in the California Health Interview Survey<sup>30</sup> or related to being

told by a healthcare provider that they had high blood pressure or diabetes in a sample of American Indian adults recruited in the Midwest.<sup>32</sup> However, these studies often rely on small regional samples and self-report among respondents that they were provided diagnoses by healthcare providers, which can introduce biases related to healthcare access and healthcare utilisation as well as recall. To date, no study has characterised food insecurity in American Indian young adults or examined the associations between food insecurity and cardiometabolic health outcomes in this age group by racial and ethnic classification.

The objective of the current study was to assess the cross-sectional relationships between food insecurity and diet-sensitive cardiometabolic risk factors in American Indian young adults in comparison with non-Hispanic white, black, Asian or Pacific Islander and Hispanic participants. The authors hypothesised that risk of food insecurity would be associated with poorer cardiometabolic health and that this association would vary by race and ethnicity of respondents. The present analyses use data from The National Longitudinal Study of Adolescent to Adult Health (Add Health), which has previously been employed to assess food insecurity and obesity, stratified by sex but not by race.<sup>33</sup>

## METHODS

### Data source

Add Health is a nationally representative cohort study conducted by the Carolina Population Center at the University of North Carolina-Chapel Hill.<sup>34</sup> Respondents were recruited as adolescents in grades 7–12 (n=20 745) at 80 schools during the 1994–1995 academic year. To date, respondents have completed five waves of longitudinal data collection to explore various determinants of health, health-related behaviours and health outcomes. During each wave of data collection, respondents complete different biometric and survey assessments. Written informed consent was collected at each wave of data collection. More details about Add Health and its methodology can be found elsewhere.<sup>35</sup>

The current study relied primarily on information from the wave 4 data collection in 2008–2009, when cohort members were 24–32 years old, as this is the only wave that included a measure of food insecurity. Over 80% of the original sample (n=15 701) participated in wave 4.<sup>36</sup> Data collection included a 90 min computer-based survey and a 30 min home-based assessment of anthropometric, blood pressure and blood spot biomarker measurements collected by trained field staff. Sociodemographic survey data collected during wave 1 data collection in 1994–1995 supplemented the wave 4 data.

### Measures

#### Food insecurity

Food insecurity was based on respondent answers to the following question:<sup>30</sup> 'In the past 12 months, was there a time

when you were (your household was) worried whether food would run out before you would get money to buy more?' Responses of 'yes' were considered at risk of food insecurity and responses of 'no' were considered not at risk of food insecurity. This item is derived from similar, lengthier, more sensitive and more specific items in the US Department of Agriculture's Food Security Survey Module.<sup>37</sup> Interpretation of the responses to signify 'risk of food insecurity' in lieu of a more definitive metric of food insecurity aligns with other abbreviated food insecurity screening tools, such as the 2-item screener that is recommended for use in healthcare settings.<sup>38</sup>

### Cardiometabolic health

Trained field staff collected measures of cardiometabolic health, including (a) body mass index (BMI), (b) glucose homeostasis and (c) blood pressure.<sup>39 40</sup> Respondents' body weight was measured to the nearest 0.1 kg. Height was assessed to the nearest 0.5 cm. BMI was calculated based on weight (kg) divided by height (m) squared. BMI values were classified as underweight ( $<18.5 \text{ kg/m}^2$ ), normal weight ( $18.5$  to  $<25 \text{ kg/m}^2$ ), overweight ( $25$  to  $<30 \text{ kg/m}^2$ ) and obese ( $\geq 30 \text{ kg/m}^2$ ). For analyses, these classifications were collapsed to obese or not obese. Glucose homeostasis was evaluated based on blood glucose (mg/dL) and haemoglobin A1c (%), determined from assays of dried blood spots. These measures were then used to classify participants as having no diabetes, pre-diabetes or diabetes. Participants were classified as having pre-diabetes if their haemoglobin A1c levels were 5.7%–6.4% or their fasting blood glucose level was 100–125 mg/dL, but they did not meet the criteria for having diabetes. Participants were classified as having diabetes if they had haemoglobin A1c  $\geq 6.5\%$ , fasting glucose  $>125 \text{ mg/dL}$ , a self-reported history of diabetes or self-reported use of diabetes medication.

Three blood pressure readings were acquired for each participant. Measures of systolic and diastolic blood pressure (mm Hg) were derived by averaging the second and third readings, or the first was used if only one reading was completed. Systolic and diastolic values were used to classify each participant's blood pressure as normal ( $<120 \text{ mm Hg}$  systolic and  $<80 \text{ mm Hg}$  diastolic), prehypertensive ( $120$ – $139 \text{ mm Hg}$  systolic or  $80$ – $89 \text{ mm Hg}$  diastolic) or hypertensive ( $\geq 140 \text{ mm Hg}$  systolic or  $\geq 90 \text{ mm Hg}$  diastolic).

### Sociodemographic characteristics

Participants' sociodemographic characteristics were derived from survey questions administered in wave 1 and wave 4 data collection periods. Wave 1 items included an assessment of biological sex (female or male), race (white; black or African American; American Indian or Native American; Asian or Pacific Islander; and other) and ethnicity (yes/no response regarding Hispanic or Latino origin). If participants selected more than one race, they were assigned to a single racial and ethnic category in the following order: American Indian, black, Asian or Pacific

Islander, Hispanic and non-Hispanic white. The intent was to maximise the representation of racial and ethnic minorities.<sup>41</sup> Age of participants was calculated in years by taking the difference between the month and year of birth recorded during wave 1 and the month and year of the wave 4 survey administration. Wave 4 surveys included assessments of household size (number of people living with the participant), education (less than high school; completion of high school or a General Educational Development test; some college; or a Bachelor's degree or more), employment (yes/no response to working 10 or more hours per week for pay), household annual income (less than US\$15,000; US\$15 000 to US\$29,999; US\$30 000 to US\$50,999; US\$50 000 to US\$74,999; US\$75,000 or more; missing), tobacco smoking (yes/no response to smoking cigarette(s) during any of the past 30 days) and alcohol use (yes/no response to consuming one or more alcoholic beverage(s) during any of the past 30 days).

### Statistical analyses

Descriptive statistics were calculated for risk of food insecurity, cardiometabolic health indicators and sociodemographic characteristics using frequencies and proportions for categorical variables and means and SD for continuous variables. Logistic multivariable regression models were used to estimate the associations between cardiometabolic health indicators and risk of food insecurity. All cardiometabolic health indicators were treated as binary with obesity compared with all other weight categories, diabetes compared with no diabetes and hypertension compared with no hypertension. For the full sample, two models were created for each cardiometabolic health indicator. The unadjusted model included the cardiometabolic health indicator as the dependent variable and risk of food insecurity as the only independent variable. The adjusted model additionally included sociodemographic characteristics (age, sex, education, household size, tobacco smoking, alcohol intake and race/ethnicity) and an interaction term for race and food insecurity. If this interaction term indicated that the relationship of food insecurity with the cardiometabolic health indicator varied by race, adjusted models stratified by race were built for participants with no missing data on variables of interest. Given that cardiometabolic health indicators are highly correlated, no multiple comparisons adjustments were made.<sup>42</sup> All statistical analyses accounted for the complex sampling strategy by incorporating sampling weights for the wave 4 data collection and identifying the primary sampling units and strata to adjust for stratification and oversampling of underrepresented groups. All analyses were conducted in Stata/MP (V.15.0, StataCorp, College Station, Texas, 2016), with the significance level set at  $\alpha=0.05$ . The protocols described were deemed as not human subject research by the Washington State University IRB, given that there was no interaction by researchers with identifiable data.

## Patient and public involvement

No patients involved.

## RESULTS

Of the 15 701 respondents who participated in wave 4 data collection, 2902 observations were removed from the sample because they lacked survey weights ( $n=901$ ) or were missing values for cardiometabolic health indicators ( $n=1290$  A1c;  $n=346$  blood pressure;  $n=121$  BMI) or sociodemographic characteristics ( $n=104$  race or ethnicity;  $n=103$  tobacco smoking;  $n=22$  alcohol use;  $n=7$  household size;  $n=4$  employment;  $n=3$  risk of food insecurity;  $n=1$  education). The result was a final analytical sample of  $n=12\,799$ . The sample included approximately equal representations of sexes (female=50%). Most respondents were non-Hispanic white ( $n=7900$ ), followed by  $n=2666$  black,  $n=943$  Hispanic,  $n=848$  Asian or Pacific Islander and  $n=442$  American Indian. Across all participants, prehypertension was the most common indicator of poor cardiometabolic health (48%), followed by obesity (37%), overweight (30%), pre-diabetes (30%), hypertension (19%) and diabetes (6%). Risk of food insecurity was reported by 11% of participants and was related to differences across many sociodemographic and cardiometabolic health variables, including sex, race or ethnicity, education, income, employment, tobacco/alcohol use, weight and glucose outcomes (not shown). Risk of food insecurity was not significantly associated with pre-diabetes ( $p=0.54$ ), prehypertension ( $p=0.45$ ) or hypertension ( $p=0.52$ ) in bivariate comparisons, so was not further assessed in multivariable models.

Characteristics related to risk of food insecurity and/or cardiometabolic health indicators were descriptively compared across racial and ethnic groups (table 1). Educational attainment varied across groups with almost half of Asian or Pacific Islander respondents attaining a bachelor's degree or more, in contrast with a sixth of Hispanic respondents. Tobacco and alcohol use in the prior 30 days also varied across racial and ethnic groups, with the highest prevalence of tobacco use occurring among American Indian respondents (46%) and highest prevalence of alcohol use occurring among non-Hispanic white respondents (65%). Obesity was the most prevalent among Black respondents (45%) and least common among Asian or Pacific Islander respondents (26%). Diabetes was the most prevalent among black respondents (15%), followed by American Indian respondents (12%) and Hispanic respondents (9%).

Table 2 shows the results of logistic regression models predicting obesity by risk of food insecurity in unadjusted and adjusted models among all participants. In unadjusted models, risk of food insecurity was associated with significantly greater odds of obesity in all participants (OR=1.39; 95% CI 1.20 to 1.60). After adjusting for sociodemographic characteristics (age, sex, education, income, household size, tobacco smoking, alcohol intake and race/ethnicity), risk of food insecurity was no longer

significantly associated with increased odds of obesity (OR=1.15; 95% CI 0.96 to 1.39). Black respondents had significantly greater odds (OR=1.29; 95% CI 1.13 to 1.48) and Asian or Pacific Islander respondents had significantly lower odds (OR=0.59; 95% CI 0.38 to 0.93) of obesity when compared with Non-Hispanic white respondents in the adjusted model. However, the interaction term of food insecurity and race/ethnicity in the adjusted model predicting obesity was not significant, so stratified models for each race/ethnicity were not analysed.

Table 3 shows the results of logistic regression models estimating the association between diabetes and risk of food insecurity in unadjusted and adjusted models among all participants. In unadjusted models, risk of food insecurity was significantly associated with increased odds of diabetes in the model including all participants (OR=1.61; 95% CI 1.23 to 2.11). When adjusting for sociodemographic characteristics (age, sex, education, income, household size, tobacco smoking, alcohol intake and race/ethnicity), risk of food insecurity remained significantly associated with greater odds of diabetes (OR=1.89; 95% CI 1.28 to 2.79). Race and ethnicity were also significantly associated with diabetes in the adjusted model, with black (OR=3.63; 95% CI 2.87 to 4.58), American Indian (OR=3.77; 95% CI 2.37 to 5.98) and Hispanic (OR=2.13; 95% CI 1.40 to 3.23) respondents at greater odds of diabetes when compared with non-Hispanic white respondents. The interaction term between risk of food insecurity and race or ethnicity was also significant, with black (OR=0.47; 95% CI 0.25 to 0.90), American Indian (OR=0.16; 95% CI 0.03 to 0.73) and Hispanic (OR=0.28; 95% CI 0.09 to 0.82) respondents who reported risk of food insecurity at lower odds of diabetes when compared with Non-Hispanic white respondents who did not report risk of food insecurity. Table 4 shows the results of logistic regression models estimating the association between diabetes and risk of food insecurity in unadjusted and adjusted models stratified by race and/or ethnicity. Risk of food insecurity was significantly related to odds of diabetes only in the models restricted to non-Hispanic white respondents (unadjusted OR=2.13; 95% CI 1.45 to 3.13 and adjusted OR=1.82; 95% CI 1.19 to 2.76).

## DISCUSSION

The aim of this study was to assess the relationship of food insecurity to cardiometabolic health indicators in young adults and to compare these relationships among American Indian respondents with other racial and ethnic groups. In support of the hypothesis that risk of food insecurity would be associated with poorer cardiometabolic health, diabetes was observed to be associated with risk of food insecurity even after adjusting for sex, age, race/ethnicity, household size, education, income, tobacco use and alcohol use. Furthermore, we characterised variation across racial and ethnic groups in the prevalence of risk of food insecurity and indicators of poor cardiometabolic health and found differences in identifiable relationships

**Table 1** Sociodemographic characteristics of participants in the study sample by race or ethnicity group

Characteristic	All (n=14800)	Non-Hispanic White (n=7900)	Black (n=2666)	American Indian (n=442)	Asian or Pacific Islander (n=848)	Hispanic (n=943)
	Age, years, mean (SE)	28.83 (0.12)	28.78 (0.13)	29.06 (0.21)	28.64 (0.19)	28.96 (0.29)
Sex						
Female, % (95% CI)	50.22 (48.92 to 51.53)	49.89 (48.28 to 51.50)	52.50 (49.29 to 55.70)	50.58 (44.35 to 56.79)	49.43 (43.53 to 55.34)	48.81 (43.87 to 53.77)
Education level						
Less than high school degree, % (95% CI)	8.93 (7.69 to 10.34)	7.77 (6.55 to 9.19)	11.89 (9.32 to 15.06)	16.64 (11.57 to 23.36)	2.31 (1.28 to 4.15)	15.28 (11.60 to 19.86)
High school degree, % (95% CI)	21.07 (19.19 to 23.08)	20.09 (18.07 to 22.27)	25.40 (21.08 to 30.26)	24.50 (16.52 to 34.73)	13.75 (7.97 to 22.69)	24.61 (19.95 to 29.94)
Some college, % (95% CI)	40.29 (38.75 to 41.86)	39.99 (37.98 to 42.03)	41.58 (37.98 to 45.27)	39.37 (33.4 to 45.67)	35.31 (29.68 to 41.38)	44.19 (38.17 to 50.39)
Bachelor's degree or more, % (95% CI)	29.71 (26.64 to 32.97)	32.16 (28.58 to 35.96)	21.13 (16.43 to 26.74)	19.48 (13.57 to 27.17)	48.63 (38.53 to 58.84)	15.92 (12.78 to 19.66)
Household income, annual						
Less than US\$15k, % (95% CI)	8.18 (7.20 to 9.29)	6.34 (5.45 to 7.35)	19.56 (16.85 to 22.59)	8.14 (5.69 to 11.51)	3.52 (2.08 to 5.91)	4.79 (2.99 to 7.58)
US\$15 to 29.9 k, % (95% CI)	12.84 (11.89 to 13.86)	11.69 (10.66 to 12.80)	18.36 (16.02 to 20.96)	17.56 (12.54 to 24.03)	9.76 (5.70 to 16.21)	12.29 (9.54 to 15.69)
US\$30 to 49.9 k, % (95% CI)	21.77 (20.64 to 22.94)	21.95 (20.57 to 23.39)	21.38 (19.54 to 23.34)	21.45 (16.37 to 27.60)	14.28 (10.37 to 19.34)	25.20 (20.28 to 30.85)
US\$50 to 74.9 k, % (95% CI)	22.73 (21.44 to 24.06)	24.26 (22.83 to 25.74)	17.26 (14.98 to 19.80)	17.66 (13.56 to 22.68)	21.53 (16.85 to 27.09)	21.34 (17.02 to 26.40)
US\$75k or more, % (95% CI)	27.60 (25.62 to 29.67)	29.98 (27.83 to 32.22)	14.35 (11.59 to 17.65)	26.49 (20.97 to 32.87)	43.25 (36.87 to 49.85)	23.31 (18.97 to 28.30)
Missing, % (95% CI)	6.88 (5.71 to 8.28)	5.79 (4.75 to 7.05)	9.09 (7.14 to 11.51)	8.70 (5.07 to 14.52)	7.68 (5.23 to 11.13)	13.07 (7.33 to 22.25)
Household size, individuals, mean (SE)	3.22 (0.04)	3.07 (0.04)	3.71 (0.13)	3.48 (0.8)	3.61 (0.21)	3.77 (0.12)
Smokes tobacco						
Yes, % (95% CI)	39.29 (37.33 to 41.29)	41.16 (39.05 to 43.30)	33.16 (29.11 to 37.48)	46.10 (38.45 to 53.94)	29.55 (23.95 to 35.84)	34.22 (29.23 to 39.59)
Drinks alcohol						
Yes, % (95% CI)	61.75 (59.62 to 63.84)	64.95 (62.62 to 67.20)	49.99 (46.60 to 53.39)	63.79 (58.40 to 68.86)	57.66 (51.56 to 63.54)	53.91 (48.20 to 59.51)
At risk of food insecurity						
Yes, % (95% CI)	12.13 (11.10 to 13.24)	10.72 (9.71 to 11.81)	19.45 (16.94 to 22.23)	20.36 (15.43 to 26.37)	6.21 (0.363 to 10.42)	9.94 (7.04 to 13.86)
Health outcomes						
Obese, % (95% CI)	37.24 (35.52 to 38.99)	35.34 (33.50 to 37.22)	45.27 (42.43 to 48.15)	42.58 (34.68 to 50.88)	25.97 (18.39 to 35.32)	43.83 (38.79 to 49.01)
Diabetes, % (95% CI)	6.56 (5.78 to 7.44)	4.48 (3.88 to 5.16)	14.93 (13.02 to 17.07)	12.23 (8.20 to 17.85)	4.85 (2.52 to 9.15)	8.77 (6.34 to 12.00)

**Table 2** Association of obesity with risk of food insecurity, in unadjusted and multivariable logistic regression models

	All participants (n=12 799)
Risk of food insecurity, unadjusted	1.39 (1.20 to 1.60)***
Risk of food insecurity	1.15 (0.96 to 1.39)
Age	1.03 (1.00 to 1.07)
Sex:† female	1.07 (0.96 to 1.20)
Education:‡ high school	1.06 (0.87 to 1.30)
Education: some college	1.11 (0.92 to 1.33)
Education: bachelor's degree or more	0.63 (0.51 to 0.78)***
Household income:§ US\$15 to 29.9k	1.06 (0.83 to 1.36)
Household income: US\$30 to 49.9k	1.13 (0.91 to 1.41)
Household income: US\$50 to 74.9k	1.02 (0.80 to 1.30)
Household income: US\$75k or more	0.89 (0.70 to 1.12)
Household income: missing	0.92 (0.66 to 1.28)
Household size	1.08 (1.03 to 1.12)**
Tobacco smoking: yes	0.73 (0.65 to 0.81)***
Alcohol intake: yes	0.77 (0.69 to 0.86)***
Race or ethnicity:¶ Black	1.29 (1.13 to 1.48)***
Race or Ethnicity: American Indian	1.31 (0.92 to 1.87)
Race or Ethnicity: Asian or Pacific Islander	0.59 (0.38 to 0.93)*
Race or Ethnicity: Hispanic	1.15 (0.90 to 1.48)
Interaction:†† Risk of Food Insecurity × Black	0.91 (0.65 to 1.26)
Interaction: Risk of Food Insecurity × American Indian	0.75 (0.38 to 1.48)
Interaction: Risk of Food Insecurity × Asian or Pacific Islander	2.62 (0.90 to 7.65)
Interaction: Risk of Food Insecurity × Hispanic	1.42 (0.70 to 2.87)

All estimates are shown for risk of obesity relative to all other weight categories. P values are denoted as \* for <0.05, \*\* for <0.01 and \*\*\* for <0.001.  
†Relative to male.  
‡Relative to less than high school.  
§Relative to less than \$15k/year.  
¶Relative to Non-Hispanic white.  
††Relative to no risk of food insecurity and Non-Hispanic white.

between risk of food insecurity and diabetes during young adulthood. Broadly, the results align with the evidence that the expected dietary changes that food insecure individuals or households enact to cope with insufficient resources are related to physical health differences<sup>12 43–45</sup> and provide new indications about how this relationship manifests across racially and ethnically diverse young adults.

Data collected during wave 4 of Add Health assessments provide a glimpse of food insecurity risk and cardiometabolic health issues already present during young adulthood. Eleven percent of young adults reported being at risk of food insecurity in the present sample, which is lower than the prevalence of food insecurity (15%–16%) in households led by adults 21–30 years old assessed in

**Table 3** Association of diabetes with risk of food insecurity, in unadjusted and multivariable logistic regression models

	All participants (n=12 799)‡
Risk of food insecurity, unadjusted	1.61 (1.23 to 2.11)**
Risk of food insecurity	1.89 (1.28 to 2.79)**
Age	1.06 (1.01 to 1.12)*
Sex:† female	0.94 (0.78 to 1.15)
Education:‡ high school	1.06 (0.74 to 1.53)
Education: some college	0.78 (0.56 to 1.08)
Education: bachelor's degree or more	0.56 (0.38 to 0.82)**
Household income:§ US\$15 to 29.9k	0.92 (0.62 to 1.37)
Household income: US\$30 to 49.9k	0.77 (0.55 to 1.09)
Household income: US\$50 to 74.9k	0.83 (0.55 to 1.26)
Household income: US\$75k or more	0.78 (0.52 to 1.17)
Household income: missing	0.85 (0.55 to 1.32)
Household size	0.98 (0.93 to 1.03)
Tobacco smoking: yes	0.76 (0.62 to 0.94)*
Alcohol intake: yes	0.84 (0.69 to 1.02)
Race or ethnicity:¶ Black	3.63 (2.87 to 4.58)***
Race or ethnicity: American Indian	3.77 (2.37 to 5.98)***
Race or ethnicity: Asian or Pacific Islander	1.19 (0.60 to 2.37)
Race or ethnicity: Hispanic	2.13 (1.40 to 3.23)***
Interaction:†† Risk of Food Insecurity × Black	0.47 (0.25 to 0.90)*
Interaction: Risk of Food Insecurity × American Indian	0.16 (0.03 to 0.73)*
Interaction: Risk of Food Insecurity × Asian or Pacific Islander	1.16 (0.46 to 2.96)
Interaction: Risk of Food Insecurity × Hispanic	0.28 (0.09 to 0.82)*

All estimates are shown for risk of diabetes relative to no diabetes. P values are denoted as \* for <0.05, \*\* for <0.01 and \*\*\* for <0.001.  
†Relative to male.  
‡Relative to less than high school.  
§Relative to less than \$15k/year.  
¶Relative to Non-Hispanic white.  
††Relative to no risk of food insecurity and Non-Hispanic white.

the 2011–2015 Current Population Survey.<sup>46</sup> This difference in prevalence is unexpected, given that wave 4 of Add Health occurred during the Great Recession and the elevated prevalence of food insecurity among the general population during that same time period.<sup>9</sup> Therefore, the sample may differ in unobserved ways from the general young adult population in the US. The characterisation of risk of food insecurity concurred with prior findings with respect to its relationships with sociodemographic characteristics, including income, education, employment, race or ethnicity and tobacco use.<sup>9 47 48</sup> However, in contrast to prior research, alcohol use was less prevalent among young adults at risk of food insecurity in the

**Table 4** Association of diabetes with risk of food insecurity stratified by race/ethnicity, in unadjusted and multivariable logistic regression models

	Non-Hispanic White (n=7900)	Black (n=2666)	American Indian (n=442)	Asian or Pacific Islander (n=848)	Hispanic (n=943)
Risk of food insecurity, unadjusted	2.13 (1.45 to 3.13)**	0.99 (0.63 to 1.57)	0.33 (0.07 to 1.50)	2.35 (0.96 to 5.73)	0.60 (0.23 to 1.54)
Risk of food insecurity	1.82 (1.19 to 2.76)**	0.93 (0.57 to 1.52)	0.27 (0.06 to 1.20)	2.17 (0.47 to 10.07)	0.59 (0.22 to 1.62)
Age	1.10 (1.01 to 1.19)*	1.03 (0.94 to 1.13)	0.97 (0.69 to 1.36)	1.31 (1.13 to 1.53)**	1.04 (0.89 to 1.21)
Sex:† female	1.03 (0.79 to 1.35)	0.80 (0.62 to 1.02)	0.79 (0.32 to 1.94)	0.88 (0.33 to 2.32)	0.98 (0.47 to 2.07)
Education:‡ high school	1.36 (0.82 to 2.28)	0.80 (0.45 to 1.43)	1.16 (0.29 to 4.63)	0.70 (0.08 to 6.21)	1.17 (0.32 to 4.19)
Education: some college	0.93 (0.58 to 1.51)	0.63 (0.43 to 0.94)*	0.48 (0.10 to 2.30)	0.20 (0.01 to 3.98)	1.72 (0.52 to 5.65)
Education: bachelor's degree or more	0.60 (0.34 to 1.06)	0.62 (0.38 to 1.01)	0.28 (0.04 to 1.91)	0.25 (0.03 to 1.96)	0.61 (0.14 to 2.55)
Household income:§ US\$15 to 29.9k	0.81 (0.44 to 1.49)	0.94 (0.52 to 1.70)	0.52 (0.06 to 4.65)	13.03 (2.40 to 70.77)**	1.14 (0.15 to 8.81)
Household income: US\$30 to 49.9k	0.62 (0.34 to 1.13)	0.74 (0.46 to 1.18)	0.47 (0.04 to 5.40)	17.43 (2.51 to 121.20)**	1.66 (0.21 to 13.06)
Household income: US\$50 to 74.9k	0.81 (0.41 to 1.57)	0.74 (0.44 to 1.27)	0.61 (0.10 to 3.74)	7.24 (4.25 to 12.30)***	0.75 (0.09 to 6.04)
Household income: US\$75k or more	0.69 (0.37 to 1.29)	0.68 (0.37 to 1.23)	0.73 (0.07 to 7.16)	9.48 (3.36 to 26.73)***	1.23 (0.14 to 10.75)
Household income: missing	0.67 (0.33 to 1.37)	0.80 (0.42 to 1.52)	1.36 (0.21 to 8.81)	7.48 (2.03 to 27.62)**	1.11 (0.12 to 10.61)
Household size	1.01 (0.94 to 1.10)	0.94 (0.83 to 1.07)	1.06 (0.90 to 1.26)	0.66 (0.52 to 0.83)**	1.02 (0.79 to 1.32)
Tobacco smoking: yes	0.76 (0.56 to 1.02)	0.71 (0.45 to 1.13)	0.73 (0.32 to 1.66)	0.49 (0.18 to 1.36)	1.04 (0.46 to 2.34)
Alcohol intake: yes	0.79 (0.60 to 1.05)	0.91 (0.66 to 1.24)	0.88 (0.39 to 1.98)	1.04 (0.31 to 3.50)	0.70 (0.35 to 1.42)

All estimates are shown for risk of diabetes relative to no diabetes. P values are denoted as \* for <0.05, \*\* for <0.01 and \*\*\* for <0.001.

†Relative to male.

‡Relative to less than high school.

§Relative to less than \$15k/year.

present sample.<sup>47 49</sup> The descriptive analyses of cardiometabolic health indicators revealed that indicators of poor cardiometabolic health are prevalent in young adulthood, with overweight or obesity impacting over two-thirds of respondents and prehypertension or hypertension prevalent among over half of the sample. However, these indicators varied by race or ethnicity, with Black and American Indian participants most likely to report obesity and/or diabetes. These disparities may be related to differences in the distribution of sociodemographic characteristics across racial and ethnic groups in the present study or in behavioural pattern differences reported in other analyses of Add Health's wave 4 data.<sup>50 51</sup>

Risk of food insecurity was significantly associated with obesity among respondents, but this relationship did not hold after adjusting for sociodemographic characteristics. Prior studies have also found that food insecurity is related to greater odds of being overweight and/or obese, but similarly to the current study, this relationship either dissipates when adjusted for other characteristics or is retained only for female respondents.<sup>33 45 52</sup> One exception to this was a study focused on older adults, which found food insecurity was related to overweight or obesity even after controlling for related characteristics.<sup>53</sup> Few prior studies assessing the relationship of food insecurity and obesity have focused on young adults. In a prior analysis of the Add Health data, food insecurity was associated with greater BMI values among female young adults even after adjusting for sociodemographic characteristics.<sup>33</sup> Differences in prior findings and the current results may have resulted from the prediction of obesity instead of continuous BMI values, but when models were stratified by sex with continuous BMI as the outcomes, no differences in significant results were identified (not shown). Thus, differences may have resulted from different sociodemographic control variables and/or inclusion criteria. Notably, in studies similarly focused on young adults that did not rely on Add Health data, analyses of this relationship have largely yielded non-significant results.<sup>54–56</sup> However, these studies often exclusively recruit college students.<sup>54 55</sup> The current results largely align with prior studies of food insecurity and obesity among young adults, but the population sampled, inclusion criteria and sociodemographic variables used as controls may lead to variation in results.

Our examination of the relationship between risk of food insecurity and diabetes found they were related when the overall sample was assessed, but findings were not consistent in models stratified by race/ethnicity. Counterintuitively, interaction terms in the model also indicated that respondents reporting risk of food insecurity and race/ethnicity of Black, American Indian or Hispanic were less likely to report diabetes in comparison to those who were both non-Hispanic white and reported no risk of food insecurity. This interaction term and the lack of relationships between risk of food insecurity and diabetes among American Indian, Hispanic and Black respondents was counter to expectations. Prior

literature has demonstrated elevated prevalence of both food insecurity and diabetes in many of these racial/ethnic groups<sup>57</sup> and studies restricted to Hispanic<sup>58</sup> and American Indian<sup>31</sup> respondents have indicated diabetes is related to food insecurity. These differences may have been driven by prior studies including predominantly middle-aged and/or older adults or measurement errors and sample size biases, which are discussed further below. In the present analyses' stratified models, risk of food insecurity was related to greater odds of diabetes only among non-Hispanic white respondents. However, these findings align with the trends in the literature on food insecurity and diabetes, which support a relationship between prevalence of diabetes as well as poorer glycaemic control, but prior studies rely on samples that are predominantly non-Hispanic white or do not disaggregate findings by racial/ethnic groups.<sup>14</sup>

There are a number of reasons that may explain the counterintuitive interaction and subsequent absence of findings for specific racial or ethnic groups. The limited sample sizes for racial/ethnic groups other than non-Hispanic white may have provided insufficient power to detect small effects. Furthermore, some characteristics exhibited limited variation, and thus small cell counts, within racial/ethnic groups. In addition, because all respondents were young adults, even though they exhibited many indicators of poor cardiometabolic health, the prevalence was relatively low compared with what would be expected in older adults. For example, when restricting the sample to only American Indian, Asian or Pacific Islander or Hispanic respondents, the number of individuals reporting both risk of food insecurity and diabetes was <20 for each group. In models adjusting for various sociodemographic characteristics, parameters are estimated using limited data sets and may identify relationships, or lack thereof, based on restricted samples, which may not reflect their larger populations. A final factor that may have limited our power to observe relationships between risk of food insecurity and cardiometabolic health outcomes is potential measurement error resulting from the reliance on a single question to identify risk of food insecurity. Though evidence suggests this single item has 93% sensitivity and 85% specificity when compared with the full 18-item Food Security Survey Module, validity evidence was not established for many of the racial and ethnic groups of interest in the present study.<sup>37 38</sup> Scholars have noted potential concerns with the use of established food insecurity questions among American Indian or Alaska Native respondents.<sup>24 31 59</sup> However, the estimates in Asian or Pacific Islander respondents had wide CIs, which may reflect the heterogeneous sociocultural and ethnic backgrounds within this group.<sup>60</sup> It is also possible that findings are not a result of measurement errors or sampling issues. It is possible that the interaction of food insecurity with race/ethnicity indicates underlying differences in how food insecurity is experienced, and coping responses enacted by various racial/ethnic groups in the USA, which warrants additional study to



extend these analyses and investigate directionality of relationships with additional longitudinal data.

The present study is not without limitations. The analyses rely on one cross-sectional wave of data collection from the Add Health study, so causality cannot be inferred. In addition, as previously noted, assessment of food insecurity was based on a one-item measure. Though evidence supports this measure's comparability with full surveys of food insecurity, it is possible that households may have been misclassified with respect to food insecurity. Thus, affirmative responses to the one-item measure must be interpreted with caution as indicative of risk of food insecurity. This interpretation does not afford the nuance that can be provided by data from the 10-item or 18-item Food Security Survey Modules, which can classify a household into one of four distinct food security categories.<sup>37</sup> An additional concern related to categorisation involves potential racial or ethnic misclassification, as Asian or Pacific Islander respondents were identified under a single aggregate term, precluding unique identification of Native Hawaiians or Pacific Islanders. Researchers have noted unique socioeconomic and cultural characteristics that warrant disaggregation of this data<sup>60</sup> and estimates of statistics in the present study for the group aggregated as Asian or Pacific Islanders often produced wide CI ranges. Finally, almost 10% of income data were missing in the present sample. However, in lieu of listwise deletion or exclusion of this factor from multivariable models, missing values were treated as a response category for income. Despite these limitations, this study has made a contribution to the literature on food insecurity and American Indian health by characterising risk of food insecurity during young adulthood and comparing the relationships between risk of food insecurity and cardiometabolic health indicators by race and ethnicity.

## Conclusion

Findings from this study contribute to the larger literature suggesting that food insecurity is related to cardiometabolic health, specifically diabetes. The present data further extend the research by providing evidence of these relationships in early adulthood. Furthermore, results highlight inequities experienced across racial and ethnic groups in prevalence of risk of food insecurity and indicators of poor cardiometabolic health. American Indian young adults exhibited elevated prevalence of risk of food insecurity and poor cardiometabolic health. However, interaction analyses and stratified regression models did not elucidate clear relationships between risk of food insecurity and cardiometabolic outcomes among individual racial or ethnic groups. Future studies should replicate these analyses with longitudinal data and/or use the full 10-item or 18-item Food Security Survey Modules. Generating additional evidence about how food insecurity and impaired cardiometabolic health manifest in various racial and ethnic groups will be important to inform relevant food and health-related policies and programmes.

**Acknowledgements** This research uses data from Add Health, a program project designed by J. Richard Udry, Peter S. Bearman, and Kathleen Mullan Harris, and funded by a grant P01-HD31921 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development, with cooperative funding from 17 other agencies. Special acknowledgement is due Ronald R. Rindfuss and Barbara Entwisle for assistance in the original design. Persons interested in obtaining Data Files from Add Health should contact Add Health, The University of North Carolina at Chapel Hill, Carolina Population Center, Carolina Square, Suite 210, 123 W. Franklin Street, Chapel Hill, NC 27516 (addhealth\_contracts@unc.edu). No direct support was received from grant P01-HD31921 for this analysis.

**Contributors** CJN, AZ-K and KS designed research; CJN and LEH analyzed data; CJN wrote paper. CJN is responsible for the overall content as guarantor. All authors read and approved the final manuscript.

**Funding** This work was directly supported by the Center for American Indian and Alaska Native Diabetes Translation Research, through a grant from the National Institute of Diabetes and Digestive and Kidney Diseases (P30DK092923). This research uses data from Add Health, a program project designed by J. Richard Udry, Peter S. Bearman, and Kathleen Mullan Harris, and funded by a grant P01-HD31921 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development, with cooperative funding from 17 other agencies. No direct support was received from grant P01-HD31921 for this analysis.

**Competing interests** None declared.

**Patient and public involvement** Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Not applicable.

**Ethics approval** The protocols described were deemed as not human subjects' research by the Washington State University Institutional Review Board, given that a secondary dataset with identifiers removed was provided by the Add Health data administrators to the researchers. Ethical review and approval of these protocols were provided by the Institutional Review Board (IRB) on Research Involving Human Subjects at the University of North Carolina at Chapel Hill. More details about Add Health and its methodology can be found elsewhere.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data may be obtained from a third party and are not publicly available. Restricted Add Health data access is available through a license with the Carolina Population Center at the University of North Carolina at Chapel Hill.

**Open access** This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

## ORCID iD

Cassandra J Nikolaus <http://orcid.org/0000-0003-2039-6295>

## REFERENCES

- 1 National Vital Statistics Reports Heron M. *Deaths: leading causes for 2017*. 68, 2019.
- 2 Nichols GA, Bell TJ, Pedula KL, *et al*. Medical care costs among patients with established cardiovascular disease. *Am J Manag Care* 2010;16:e86–93.
- 3 Shrestha SS, Honeycutt AA, Yang W, *et al*. Economic costs attributable to diabetes in each U.S. state. *Diabetes Care* 2018;41:2526–34.
- 4 Jia H, Zack MM, Thompson WW. The effects of diabetes, hypertension, asthma, heart disease, and stroke on quality-adjusted life expectancy. *Value Health* 2013;16:140–7.
- 5 National Center for Health Statistics. *Table A-1a. age-adjusted percentages (with standard errors) of selected circulatory diseases among adults aged 18 and over, by selected characteristics: United States*. 2016, 2016.
- 6 Rodríguez JE, Campbell KM. Racial and ethnic disparities in prevalence and care of patients with type 2 diabetes. *Clin Diabetes* 2017;35:66–70.
- 7 World Health Organization. A conceptual framework for action on the social determinants of health; 2010.
- 8 Catalyst N. Social determinants of health. *N Engl J Med* 2017;3.

- 9 Coleman-Jensen A, Rabbitt MP, Gregory CA, Singh A, Household food security in the United States in 2019. Economic research services; 2020.
- 10 Leddy AM, Weiser SD, Palar K, et al. A conceptual model for understanding the rapid COVID-19-related increase in food insecurity and its impact on health and healthcare. *Am J Clin Nutr* 2020;112:1162–9.
- 11 America F. The impact of the coronavirus on food insecurity; 2020.
- 12 Seligman HK, Schillinger D. Hunger and socioeconomic disparities in chronic disease. *N Engl J Med* 2010;363:6–9.
- 13 Laraia BA. Food insecurity and chronic disease. *Adv Nutr* 2013;4:203–12.
- 14 Flint KL, Davis GM, Umpierrez GE. Emerging trends and the clinical impact of food insecurity in patients with diabetes. *J Diabetes* 2020;12:187–96.
- 15 Men F, Gundersen C, Urquia ML, et al. Food insecurity is associated with higher health care use and costs among Canadian adults. *Health Aff* 2020;39:1377–85.
- 16 Berkowitz SA, Basu S, Gundersen C, et al. State-level and county-level estimates of health care costs associated with food insecurity. *Prev Chronic Dis* 2019;16:E90.
- 17 Walker RJ, Chawla A, Garacci E, et al. Assessing the relationship between food insecurity and mortality among U.S. adults. *Ann Epidemiol* 2019;32:43–8.
- 18 Men F, Gundersen C, Urquia ML, et al. Association between household food insecurity and mortality in Canada: a population-based retrospective cohort study. *CMAJ* 2020;192:E53–60.
- 19 Wen CP, David Cheng TY, Tsai SP, et al. Are Asians at greater mortality risks for being overweight than Caucasians? redefining obesity for Asians. *Public Health Nutr* 2009;12:497–506.
- 20 Pan W-H, Flegal KM, Chang H-Y, et al. Body mass index and obesity-related metabolic disorders in Taiwanese and US whites and blacks: implications for definitions of overweight and obesity for Asians. *Am J Clin Nutr* 2004;79:31–9.
- 21 Chen L, Simonsen N, Liu L. Racial differences of pediatric hypertension in relation to birth weight and body size in the United States. *PLoS One* 2015;10:e0132606.
- 22 Manson S. NIMHD minority health and health disparities research framework: adapted to reflect historic and socio-cultural influences for American Indian and Alaska native nations: us. Department of health and human services; n.d.. Available: <https://www.nimhd.nih.gov/about/overview/research-framework/adaptation-framework.html>
- 23 Devi S. Native American health left out in the cold. *Lancet* 2011;377:1481–2.
- 24 Gurney RM, Caniglia BS, Mix TL, et al. Native American food security and traditional foods: a review of the literature. *Social Compass* 2015;9:681–93.
- 25 Urban Indian Health Institute. Best practices for American Indian and Alaska native data collection; 2020.
- 26 Bauer KW, Widome R, Himes JH, et al. High food insecurity and its correlates among families living on a rural American Indian reservation. *Am J Public Health* 2012;102:1346–52.
- 27 Brown B, Noonan C, Nord M. Prevalence of food insecurity and Health-Associated outcomes and food characteristics of northern plains Indian households. *J Hunger Environ Nutr* 2007;1:37–53.
- 28 Pardilla M, Prasad D, Suratkar S, et al. High levels of household food insecurity on the Navajo nation. *Public Health Nutr* 2014;17:58–65.
- 29 Jernigan VBB, Huyser KR, Valdes J, et al. Food insecurity among American Indians and Alaska natives: a national profile using the current population Survey-Food security supplement. *J Hunger Environ Nutr* 2017;12:1–10.
- 30 Jernigan VBB, Garrouette E, Krantz EM, et al. Food insecurity and obesity among American Indians and Alaska natives and whites in California. *J Hunger Environ Nutr* 2013;8:458–71.
- 31 Blue Bird Jernigan V, Wetherill MS, Heard J, et al. Food insecurity and chronic diseases among American Indians in rural Oklahoma: the thrive study. *Am J Public Health* 2017;107:441–6.
- 32 Berryhill K, Hale J, Chase B, et al. Food security and diet among American Indians in the Midwest. *J Community Health* 2018;43:901–7.
- 33 Gooding HC, Walls CE, Richmond TK. Food insecurity and increased BMI in young adult women. *Obesity* 2012;20:1896–901.
- 34 The National longitudinal study of adolescent to adult health (add health) study design n.d. <https://addhealth.cpc.unc.edu/documentation/study-design/>
- 35 Harris KM, Udry JR, Inter-university Consortium for Political and Social Research (ICPSR). National longitudinal study of adolescent health (add health), 1994–2008; 2014.
- 36 Harris KM, Halpern CT, Whitsel EA, et al. Cohort profile: the National longitudinal study of adolescent to adult health (add health). *Int J Epidemiol* 2019;48:1415–k
- 37 Bickel G, Nord M, Price C, Hamilton W, Cook J. Guide to measuring household food security; 2000.
- 38 Hager ER, Quigg AM, Black MM, et al. Development and validity of a 2-item screen to identify families at risk for food insecurity. *Pediatrics* 2010;126:e26–32.
- 39 Entzel P, Whitsel EA, Richardson A, Tabor J, Hallquist S, Hussey J. Add health wave IV documentation: cardiovascular and anthropometric measures; 2009.
- 40 Whitsel EA, Tabor JW, Nguyen QC, Cuthbertson CC, Wener MH, Potter AJ. Add health wave IV documentation: measures of glucose homeostasis; 2012.
- 41 Lin SS, Kelsey JL. Use of race and ethnicity in epidemiologic research: concepts, methodological issues, and suggestions for research. *Epidemiol Rev* 2000;22:187–202.
- 42 Streiner DL, Best SDL. Best (but oft-forgotten) practices: the multiple problems of multiplicity-whether and how to correct for many statistical tests. *Am J Clin Nutr* 2015;102:721–8.
- 43 Berkowitz SA, Berkowitz TSZ, Meigs JB, et al. Trends in food insecurity for adults with cardiometabolic disease in the United States: 2005–2012. *PLoS One* 2017;12:e0179172.
- 44 Eicher-Miller HA, Mason AC, Weaver CM, et al. Food insecurity is associated with iron deficiency anemia in US adolescents. *Am J Clin Nutr* 2009;90:1358–71.
- 45 Seligman HK, Laraia BA, Kushel MB. Food insecurity is associated with chronic disease among low-income NHANES participants. *J Nutr* 2010;140:304–10.
- 46 Blagg K, Gundersen C, Schanzenbach DW, et al. *Assessing food insecurity on campus*. Urban Institute, 2017.
- 47 Bergmans RS, Coughlin L, Wilson T, et al. Cross-sectional associations of food insecurity with smoking cigarettes and heavy alcohol use in a population-based sample of adults. *Drug Alcohol Depend* 2019;205:107646.
- 48 Armour BS, Pitts MM, Lee C-W. Cigarette smoking and food insecurity among low-income families in the United States, 2001. *Am J Health Promot* 2008;22:386–90.
- 49 Reitzel LR, Chinamuthevi S, Daundasekara SS, et al. Association of problematic alcohol use and food insecurity among homeless men and women. *Int J Environ Res Public Health* 2020;17. doi:10.3390/ijerph17103631. [Epub ahead of print: 21 05 2020].
- 50 Zamora-Kapoor A, Fyfe-Johnson A, Omidpanah A, et al. Risk factors for pre-diabetes and diabetes in adolescence and their variability by race and ethnicity. *Prev Med* 2018;115:47–52.
- 51 Zamora-Kapoor A, Hebert LE, Montañez M, et al. Risk factors in adolescence for the development of elevated blood pressure and hypertension in American Indian and Alaskan native adults. *J Immigr Minor Health* 2021;23:717–724.
- 52 Franklin B, Jones A, Love D, et al. Exploring mediators of food insecurity and obesity: a review of recent literature. *J Community Health* 2012;37:253–64.
- 53 Kim K, Frongillo EA. Participation in food assistance programs modifies the relation of food insecurity with weight and depression in elders. *J Nutr* 2007;137:1005–10.
- 54 Bruening M, Brennhöfer S, van Woerden I, Woerden van I, et al. Factors related to the high rates of food insecurity among diverse, urban College Freshmen. *J Acad Nutr Diet* 2016;116:1450–7.
- 55 Knol LL, Robb CA, McKinley EM, et al. Food insecurity, self-rated health, and obesity among college students. *Am J Health Educ* 2017;48:248–55.
- 56 Lee AM, Scharf RJ, DeBoer MD. Food insecurity is associated with prediabetes and dietary differences in U.S. adults aged 20–39. *Prev Med* 2018;116:180–5.
- 57 Coleman-Jensen A, Rabbitt MP, Gregory CA. U.S. Department of Agriculture, Economic Research Service. In: *Household food security in the United States in 2020*, 2021.
- 58 Fitzgerald N, Hromi-Fiedler A, Segura-Pérez S, et al. Food insecurity is related to increased risk of type 2 diabetes among Latinas. *Ethn Dis* 2011;21:328–34.
- 59 Gundersen C. Measuring the extent, depth, and severity of food insecurity: an application to American Indians in the USA. *J Popul Econ* 2007;21:191–215.
- 60 Srinivasan S, Guillermo T. Toward improved health: disaggregating Asian American and native Hawaiian/Pacific Islander data. *Am J Public Health* 2000;90:1731–4.