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SYSTEMATIC REVIEWS AND META-ANALYSES

Food insecurity and housing instability as determinants of cardiovascular health outcomes: A systematic review

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KEYWORDS
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Food insecurity;
Social determinants of health;
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Health disparities

Abstract *Aims:* The primary objective of this study is to conduct a systematic review of existing literature on the association between food insecurity and housing instability with CVD and its subtypes-related outcomes. Summarizing the comprehensive evidence for independent/interchangeable relationship of food and housing instability with CVD outcomes may inform specific interventions strategies to reduce CVD-risk.
Data synthesis: The search focused on English-language articles in PubMed/Medline, from January 1, 2010, to June 1, 2021, with restriction to the US adult population. We included studies estimating the association between food insecurity or/and housing instability(exposure) and CVD-subtypes-related health outcomes (outcome). The study methodological quality was assessed using the Study Quality Assessment Tools (SQAT). Nineteen studies met eligibility criteria, consisted of 15 cross-sectional and 4 cohort studies. Of total studies, 7 examined housing instability, 11 studies focused on food insecurity, and one examined both. Food insecurity/housing instability was associated with increased overall CVD-mortality rate and greater healthcare cost utilization, while evidence were mixed for hospital readmission rate. By subtype, stroke mortality was greater with food insecurity but not with housing instability. The likelihood of myocardial infarction, coronary heart disease, and congestive heart failure was greater with food insecurity. Although mortality with MI was higher with housing instability, readmission and surgical procedure rates were significantly lower than housing stable adults.
Conclusion: Findings from this review suggest an urgent need to test the impact of screening for food and housing insecurities, referral services, and community engagement for CV health, within clinical and public health settings.
Protocol registration: Prospero CRD4202123352.

1. Introduction

Traditional efforts to improve health in the United States have been driven by attention on fixing the health care system. Other approaches have a wider focus to also address social, economic, and environmental factors that influence health. Recently, the central importance of the association of social determinants of health (SDOH) with

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health outcomes specifically in the context of cardiovascular diseases (CVD) was underscored by the American Heart Association (AHA) and the American College of Cardiology in their 2019 guidelines for clinical risk assessment [1]. However, most studies have addressed SDOH defined as education, socioeconomic status, healthcare access, or racial disparities in CVD [2–7]. Studies of socioeconomic status have focused largely on income and poverty [2,8], whereas more granular measures such as food insecurity, housing instability, have received less attention as drivers of CVD outcomes [6,9,10].

Although the mortality from CVDs has been declining, the prevalence of CVD in the US is expected to rise by 10% by 2030 [11], with persistent geographic disparities in CVD health [12]. This trajectory of CVD burden is possibly the result of a dramatic rise in modifiable risk factors such as obesity, hypertension, diabetes, and physical inactivity over the last three decades. While there is no consensus on the precise cause of the increased CVD burden in the US population, research using comparative risk assessment methods on nationally representative data shows that nearly 45% of cardiometabolic deaths are attributable to poor diets, such as high sodium and processed meat intake, and lower consumption of fruits, vegetables, nuts/seeds, which have also been linked to food insecurity [13–15]. Moreover, poor adherence to modifiable risk factors has been linked to food insecurity, indicating a stronger association with cardiovascular health [16,17].

In 2018, more than 1 in 10 adults were food insecure, and nearly 15% of US adults reported having housing instability (state-variation reported in Supplement 1). A growing body of literature indicates greater cardiometabolic risk from food insecurity and housing insecurity by overlapping pathways from physiological stress response, poor coping mechanisms, and ability to manage chronic conditions [18,19]. More importantly, evidence also indicates a strong positive correlation between food insecurity and housing insecurity as measures reflecting material hardship [20,21], and a potential bidirectional relationship [22]. However, there is a lack of synthesis of recent literature to assess how these two factors, independently and interchangeably, may be associated with CVD outcomes. Existing evidence also varies considerably by CVD outcomes and analytical approaches. In particular, substantial heterogeneity in individual-level cardiovascular events (mortality, myocardial infarction, stroke, coronary heart disease, ischemic heart disease, cardiomyopathy) has not been explored before in the context of both food insecurity and housing instability. With these limitations, the primary objective of this study is to conduct a systematic review of existing literature on the association between food insecurity and housing instability with a range of CVD outcomes. Summarizing the comprehensive evidence for the relationship between food and housing instability with CVD outcomes may inform specific interventions strategies to reduce CVD risk. We additionally provide state-level distribution of these measures, acknowledging pervasive spatial disparities in food and housing instability and CVD mortality. Potential intervention design and policy implications are included in the discussion of the findings.

2. Methods

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) format for this review [23]. The review protocol is registered in PROSPERO (CRD42021233527). The SDOH were selected based on the Healthy People 2020 SDOH Model that includes economic stability as a key dimension. Economic stability includes four sub-domains: poverty, employment, housing instability, and food insecurity [24]. Considering the substantial evidence on poverty and employment as CVD risk factors [25], we narrowed our focus to the other two sub-domains on food insecurity and housing instability. We use three indicators of housing instability (homelessness, housing insecurity, and affordability) from AHA's scientific statement and *Healthy People 2020* [18,24,26]. Food insecurity is defined as the disruption of food intake or eating patterns due to financial issues and other resources [27]. The following CVD subtype outcome categories were selected: CVD-subtype diagnosis; prevalence and incidence; mortality; post-surgical outcomes; hospitalization; and quality of life.

2.1. Study selection

Our inclusion criteria consisted of published original research on associations of housing instability and food insecurity with CVD in adults. Exclusion criteria included: (1) non-human studies, (2) study populations $<$ age18, (3) studies not published in English, (4) studies published outside the United States, (5) reviews, case reports, conference, and letters, (6) studies in which the association between housing instability or food insecurity with CVD was not reported, (7) articles focusing on acquired, congenital, or genetic variants of cardiac conditions, (8) studies classifying race/ethnicity and socioeconomic disparities as pre-existing SDOH, (9) studies with CVD and its subtypes as exposure, and housing instability or food insecurity as outcomes.

2.2. Data source and searches

A literature search was conducted via PubMed/Medline to retrieve records using natural language and vocabulary related to housing instability, food insecurity, and cardiovascular disease outcomes from January 1, 2010, to June 1, 2021. The initial search using the terms below in combination with MeSH, title or abstract headings yielded 993 articles. Key search terms included: "homeless," "housing," "population density," "deprived areas," "urban," "rural," "public housing," "housing affordability," "housing instability," "shelter," "eviction," "foreclosure," "rent," "food insecurity," "food security," "food hardship," "food insufficiency," "hunger," "food stress," "food assistance," "nutritional status," "heart disease," "cardiovascular disease," "ischemic heart disease," "myocardial infarction,"

"pulmonary heart disease," "coronary heart disease," "hypertensive heart disease," and "stroke."

2.3. Data extraction, synthesis, and quality assessment

The reference lists of identified articles were also searched for relevant articles not identified from the search strategy. Of the initial search of 993 articles, 83 were selected for full-text screening based on strict inclusion and exclusion criteria described above. After initial screening, a full-text review was performed using pre-defined criteria to finalize the articles for the systematic review, resulting in 19 included articles (Fig. 1). We simplified the study findings first by the overall summary of the articles and then by sub-types of CVD and related outcomes. Since we found greater variation in how housing and food insecurities were captured, we also synthesized data sources and approaches to collecting such data for future references. The study methodological quality was assessed by the Study Quality Assessment Tools (SQAT) developed by the National Institutes of Health for observational cohort and cross-sectional studies [28].

3. Results

The literature search identified a total of 993 potential studies. After removing duplicates, we reviewed the titles and abstracts of 821 articles and identified 83 studies for inclusion. After a full-text review, 19 of the 83 articles were included in this systematic review. The most common reasons for exclusion were studies not examining housing instability or food insecurity (n = 59), and studies conducted outside of the United States (n = 571).

The 19 studies consisted of 15 cross-sectional and 4 cohort studies (Table 1). Of the total, two studies focused on hospitalized adults, two studies included homeless adults, one study focused on adults with HIV/AIDS, and one studied adults with obesity. One study specifically focused on

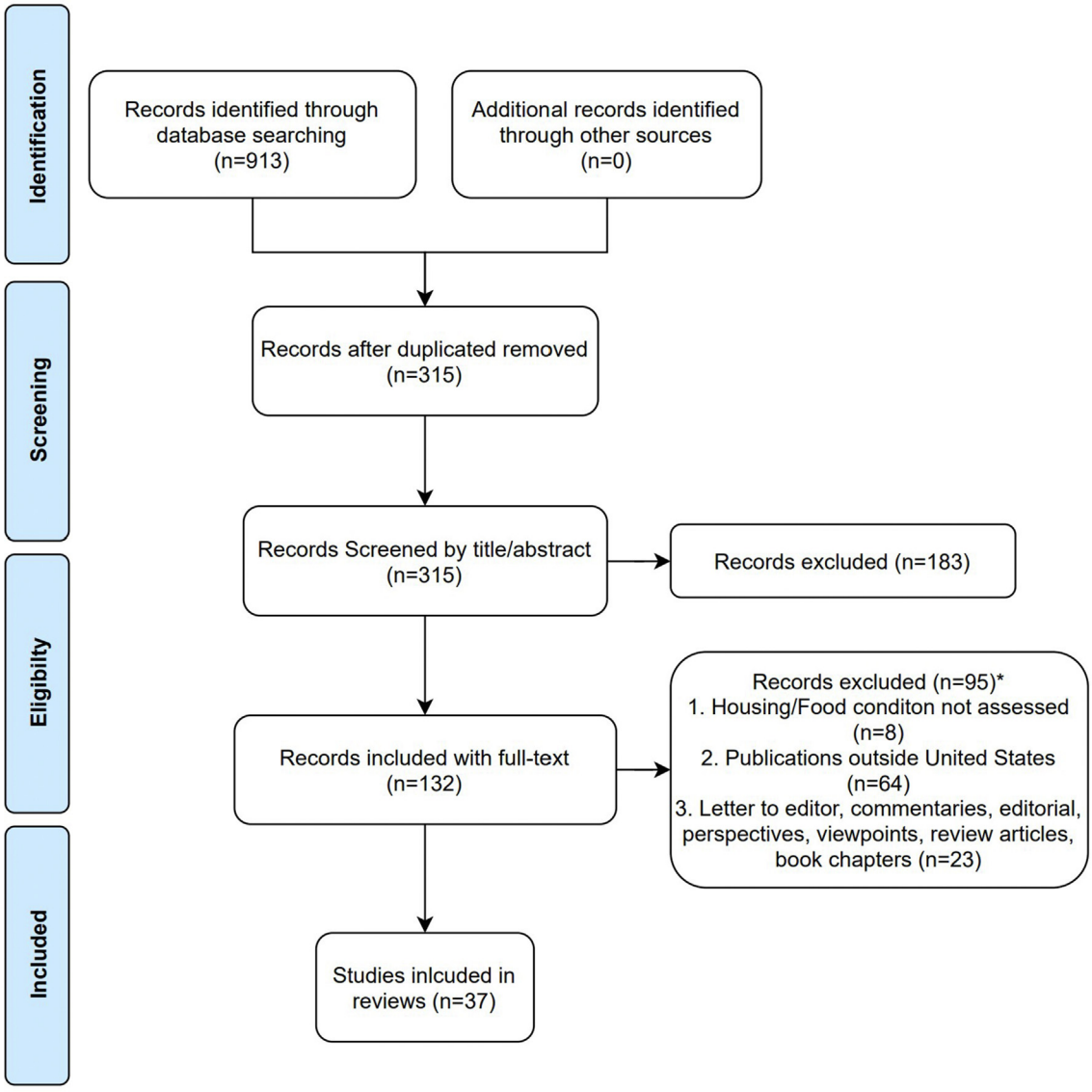

Figure 1 PRISMA diagram.

Table 1 Summary of included studies.

Study Name	Study Design	Study population	Sample size	Age, Mean (SD)	Female (%)	Exposure	Geographic Location
Baggett et al., 2013 [29]	Retrospective Cohort	Homeless adults aged 18 years or older	28,033	41.0 (12.4)	33.6	Housing instability – homelessness	Greater Boston, MA
Balla et al., 2020 [30]	CS	Adult AMI patients aged 18 years or older.	1100241	57.0 (10.0)	N/A	Housing instability – homelessness	Nationwide
Banerjee et al., 2021 [36]	CS	Adults 20 years or older	25,247	46.5 (0.22)	52.1%	Food insecurity	Nationwide
Berkowitz et al., 2014 [37]	CS	Adults aged 19 years or older with at least one chronic condition.	9696	60.9 (0.2)	N/A	Food insecurity	Nationwide
Berkowitz et al., 2017 [38]	CS	Adults aged 19 years or older	21,196	N/A	~ 51.0	Food insecurity	Nationwide
Dean et al., 2021 [39]	CS	Adults aged 18 years or older	13,465	N/A	52.8	Food insecurity	Nationwide
Dirmyer et al., 2016 [31]	Retrospective Cohort	Homeless adults aged 18 years or older	850	43.8 y	29.6	Housing instability-Homelessness	New Mexico
Ford et al., 2013 [40]	CS	Adults aged 20 years or older and free of self-reported cardiovascular disease	10,455	Median: 43.8 y	50.0	Food insecurity	Nationwide
Garcia et al., 2018 [41]	CS	Adults 50 years or older with chronic conditions	14,879	N/A	57.0	Food insecurity	Nationwide
Hessol et al., 2019 [32]	Retrospective Cohort	Individuals diagnosed with HIV/AIDS and death at age 19 years or older	4158	N/A	13.0	Housing instability - homelessness	San Francisco, CA
Palakshappa et al., 2019 [42]	CS	Obese adults (BMI≥30) aged 20 years or older	9203	48.5 (16.1)	65.4	Food insecurity	Nationwide
Pollack et al., 2010 [33]	CS	Adults aged 18 years or older	10,006	N/A	N/A	Housing instability-Affordability	Five counties, PA
Roncarati et al., 2018 [34]	Prospective Cohort	Adults aged 18 years or older	445	44.0 (11.4)	27.6	Housing instability-homelessness	Boston, MA
Saiz et al., 2016 [43]	CS	Adults aged between 21 and 74 years	2935	41.4	50.0	Food insecurity	Wisconsin
Stuppelbeen 2019 [47]	CS	Native Hawaiian Adults aged 18 years or older	9907	N/A	55.6%	Housing instability - insecurity	Nationwide
Stuppelbeen 2019 [47]	CS	Native Hawaiian Adults aged 18 years or older	9907	N/A	55.6%	Food insecurity	Nationwide
Sun et al., 2020 [44]	CS	Adults 40 years or older	27,188	N/A	~55%	Food insecurity	Nationwide
Venci et al., 2018 [45]	CS	Adults aged 18 years or older	30,010	N/A	50.6	Food insecurity	Nationwide
Vercammen et al., 2019 [46]	CS	Adults aged 19 years or older	13,518	~ 40 y	50.0	Food insecurity	Nationwide
Wadhera et al., 2020 [35]	CS	Adults aged 18 years or older	1852790	65.1 (14.8)	N/A	Housing instability-Homelessness	New York, Massachusetts, Florida

CS: Cross-sectional; N/A: Not Available.

Table 2 Summary of evidence by SDOH and CVD outcomes.

Common CVD Conditions	Author Name	Data Source	Exposure Source	Outcome Source	Outcomes related to CVD	Adjusted variables	Bias	Findings
Housing Insecurity								
Overall CVD								
	Baggett et al., 2013 [29]	BHCHP data linked with MDPH death occurrence files. Data year: 2003−2008	Hospital records	ICD-10 Codes	CVD Mortality	Demographics	Conservative bias: The study included currently and formerly homeless adults, and those who exited homelessness may have a lower mortality rate. Not Addressed	Heart disease accounted for 15.6% of all causes of death overall, and a leading cause of death among 45-64-year-old homeless with race-adjusted RR 3.5 (95% CI: 2.8−4.3) in men, and RR 3.0 (95% CI: 1.5−6.1) in women than the general population
	Dirmyer et al., 2016 [31]	State HIDD Data year: 2010−2012	Hospital records and Homeless Shelter Directory	ICD-9 Codes	CVD related 30-day readmission rate	Demographics, length of stay, admissions, discharge status	N/A	The prevalence of CVD was average 6.43% among homeless adults. Patients with CVD were 52% less likely [unadjusted OR 0.48 (95% CI: 0.27−0.84)] to be readmitted. Association was not significant once adjusted
	Hessol et al., 2019 [32]	SFDPH HIV surveillance registry. Data year: 2002−2016	Medical records	ICD-10 codes and death certificate	CVD as opportunistic infection and cause of death in HIV patients	Demographics, a concurrent initial diagnosis of HIV and AIDS, HIV transmission category, income, county of residence at death, year of death	Misclassification bias from death certificate- cause of death. Not Addressed	No significant results were found for mortality due to CVD among homeless individuals with HIV. [unadjusted PR 0.86 (95% CI: 0.71−1.04)]

	Pollack et al., 2010 [33]	SPHHS Data year: 2008	Self-reported	Self-reported	CVD as health measure and healthcare utilization	Demographics, poverty, county of residence, neighborhood safety, quality food access, and a strong social environment	Selection bias: Addressed with propensity score matching	There was no significant association between housing affordability and heart disease [OR 1.04 (95% CI: 0.73 −1.49)]
	Roncarati et al., 2018 [34]	BHCHP data linked with the MDPH death occurrence files, and NDI. Data year: 2000 −2009	Face-to-face encounter records	ICD-10 codes and death certificate	CVD Mortality	Age	Selection bias by enrollment of homeless adults who sought health services. Not addressed.	Higher CVD mortality rates in the unsheltered cohort (18 of 134 deaths [13.4%]) than in the Massachusetts population and in the sheltered adult homeless cohort. Increased SMRs among the unsheltered cohort compared with both the Massachusetts population (SMR, 6.4; 95%CI,3.9−9.9) and the sheltered adult homeless cohort (SMR, 2.4; 95%CI, 1.4−3.7)
	Stuppelbeen 2019 [47]	BRFSS Survey Data year: 2009 −2012	Self-reported	Self-reported	Prevalence and association with CVD	Demographics, number of children in the household, binge drinking, smoking status, body mass index, any exercise in the last 30 days, last doctor checkup, and year	N/A	Compared with housing secure respondents, housing insecure NHOPIs had 85% higher odds of CVD [adjusted OR 1.85 (95% CI: 1.04 −3.28)].

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Table 2 (*continued*)

Common CVD Conditions	Author Name	Data Source	Exposure Source	Outcome Source	Outcomes related to CVD	Adjusted variables	Bias	Findings
Heart Attack/AMI								
	Balla et al., 2020 [30]	NRD Data year: 2015 −2016	ICD-9 and ICD-10 code: Z59.0	ICD-9/10 codes	Rates of CVD invasive assessment and revascularization; In-hospital morbidity, mortality, and cost; and 30-day readmission rates and reasons for readmission.	Demographics	Selection bias: Addressed with propensity score matching.	Homeless patients with AMI hospitalization were less likely to undergo coronary angiography (38.1% vs 54%, $p < 0.001$), percutaneous coronary intervention (24.1% vs 38.7%, $p < 0.001$), or coronary artery bypass grafting (4.9% vs 6.7%. $p < 0.001$). Thirty-day readmission rates were significantly higher in homeless patients (22.5% vs 10%, $p < 0.001$) than in the general population.
	Wadhera et al., 2020 [35]	SID Data year: 2010 −2015	Hospital records	ICD-10 code	In-hospital CVD mortality; Cost of CVD invasive interventions.	Demographics, insurance payer, and clinical comorbidities	N/A	Homeless adults hospitalized for AMI were less likely to undergo coronary angiography compared with non-homeless adults (39.5% vs 70.9%), percutaneous coronary intervention (24.8% vs 47.4%), and coronary artery bypass graft (2.5% vs 7.0%). Risk-standardized mortality was higher for homeless persons with ST-elevation AMI compared with non-homeless persons (8.3% vs 6.2%).

Ischemic Heart Disease								
	Hessol et al., 2019 [32]	SFDPH HIV surveillance registry. Data year: 2002 −2016	Medical records	ICD-10 codes and death certificate	Ischemic heart disease as an opportunistic infection.	Demographics, a concurrent initial diagnosis of HIV and AIDS, HIV transmission category, income, county of residence at death, year of death	Misclassification bias from death certificate- cause of death. Not Addressed.	Homeless individuals were 41% less likely [unadjusted PR 0.59 (95% CI: 0.39−0.88)] to die from ischemic heart disease. Association was not significant once adjusted [aPR 0.87 (95% CI: 0.55−1.38)]
Cardiomyopathy								
	Hessol et al., 2019 [32]	SFDPH HIV surveillance registry. Data year: 2002 −2016	Medical records	ICD-10 codes and death certificate	Cardiomyopathy as an opportunistic infection	Demographics, a concurrent initial diagnosis of HIV and AIDS, HIV transmission category, income, county of residence at death, year of death	Misclassification bias from death certificate- cause of death. Not Addressed.	No significant results were found for mortality due to cardiomyopathy among homeless individuals with HIV. [unadjusted PR 0.89 (95% CI: 0.47 −1.66)]
Stroke								
	Balla et al., 2020 [30]	NRD. Data year: 2015 −2016	ICD-9 and ICD-10 code: Z59.0	ICD-9/10 codes	Stroke-related 30-day readmission rate.	Demographics	Selection bias: Addressed with propensity score matching.	No significant difference was found in clinical stroke as in-hospital outcomes between homeless vs. non-homeless individuals.
	Hessol et al., 2019 [32]	SFDPH HIV surveillance registry. Data year: 2002 −2016	Medical records	ICD-10 codes and death certificate	Stroke as an opportunistic infection	Demographics, a concurrent initial diagnosis of HIV and AIDS, HIV transmission category, income, county of residence at death, year of death	Misclassification bias from death certificate- cause of death. Not Addressed.	No significant results were found for mortality due to cerebrovascular disease among homeless individuals with HIV [unadjusted PR 0.71 (95% CI: 0.41 −1.23)].
	Wadhera et al., 2020 [35]	SID Data year: 2010 −2015	Hospital records	ICD-10 code	In-hospital mortality; Cost of stroke-related invasive interventions	Demographics, insurance payer, and clinical comorbidities	N/A	Homeless adults with stroke were less likely than non-homeless individuals to undergo cerebral angiography (2.9% vs 9.5).

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Table 2 (*continued*)

Common CVD Conditions	Author Name	Data Source	Exposure Source	Outcome Source	Outcomes related to CVD	Adjusted variables	Bias	Findings
Food Insecurity								
Overall CVD								
	Banerjee et al., 2021 [36]	NHANES Data year: 1999−2010	Self-reported	ICD-10 code	CVD Mortality	Demographics, poverty-income ratio, diabetes, CKD, preexisting CVD, and obesity	N/A	Adjusted HRs for cardiovascular mortality (HR 1.75, 95% CI: 1.19−2.57) were significantly higher among food-insecure individuals
	Berkowitz et al., 2014 [37]	NHIS Data year: 2011	Self-reported	Self-reported	Association with history of CVD	Demographics, social, and clinical variables	N/A	The prevalence of food insecurity was 4 times higher among adults with CVD [OR 4.25 (95% CI: 3.44−5.24)].
	Dean et al., 2021 [39]	MEPS Data year: 2016	Self-reported	ICD-10 code	Healthcare expenditure - overall/outpatient/ inpatient/ emergency department/drugs	Demographics, health insurance, region, SNAP receipt, chronic health conditions.	N/A	Relative to food-secure households with CVD, very low food secure households with CVD are 1.9% points (AME 0.019, $P < 0.001$) more likely to have any health care expenditure. Results are not significant for conditional healthcare spending.
	Ford et al., 2013 [40]	NHANES Data year: 2003−2008	Self-reported	Self-reported	10-year cardiovascular disease risk prediction	Demographics, health insurance coverage, and alcohol use, clinical profile	N/A	Participants aged 30−59 years with very low food security were more likely to have a predicted 10-year cardiovascular disease risk greater than 20% than fully food secure participants (adjusted PR 2.38, 95% CI: 1.31−4.31)

	Saiz et al., 2016 [43]	SHOW Data year: 2008–2014	Self-reported	Self-reported	Ideal Cardiovascular Health	Demographics, region, military service, and marital status.	N/A	Food insecurity was associated with being almost half as likely to be in "good" cardiovascular health compared to those who were food secure (OR 0.53, 95% CI: 0.31–0.92)
	Stuppelbeen 2019 [47]	BRFSS Data year: 2009–2012	Self-reported	Self-reported	Prevalence and association with CVD	Demographics, number of children in the household, binge drinking, smoking status, body mass index, any exercise in the last 30 days, last doctor checkup, and year	N/A	Food insecurity was associated with 88% higher odds of CVD (OR 1.88, 95% CI:1.16–3.05) among Whites, and 2-times higher odds (OR 2.08, 95% CI: 1.10–3.78) among NHOPI. Results were not significant for Asians.
	Sun et al., 2020 [44]	NHANES Data year: 1999–2014	Self-reported	ICD-10 Code	CVD Mortality	Demographics, smoking status, alcohol intake, physical activity levels, total energy intake, and Healthy Eating Index 2010 score.	Residual confounding was addressed with propensity score matching.	Participants with very low food security had a higher risk of all-cause and cardiovascular disease mortality, with multivariable-adjusted HRs of 1.32 (95% CI, 1.07–1.62), and 1.53 (95% CI, 1.04–2.26), respectively, compared with those with high food security.
	Vercammen et al., 2019 [46]	NHANES Data year: 2007–2014	Self-reported	Self-reported	10-year risk for CVD event	Age, sex, race/ethnicity, education, marital status, household income, household SNAP participation, and physical activity	Biological data was used to examine CVD risk, to avoid potential biases in self-reported measures	Compared with adults with full food security, those with very low food security had higher odds of ≥20% 10-year cardiovascular disease risk (OR 2.36, 95% CI: 1.25, 4.46)

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Table 2 (*continued*)

Common CVD Conditions	Author Name	Data Source	Exposure Source	Outcome Source	Outcomes related to CVD	Adjusted variables	Bias	Findings
Congestive Heart Failure								
	Berkowitz et al., 2017 [38]	NHANES Data year: 2005 −2012	Self-reported	Self-reported	Association with history of CHF	Not clear	N/A	Food insecurity was greater in participants with congestive heart failure (18.4% vs. 12.1%, $p < 0.05$)
	Venci et al., 2018 [45]	NHIS Data year: 2011	Self-reported	Self-reported	Prevalence and association with CHD	Demographics, number of children in the household, region of residence, weight, and smoking status.	N/A	Adults with low food security had 75% higher odds of CHD (OR: 1.75; 95% CIs: 1.37, 2.24) than food-secure adults.
Coronary Artery Disease/Coronary Heart Disease								
	Berkowitz et al., 2017 [38]	NHANES Data year: 2005 −2012	Self-reported	Self-reported	Association with history of CHD	Not clear	N/A	Food insecurity was greater in participants with CHD (20.5% vs. 11.9%, $p < 0.05$)
	Garcia et al., 2018 [41]	MEPS linked with NHIS Data year: 2013 −2015	Self-reported	Self-reported	Prevalence and Healthcare cost of CAD	Demographics, region, poverty level, health insurance status, adult living alone, SNAP participation, year, and chronic conditions.	N/A	Incremental costs associated with food insecurity among older adults with CHD were $650 (95% CI: −280 to 1680) without any other chronic conditions.
	Palakshappa et al., 2019 [42]	NHANES Data year: 2007 −2014	Self-reported	Self-reported	Obesity-related prevalence and association with coronary artery disease	Demographics, income-to-poverty ratio, smoking status, health insurance, food support program participation.	Residual confounding was addressed with propensity score matching.	Food insecurity was associated with 50% higher odds of CAD (OR: 1.5, 95% CI: 1.1, 2.0).
Stroke								
	Garcia et al., 2018 [41]	MEPS linked with NHIS Data year: 2013 −2015	Self-reported	Self-reported	Prevalence and healthcare cost of stroke	Demographics, region, poverty level, health insurance status, adult living alone, SNAP participation, year, and chronic conditions.	N/A	Incremental costs associated with food insecurity among older adults with stroke was $950 (95% CI: 80 to 1980) without any other chronic conditions.

	Sun et al., 2020 [44]	NHANES Data year: 1999 −2014	Self-reported	ICD-10 Code	Stroke mortality	Demographics, smoking status, alcohol intake, physical activity levels, total energy intake, and Healthy Eating Index 2010 score.	Residual confounding was addressed with propensity score matching.	Compared with participants with high food security, the multivariable-adjusted Stroke HRs (95% CIs) for participants with marginal food security, low food security, and very low food security were 1.08 (0.59 −1.98), 1.35 (0.63 −2.90), and 1.76 (0.65−4.77), respectively.
	Venci et al., 2018 [45]	NHIS Data year: 2011	Self-reported	Self-reported	Prevalence and association with stroke	Demographics, number of children in the household, region of residence, weight, and smoking status.	N/A	Association was not significant between food insecurity and stroke [OR: 1.10 (95% CI: 0.82 −1.48)].
Heart Attack/AMI								
	Venci et al., 2018 [45]	NHIS Data year: 2011	Self-reported	Self-reported	Prevalence and association with a heart attack	Demographics, number of children in the household, region of residence, weight, and smoking status.	N/A	Adults with low food security had 40% higher odds of heart attack (OR: 1.40; 95% CI: 1.08, 1.81) than food-secure adults.

Table 3 Housing instability and food insecurity database and questionnaires.

Database	Questionnaire
Housing Instability	
BHCHP	Identified by the federal definition of homelessness under Boston Health Care for Homeless Program (BHCHP). Unsheltered adults were identified if they reported sleeping outside for 1 or more nights during the survey year and had at least one face-to-face encounter with BHCHP's street team staff on the street or at an outside location during daytime or nighttime clinical session in the same year. Source: www.bhchp.org Availability – restricted
NRD	ICD9 V60.0 & ICD-10 Z59.0 code Source: https://www.hcup-us.ahrq.gov/nrdoverview.jsp Availability – restricted, purchase required
HIDD	A homeless record was defined by the patient's address; either recorded as "homeless," "none," or an address for a shelter in Albuquerque from Homeless Shelter Directory (2015) website. Source: https://www.nmhealth.org/about/erd/hsep/hidd/Availability – restricted, purchase required from HCUP
SFO HIV Surveillance Registry	An individual is defined as homeless based on federal definition if their periodic review of medical records denote that the patient is not housed or homeless at the time of HIV or AIDS diagnosis, at follow-up, or at death. Source: https://www.sfdph.org/dph/comupg/oprograms/HIVepiSec/HIVepiSecReports.asp Availability – restricted, access upon request
Southeastern Pennsylvania Household Health Survey	Housing affordability was assessed with a single item: Housing costs refer to the money that you and your household spend on utility bills, rent, mortgage payments, and property taxes. Overall, how difficult was it for you to afford your housing costs during the past year? Response options were very difficult, somewhat difficult, not very difficult, and not difficult at all. Source: https://research.phmc.org/52-project-spotlight/248-southeastern-pennsylvania-household-health-survey Availability – restricted, access upon request
BRFSS	"How often in the past 12 months would you say you were worried or stressed about having enough money to pay for your rent/mortgage?" was scored on a 5-point scale from "always" to "never." Source: https://www.cdc.gov/brfss/annual_data/annual_data.htm Availability – publicly available to download, free
SID	Homelessness is directly reported by the hospitals. There is an indicator for each discharge from inpatient hospitals or hospital-affiliated Eds regarding patients' homelessness status. Source: https://www.hcup-us.ahrq.gov/sidoverview.jsp Availability – restricted, purchase required
Food Insecurity	
NHIS/MEPS	1. I worried whether our food would run out before we got money to buy more. 2. The food that we bought just didn't last, and we didn't have money to get more. 3. We couldn't afford to eat balanced meals. 4. In the last 30 days, did you or other adults in your household ever cut the size of your meals or skip meals because there wasn't enough money for food? 5. How often did this happen — range 1–30 days 6. In the last 30 days, did you ever eat less than you felt you should because there wasn't enough money to buy food? 7. In the last 30 days, were you ever hungry but didn't eat because you couldn't afford enough food? 8. Sometimes people lose weight because they don't have enough to eat. In the last 30 days, did you lose weight because there wasn't enough food? 9. In the last 30 days, did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food? 10. How often did this happen — range 1–30 days. Source: NHIS: https://www.cdc.gov/nchs/nhis/data-questionnaires-documentation.htm MEPS: https://www.meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp Availability – publicly available to download, free
BRFSS	How often in the past 12 months would you say you were worried or stressed about having enough money for nutritious meals? The score ranged on a 5-point scale from "always" to "never." Source: https://www.cdc.gov/brfss/annual_data/annual_data.htm Availability – publicly available to download, free

Table 3 (*continued*)

Database	Questionnaire
NHANES	1. I worried whether our food would run out before we got money to buy more. 2. The food that we bought just didn't last, and we didn't have money to get more. 3. We couldn't afford to eat balanced meals. 4. In the last 12 months, did you or other adults in your household ever cut the size of your meals or skip meals because there wasn't enough money for food? 5. How often did this happen — almost every month, some months but not every month, or in only one or two months? 6. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money to buy food? 7. In the last 12 months, were you ever hungry but didn't eat because you couldn't afford enough food? 8. Sometimes people lose weight because they don't have enough to eat. In the last 12 months, did you lose weight because there wasn't enough food? 9. In the last 12 months, did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food? 10. How often did this happen — almost every month, some months but not every month, or in only one or two months? Source: https://wwwn.cdc.gov/nchs/nhanes/Default.aspx Availability – publicly available to download, free
SHOW	In the last 12 months, have you been concerned about having enough food for you or your family? – Yes/No Source: https://show.wisc.edu/data/Availability – Restricted, access upon request, free

BHCHP: Boston Health Care for Homeless Program; MDPH: Massachusetts Department of Public Health; NDI: National Death Index; HIDD: Hospital Inpatient and Discharge Database; HCUP: Healthcare Cost and Utilization Project; SFDPH: San Francisco Department of Public Health; SPHHS: Southeastern Pennsylvania Household Health Survey; BRFSS: Behavioral Risk Factor Surveillance System; NRD: National Readmission Database; SID: State Inpatient Database; NHANES: National Health and Nutrition Examination Survey; NHIS: National Health Interview Survey; MEPS: Medical Expenditure Panel Survey; SHOW: Survey of the Health of Wisconsin.

individuals of Hawaiian race. Sample sizes ranged from 568 to 1,852,790. Of the total, 12 studies drew data from national, 2 studies from state-level, and 5 studies from county-level datasets or surveys. Overall 12 studies were published on or after 2018 and were conducted at a national level.

Of the 19 included studies, 7 studies examined housing instability [29–35], 11 studies examined food insecurity [36–46], and 1 study examined both as social determinants of cardiovascular outcomes [47].

3.1. Housing instability and CVD

Eight articles were identified that examined housing instability associations with CVD health outcomes (Table 2). Six studies focused on homelessness [29–32,34,35], one on housing affordability [33], and one on housing insecurity [47], as characteristics of instability. Three studies included 100% homeless population to identify an association with CVD outcomes [29,31,34]. The prevalence of housing instability ranged from 0.4% to 14% in other studies. Of the total, five studies used administrative data from hospital discharge and readmission [29–31,34,35], while three studies used survey data [32,33,47]. Three studies identified housing status from hospital records [29,31,35], two from self-reported survey questions [33,47], one from a medical record [32], one from face-to-face encounters [34], and one from diagnostic codes [30]. CVD outcomes ranged from mortality, invasive treatment assessment, in-hospital morbidity, 30-day readmission rate, admission cost, healthcare utilization, and CVD as an opportunistic infection. CVD was reported as a leading cause of death among homeless people, with a 2–3 fold higher rate than the general population [29,34]. A study from the surveillance of homeless HIV patients reported a 41% lower likelihood of death from ischemic heart disease than non-homeless HIV-positive individuals [32]. Patients with Acute Myocardial Infarction (AMI) who were homeless were also less likely to undergo coronary angiography (38.1% vs 54%, $p < 0.001$), percutaneous coronary intervention (24.1% vs 38.7%, $p < 0.001$), or coronary artery bypass grafting (4.9% vs 6.7%, $p < 0.001$) than the general population [30]. One study found that patients who were homeless were 52% less likely to be readmitted with a primary diagnosis of CVD [31], while another study found a higher rate of 30-day readmission (8.3% vs. 6.2%, $p < 0.001$) than adults with AMI who were not homeless [30]. There was no significant association found between housing affordability and CVD outcomes [33]. However, individuals reporting housing insecurities had 85% higher odds of CVD (OR = 1.85; 95% CI 1.04–3.28) than housing-secure respondents of the Hawaiian race [47].

Three studies reported stroke mortality as an outcome among adults who were homeless and not homeless, and found no differences[30,32,35]. However, adults with stroke who were homeless were less likely to undergo cerebral angiography (2.9% vs. 9.5%, $p < 0.001$) than their counterparts [35].

3.2. Food insecurity and CVD

Eleven studies assessed the effect of food insecurity on CVD outcomes [37–47]. All studies were conducted using cross-sectional surveys. Of the total, only one study used a state-level health survey [43], whereas the other studies used national survey data, mainly National Health

Interview Survey (NHIS), National Health and Nutrition Examination Survey (NHANES), Medical Expenditure Panel Survey (MEPS), and Behavioral Risk Factor Surveillance System (BRFSS) (Table 3). The prevalence of food insecurity ranged from 5.7% to 18.8% in these studies. Food insecurity was measured using self-reported survey questions in all studies. Five studies were conducted using NHANES, which measured food insecurity using a validated questionnaire [38,40,42,44,46]. Two studies used NHIS, one used MEPS, and one with BRFSS data, which measured self-reported food insecurity [37,45,47].

All studies measured self-reported CVD outcomes, except two studies measuring with ICD-10 codes. All studies reported a positive association between food insecurity and CVD outcomes. The prevalence of food insecurity was significantly higher among adults with a history of CVD. Overall, food insecurity was associated with 2–4 times greater odds of CVD. One study found 75% higher odds of CHD (OR = 1.75; 95% CI: 1.37–2.24) among adults with low food security. The mean incremental cost of CHD was $650, and $950 for stroke among adults with food insecurity and without any other chronic conditions. Adults aged 30–59 years with food insecurity had a predicted 10-year cardiovascular risk 20% greater than food-secure individuals [40]. Of two studies with CVD outcomes based on ICD-10 codes, one reported a 53% greater CVD mortality due to food insecurity compared to food-secure individuals, while the other reported higher healthcare expenditure [39,44].

3.3. Quality of studies

Fifteen studies were assessed as fair quality, and 4 studies as poor quality (Table 4). All studies had a participation rate greater than 50%. Most studies had self-reported exposure of interest (food insecurity or housing instability) prior to CVD outcomes. Moreover, 10 studies also relied on self-reported CVD outcomes. These findings were more common in studies focused on food insecurities. Since many studies were cross-sectional in nature, the designs were weak and lacked a convincing comparison group. Further, the timeframe would not be insufficient to reasonably expect to see any association between food insecurity or housing instability and CVD outcomes. The factors contributing to a fair

Table 4 Study quality assessment.

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Overall
Baggett et al., 2013 [29]	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	Fair
Balla et al., 2020 [30]	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	N	Y	Y	Fair
Banerjee et al., 2021 [36]	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	Y	Fair
Berkowitz et al., 2014 [37]	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	Y	Poor
Berkowitz et al., 2017 [38]	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	N	Y	N	Poor
Dean et al., 2021 [39]	Y	Y	Y	Y	N	N	N	Y	Y	N	Y	N	N	Y	Poor
Dirmyer et al., 2016 [31]	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	N	Y	Y	Fair
Ford et al., 2013 [40]	Y	Y	Y	Y	Y	N	Y	Y	Y	N	Y	N	Y	Y	Fair
Garcia et al., 2018 [41]	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	Y	Fair
Hessol et al., 2019 [32]	Y	Y	Y	N	Y	Y	Y	N	Y	N	Y	N	Y	Y	Fair
Palakshappa et al., 2019 [42]	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	Y	Fair
Pollack et al., 2010 [33]	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	N	Y	Y	Fair
Roncarati et al., 2018 [34]	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N	Y	Y	Fair
Saiz et al., 2016 [43]	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	Y	Fair
Stuppelbeen 2019 [47]	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	N	Y	Y	Poor
Sun et al., 2020 [44]	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	Y	Fair
Venci et al., 2018 [45]	Y	Y	Y	Y	Y	N	Y	Y	Y	N	Y	N	Y	Y	Fair
Vercammen et al., 2019 [46]	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N	Y	Y	Fair
Wadhera et al., 2020 [35]	Y	Y	Y	Y	N	N	N	N	Y	N	Y	N	Y	Y	Fair

Questions.
1. Was the research question or objective in this paper clearly stated?.
2. Was the study population clearly specified and defined?.
3. Was the participation rate of eligible persons at least 50%?.
4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?.
5. Was a sample size justification, power description, or variance and effect estimates provided?.
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?.
7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?.
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as a continuous variable)?.
9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?.
10. Was the exposure(s) assessed more than once over time?.
11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?.
12. Were the outcome assessors blinded to the exposure status of participants?.
13. Was loss to follow-up after baseline 20% or less?.
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcomes(s)?.

quality assessment included cohort studies with a reasonable timeframe for someone to expect any association, clearly defined exposures, and outcomes with valid and reliable sources, and attempt to address study biases.

Of the total, four studies provided information on variance and effect estimates and used propensity score matching to ensure covariate balancing in both treatment and control groups and thus partially controlled for selection bias at least on observable factors [30,33,42,44]. There was also a high risk of detection bias, as outcome assessors and data analysts were unblinded in all studies. Since most studies used surveys with self-reported measures rather than objective measures, they are also subject to recall and other biases.

4. Discussion

This systematic review is the first to synthesize the literature regarding the impact of food insecurity and housing instability on cardiovascular disease outcomes in adults. Of total 19 articles, 7 studies examined housing instability, 11 studies examined food insecurity, and 1 study examined both as social determinants of CVD outcomes. All studies were observational rather than interventional. For the most part, studies were cross-sectional or cohort design, limiting the causal interpretation. Many examined the most extreme forms of housing or food insecurity, limiting their generalizability. However, based on the studies reviewed, there is an association with CVD-related hospitalization, frequent readmission, mortality, invasive procedural outcomes, and cost of care to varying degrees. This suggests that further study is needed on how food insecurity and housing instability as SDOH influence the progression of cardiovascular health and to identify intervention points. One testable intervention approach could be to routinely screen CVD patients for housing and food insecurities across care settings, including annual and routine visits, diabetes or obesity clinics, community health centers, primary care, and specialty practices and to connect patients with food and housing resources where they exist.

The review findings indicate that CVD is a leading cause of death among individuals who are homeless. Evidence shows that barriers to CVD care in individuals who are homeless are likely to be prevalent, such as locating nightly shelter, necessary clothing, adequate and appropriate food, access to regular health care, and medication adherence [18]. The prevalence of CVD risk factors may also be higher among individuals who confront housing instability [48]. One study reported that developing CVD may have led to housing insecurity. However, the cross-sectional nature of this study limits the identification of the possible direction of this relationship. Another study using similar data from BRFSS, examined data on respondents in Hawaii and found that housing insecurity was associated with CVD in native Hawaiian and other Pacific Islanders [47]. In contrast, a study of Philadelphia metropolitan residents found no association between housing insecurities and self-reported CVD [33]. A study using hospital discharge data from New Mexico state found that patients who were homeless were less likely to be readmitted with a primary diagnosis of CVD [31], while another study using national hospital discharge data found a higher rate of 30-day readmission [30]. Another factor driving readmission and lower surgical rates for individuals who are homeless may be physicians' concern about lack of medication adherence post-surgery and potential harm [18,35,49]. Homeless adults in one study were found to be less likely to undergo cardiac procedures than the general population, which could be attributable to a variety of reasons such as stress, hygiene, and medication adherence challenges [31]. In this study the uninsured rate among individuals who were homeless was 4.9%, indicating that financial access to health care was not a barrier for most. However, this study included only three states, Massachusetts, New York, and Florida, and uninsured rates may be higher in other parts of the country, particularly in states that have not expanded Medicaid. Moreover, not all providers participate in Medicaid which covers a disproportionate fraction of adults who are homeless.

We noted inconsistencies in how housing instability has been measured across the studies. Four studies identified housing instability using hospital records, two used medical records (ICD codes), one used a self-rated survey, and one a face-to-face interview. In contrast, food insecurity measurement was more consistent across studies, mainly because they relied on national survey data. Two major databases, NHIS and NHANES, have consistent 10-item food insecurity measures. In contrast, the BRFSS survey measures food insecurity with one to three questions. However, a study published by the CDC researchers noted greater reliability of the BRFSS food insecurity module when compared with USDA's CPS-FSS measure with the primary purpose of having a concise measure in a single-question format for the benefit of larger health surveys in capturing SDOH [50].

We also noted a lack of well-designed studies aimed at unraveling causality between food insecurity or housing instability and poor CVD outcomes, which is at odds with the widespread acceptance of these conditions as risk factors for CVD [51]. To be more clear, consider the case of food insecurity. In the reviewed studies, food insecurity is interpreted as leading to poor CVD outcomes—meaning, in regression analysis, CVD outcomes are the dependent variable and food insecurity is one of the independent variables. In contrast, several studies have used CVD as a predictor variable and food insecurity as a dependent variable [48,52]. In all reviewed studies, the causal effects of housing instability and food insecurity were not clearly identified after controlling for other observed characteristics from the database. Two studies from the Boston Healthcare for Homeless Program (BHCHP) measured homelessness from a one-time face-to-face encounter with staff members and measured CVD from ICD codes [29,34]. One of these two studies controlled only for age, while the other additionally controlled for sex and race. Neither controlled for food insecurity. Future studies should consider strong designs to account for confounding and interactive effects of food insecurity and housing instability on CVD outcomes. Addressing these modifiable

risk factors likely to reduce stress and increase medication adherence among other pathways by which food insecurity and housing instability affect CVD health [18,19].

One major takeaway from the literature was the lack of interventional studies or strong natural experiments to identify the effects of housing and food insecurities on CVD and related risk factors. There have been many interventions including healthy home education, housing and food vouchers, and affordable housing initiatives to improve overall health [53–55], however, we still have not explored the effects of such programs on CVD as a leading cause of death. Future research should consider using longitudinal studies with appropriate methods to address causality.

4.1. Policy implications

Our study findings have important implications for clinical practice, research, and policy, as we have identified several unanswered questions. No published studies were identified that addressed the interdependent association of housing and food insecurities with CVD outcomes. While it is likely that individuals who are homeless may suffer from food insecurities [22,56], these two conditions together could potentially have larger effects on CVD. Although this review considers homelessness, affordability, and insecurity as a measure of instability, it is important to understand that other housing constructs such as quality and safety, accessibility, and neighborhood environment may also influence cardiovascular health outcomes [18,57–59]. The majority of studies have measured housing and food insecurities using valid and reliable survey questions. However, there is no standardized questionnaire or measurement scale, leading to variation in findings. Moreover, none of the studies attempted to capture the duration of housing instability and food insecurity over time. The dimensions of these conditions are measured in a variety of surveys and administrative databases. However, our current measurements are still limited in capturing how people become housing or food insecure, how they move between different types of housing instability or food insecurity, and how they exit from these conditions into a more stable environment. Future efforts should target collecting such information, which could help policymakers and practitioners make decisions about how and where to target resources.

Public programs like Housing Choice Vouchers and Supplemental Nutrition Assistance Program (SNAP) address housing and food insecurities. However, evidence of their effectiveness relative to CVD is mixed. A prospective study of a large study sample found that individuals participating in SNAP had higher CVD mortality than nonparticipants, highlighting differences in the client characteristics of those who select into these programs [60]. A report from the Center on Budget and Policy Priorities (CBPP) stated that 75% of low-income at-risk renters do not receive federal rental assistance [61]. These findings highlight the potential for a broader partnership of healthcare, food, and housing sectors in improving health disparities [62,63]. ProMedica, a health system in Ohio and Michigan began screening hospitalized patients for food insecurity with their two-questionnaire screening tool and opened two "food pharmacies," where food-insecure patients are referred by primary care physicians, and counseled by dietitians [62]. Different forms of this innovative approach could be studied in other health systems. Other testable approaches could be financial incentives embedded in the accountable care models and other value-based payments, which are designed to encourage health systems to play a larger role in identifying, referring, and possible directly addressing housing and food challenges [64].

Several studies recorded housing instability using hospital records or ICD codes, which highlights an opportunity to implement a program or data collection strategy that captures SDOH in electronic health records [30–32]. Recent trends in the United States have raised grave concern, as we are witnessing for the first time in decades a decline in the slowdown of CVD mortality against persistent health disparities [65,66]. One way to tackle this situation would be to reduce the knowledge gap related to successful interventions among vulnerable populations, such as adults who are homeless or food-insecure.

4.2. Limitations

The result of this systematic review should be interpreted in the context of the following limitations. First, the search was restricted to studies published in the English language and conducted in the United States only, which limits the generalizability of these findings. Second, the majority of studies were of poor to fair quality, which limits their usefulness in guiding efforts related to CVD. Many of the studies measured exposures and outcomes from self-reported survey questions. However, some of these studies utilized national survey data with validated survey questions. Third, all but 4 studies used a cross-sectional design. While cross-sectional designs are useful in determining the prevalence of exposures in a given population, these studies are limited in their ability to determine predictive and causal relationships. Fourth, owing to the heterogeneity among the included studies (e.g., different CVD outcomes, various sources, variation in SDOH measurement), it was not possible to conduct a meta-analysis.

5. Conclusion

Food and housing are the major correlates of adverse cardiovascular health outcomes in adults. This review findings underscore that housing instability and food insecurity are independently associated with many CVD-subtypes related outcomes, including mortality, frequent hospitalizations, readmission, limited invasive procedures, worse outcomes, and greater financial burden and inpatient resource utilization. Future studies should focus on effectively capturing SDOH in CVD patients and conducting longitudinal studies with innovative interventions. Findings from this review suggest an urgent need to test a holistic vision of cardiovascular health with routine SDOH screening and referral services, along with community engagement.

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Appendix A. Supplementary data

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References

[1] Hammond G, Joynt Maddox KE. A theoretical framework for clinical implementation of social determinants of health. JAMA Cardiol 2019;4:1189–90. https://doi.org/10.1001/jamacardio.2019.3805.

[2] Schultz WM, Kelli HM, Lisko JC, Varghese T, Shen J, Sandesara P, et al. Socioeconomic status and cardiovascular outcomes: challenges and interventions. Circulation 2018;137:2166–78. https://doi.org/10.1161/CIRCULATIONAHA.117.029652.

[3] Rosengren A, Smyth A, Rangarajan S, Ramasundarahettige C, Bangdiwala SI, AlHabib KF, et al. Socioeconomic status and risk of cardiovascular disease in 20 low-income, middle-income, and high-income countries: the Prospective Urban Rural Epidemiologic (PURE) study. Lancet Global Health 2019;7:e748–60. https://doi.org/10.1016/S2214-109X(19)30045-2.

[4] Karnati SA, Wee A, Shirke MM, Harky A. Racial disparities and cardiovascular disease: one size fits all approach? J Card Surg 2020;35:3530–8. https://doi.org/10.1111/jocs.15047.

[5] Graham G. Disparities in cardiovascular disease risk in the United States. Curr Cardiol Rev 2015;11:238–45. https://doi.org/10.2174/1573403X11666141122220003.

[6] Parekh T, Desai R, Pemmasani S, Cuellar A. Impact of social determinants of health on cardiovascular diseases. J Am Coll Cardiol 2020;75:1989. https://doi.org/10.1016/S0735-1097(20)32616-4.

[7] Desai R, Patel U, Parekh T, Hanna B, Sitammagari K, Fong HK, et al. Nationwide trends in prevalent cardiovascular risk factors and diseases in young adults: differences by sex and race and in-hospital outcomes. South Med J 2020;113:311–9. https://doi.org/10.14423/smj.0000000000001106.

[8] Economic stability - healthy people 2030. health.gov n.d, https://health.gov/healthypeople/objectives-and-data/browse-objectives/economic-stability. [Accessed 9 February 2022].

[9] Jilani MH, Javed Z, Yahya T, Valero-Elizondo J, Khan SU, Kash B, et al. Social determinants of health and cardiovascular disease: current state and future directions towards healthcare equity. Curr Atherosclerosis Rep 2021;23:55. https://doi.org/10.1007/s11883-021-00949-w.

[10] Parekh T. Age-standardized prevalence of social determinants of health and associated race-ethnic disparities in stroke survivors. Eur J Prev Cardiol 2021;28. https://doi.org/10.1093/eurjpc/zwab061.210.

[11] Heidenreich PA, Albert NM, Allen LA, Bluemke DA, Butler J, Fonarow GC, et al. Forecasting the impact of heart failure in the United States: a policy statement from the American Heart Association. Circ Heart Fail 2013;6:606–19. https://doi.org/10.1161/HHF.0b013e318291329a.

[12] Parcha V, Kalra R, Suri SS, Malla G, Wang TJ, Arora G, et al. Geographic variation in cardiovascular health among American adults. Mayo Clin Proc 2021;96:1770–81. https://doi.org/10.1016/j.mayocp.2020.12.034.

[13] Micha R, Peñalvo JL, Cudhea F, Imamura F, Rehm CD, Mozaffarian D. Association between dietary factors and mortality from heart disease, stroke, and type 2 diabetes in the United States. JAMA 2017;317:912–24. https://doi.org/10.1001/jama.2017.0947.

[14] Hanson KL, Connor LM. Food insecurity and dietary quality in US adults and children: a systematic review. Am J Clin Nutr 2014;100:684–92. https://doi.org/10.3945/ajcn.114.084525.

[15] Leung CW, Epel ES, Ritchie LD, Crawford PB, Laraia BA. Food insecurity is inversely associated with diet quality of lower-income adults. J Acad Nutr Diet 2014;114:1943–1953.e2. https://doi.org/10.1016/j.jand.2014.06.353.

[16] Eicher-Miller HA. A review of the food security, diet and health outcomes of food pantry clients and the potential for their improvement through food pantry interventions in the United States. Physiol Behav 2020;220:112871. https://doi.org/10.1016/j.physbeh.2020.112871.

[17] Gundersen C, Ziliak JP. Food insecurity and health outcomes. Health Aff Proj Hope 2015;34:1830–9. https://doi.org/10.1377/hlthaff.2015.0645.

[18] Mario Sims, Kershaw Kiarri N, Khadijah Breathett, Jackson Elizabeth A, Lewis Lisa M, Mujahid Mahasin S, et al. Importance of housing and cardiovascular health and well-being: a scientific statement from the American heart association. Circ Cardiovasc Qual Outcomes 2020;13:e000089. https://doi.org/10.1161/HCQ.0000000000000089.

[19] Palakshappa D, Ip EH, Berkowitz SA, Bertoni AG, Foley KL, Miller DP, et al. Pathways by which food insecurity is associated with atherosclerotic cardiovascular disease risk. J Am Heart Assoc 2021;10:e021901. https://doi.org/10.1161/JAHA.121.021901.

[20] King C. Food insecurity and housing instability in vulnerable families. Rev Econ Househ 2018;16:255–73.

[21] Kushel MB, Gupta R, Gee L, Haas JS. Housing instability and food insecurity as barriers to health care among low-income Americans. J Gen Intern Med 2006;21:71–7. https://doi.org/10.1111/j.1525-1497.2005.00278.x.

[22] Lee CY, Zhao X, Reesor-Oyer L, Cepni AB, Hernandez DC. Bidirectional relationship between food insecurity and housing instability. J Acad Nutr Diet 2021;121:84–91. https://doi.org/10.1016/j.jand.2020.08.081.

[23] Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 2009;151:264–9. https://doi.org/10.7326/0003-4819-151-4-200908180-00135. W64.

[24] Social determinants of health. Healthy People; 2020. n.d, https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-health/interventions-resources. [Accessed 26 February 2022].

[25] Virtanen M, Nyberg ST, Batty GD, Jokela M, Heikkilä K, Fransson EI, et al. Perceived job insecurity as a risk factor for incident coronary heart disease: systematic review and meta-analysis. BMJ 2013;347:f4746. https://doi.org/10.1136/bmj.f4746.

[26] Housing instability. Healthy people. 2020. Retrieved from, https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-health/interventions-resources/housing-instability#1 n.d.

[27] Food insecurity. Health people. 2020. Retrieved from, https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-health/interventions-resources/food-insecurity n.d.

[28] Study quality assessment tools | NHLBI, NIH. n.d, https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools. [Accessed 4 August 2021].
[29] Baggett TP, Hwang SW, O'Connell JJ, Porneala BC, Stringfellow EJ, Orav EJ, et al. Mortality among homeless adults in Boston: shifts in causes of death over a 15-year period. JAMA Intern Med 2013;173:189–95. https://doi.org/10.1001/jamainternmed.2013.1604.
[30] Balla S, Alqahtani F, Alhajji M, Alkhouli M. Cardiovascular outcomes and rehospitalization rates in homeless patients admitted with Acute myocardial infarction. Mayo Clin Proc 2020;95:660–8. https://doi.org/10.1016/j.mayocp.2020.01.013.
[31] Dirmyer VF. The frequent fliers of New Mexico: hospital readmissions among the homeless population. Soc Work Publ Health 2016;31:288–98. https://doi.org/10.1080/19371918.2015.1101036.
[32] Hessol NA, Eng M, Vu A, Pipkin S, Hsu LC, Scheer S. A longitudinal study assessing differences in causes of death among housed and homeless people diagnosed with HIV in San Francisco. BMC Publ Health 2019;19:1440. https://doi.org/10.1186/s12889-019-7817-7.
[33] Pollack CE, Griffin BA, Lynch J. Housing affordability and health among homeowners and renters. Am J Prev Med 2010;39:515–21. https://doi.org/10.1016/j.amepre.2010.08.002.
[34] Roncarati JS, Baggett TP, O'Connell JJ, Hwang SW, Cook EF, Krieger N, et al. Mortality among unsheltered homeless adults in Boston, Massachusetts, 2000-2009. JAMA Intern Med 2018;178:1242–8. https://doi.org/10.1001/jamainternmed.2018.2924.
[35] Wadhera RK, Khatana SAM, Choi E, Jiang G, Shen C, Yeh RW, et al. Disparities in care and mortality among homeless adults hospitalized for cardiovascular conditions. JAMA Intern Med 2020;180:357–66. https://doi.org/10.1001/jamainternmed.2019.6010.
[36] Banerjee S, Radak T, Khubchandani J, Dunn P. Food insecurity and mortality in American adults: results from the NHANES-linked mortality study. Health Promot Pract 2021;22:204–14. https://doi.org/10.1177/1524839920945927.
[37] Berkowitz SA, Seligman HK, Choudhry NK. Treat or eat: food insecurity, cost-related medication underuse, and unmet needs. Am J Med 2014;127:303–310.e3. https://doi.org/10.1016/j.amjmed.2014.01.002.
[38] Berkowitz SA, Berkowitz TSZ, Meigs JB, Wexler DJ. Trends in food insecurity for adults with cardiometabolic disease in the United States: 2005-2012. PLoS One 2017;12:e0179172. https://doi.org/10.1371/journal.pone.0179172.
[39] Dean EB, French MT, Mortensen K. Food insecurity, health care utilization, and health care expenditures. Health Serv Res 2020;55(Suppl 2):883–93. https://doi.org/10.1111/1475-6773.13283.
[40] Ford ES. Food security and cardiovascular disease risk among adults in the United States: findings from the National Health and Nutrition Examination Survey, 2003-2008. Prev Chronic Dis 2013;10:E202. https://doi.org/10.5888/pcd10.130244.
[41] Garcia SP, Haddix A, Barnett K. Incremental health care costs associated with food insecurity and chronic conditions among older adults. Prev Chronic Dis 2018;15:E108. https://doi.org/10.5888/pcd15.180058.
[42] Palakshappa D, Speiser JL, Rosenthal GE, Vitolins MZ. Food insecurity is associated with an increased prevalence of comorbid medical conditions in obese adults: NHANES 2007-2014. J Gen Intern Med 2019;34:1486–93. https://doi.org/10.1007/s11606-019-05081-9.
[43] Saiz AMJ, Aul AM, Malecki KM, Bersch AJ, Bergmans RS, LeCaire TJ, et al. Food insecurity and cardiovascular health: findings from a statewide population health survey in Wisconsin. Prev Med 2016;93:1–6. https://doi.org/10.1016/j.ypmed.2016.09.002.
[44] Sun Yangbo, Liu Buyun, Rong Shuang, Yang Du, Xu Guifeng, Snetselaar Linda G, et al. Food insecurity is associated with cardiovascular and all-cause mortality among adults in the United States. J Am Heart Assoc 2020;9:e014629. https://doi.org/10.1161/JAHA.119.014629.
[45] Venci BJ, Lee S-Y. Functional limitation and chronic diseases are associated with food insecurity among U.S. adults. Ann Epidemiol 2018;28:182–8. https://doi.org/10.1016/j.annepidem.2018.01.005.
[46] Vercammen KA, Moran AJ, McClain AC, Thorndike AN, Fulay AP, Rimm EB. Food security and 10-year cardiovascular disease risk among U.S. Adults. Am J Prev Med 2019;56:689–97. https://doi.org/10.1016/j.amepre.2018.11.016.
[47] Stupplebeen DA. Housing and food insecurity and chronic disease among three racial groups in hawai'i. Prev Chronic Dis 2019;16:E13. https://doi.org/10.5888/pcd16.180311.
[48] Charkhchi P, Fazeli Dehkordy S, Carlos RC. Housing and food insecurity, care access, and health status among the chronically ill: an analysis of the behavioral risk factor surveillance system. J Gen Intern Med 2018;33:644–50. https://doi.org/10.1007/s11606-017-4255-z.
[49] Omerov P, Craftman ÅG, Mattsson E, Klarare A. Homeless persons' experiences of health- and social care: a systematic integrative review. Health Soc Care Community 2020;28:1–11. https://doi.org/10.1111/hsc.12857.
[50] Njai R. Prevalence of perceived food and housing security — 15 states, 2013. MMWR Morb Mortal Wkly Rep 2017;66. https://doi.org/10.15585/mmwr.mm6601a2.
[51] Havranek Edward P, Mujahid Mahasin S, Barr Donald A, Blair Irene V, Cohen Meryl S, Cruz-Flores Salvador, et al. Social determinants of risk and outcomes for cardiovascular disease. Circulation 2015;132:873–98. https://doi.org/10.1161/CIR.0000000000000228.
[52] Mendy VL, Vargas R, Cannon-Smith G, Payton M, Enkhmaa B, Zhang L. Food insecurity and cardiovascular disease risk factors among Mississippi adults. Int J Environ Res Publ Health 2018;15. https://doi.org/10.3390/ijerph15092016.
[53] Sandel M, Desmond M. Investing in housing for health improves both mission and margin. JAMA 2017;318:2291–2. https://doi.org/10.1001/jama.2017.15771.
[54] Blewett LA, Owen RA. Accountable care for the poor and underserved: Minnesota's hennepin health model. Am J Publ Health 2015;105:622–4. https://doi.org/10.2105/AJPH.2014.302432.
[55] Basu S, Gardner CD, White JS, Rigdon J, Carroll MM, Akers M, et al. Effects of alternative food voucher delivery strategies on nutrition among low-income adults. Health Aff Proj Hope 2019;38:577–84. https://doi.org/10.1377/hlthaff.2018.05405.
[56] Baggett TP, Singer DE, Rao SR, O'Connell JJ, Bharel M, Rigotti NA. Food insufficiency and health services utilization in a national sample of homeless adults. J Gen Intern Med 2011;26:627–34. https://doi.org/10.1007/s11606-011-1638-4.
[57] Lloyd EL, McCormack C, McKeever M, Syme M. The effect of improving the thermal quality of cold housing on blood pressure and general health: a research note. J Epidemiol Community Health 2008;62:793–7. https://doi.org/10.1136/jech.2007.067835.
[58] Chambers EC, Hanna DB, Hua S, Duncan DT, Camacho-Rivera M, Zenk SN, et al. Relationship between area mortgage foreclosures, homeownership, and cardiovascular disease risk factors: the Hispanic Community Health Study/Study of Latinos. BMC Publ Health 2019;19:77. https://doi.org/10.1186/s12889-019-6412-2.
[59] Diez Roux AV. Residential environments and cardiovascular risk. J Urban Health Bull N Y Acad Med 2003;80:569–89. https://doi.org/10.1093/jurban/jtg065.
[60] Conrad Z, Rehm CD, Wilde P, Mozaffarian D. Cardiometabolic mortality by supplemental nutrition assistance program participation and eligibility in the United States. Am J Publ Health 2017;107:466–74. https://doi.org/10.2105/AJPH.2016.303608.
[61] Center on Budget and Policy Priorities. Three in four low-income at-risk renters do not receive federal rental assistance. July 2021. n.d.
[62] Hostetter M, Klein S. In focus: hospitals invest in building stronger. Healthier Communities | Commonwealth Fund; 2016.
[63] Amarasingham R, Xie B, Karam A, Nguyen N, Kapoor B. Using community partnerships to integrate health and social services for high-need, high-cost patients. The Commonwealth Fund; 2018.
[64] Using Medicaid Resources to Pay for Health-Related Supportive Services: Early Lessons. Cent health care strategy. https://www.chcs.org/resource/using-medicaid-resources-pay-health-related-supportive-services-early-lessons/. [Accessed 26 July 2021].
[65] Curtin SC. Trends in cancer and heart disease death rates among adults aged 45-64: United States, 1999-2017. Natl Vital Stat Rep Cent Dis Control Prev Natl Cent Health Stat Natl Vital Stat Syst 2019;68:1–9.
[66] Sidney S, Go AS, Jaffe MG, Solomon MD, Ambrosy AP, Rana JS. Association between aging of the US population and heart disease mortality from 2011 to 2017. JAMA Cardiol 2019;4:1280–6. https://doi.org/10.1001/jamacardio.2019.4187.