RESEARCH ARTICLE

Multimorbidity and food insecurity in adults: A systematic review and meta-analysis

Maria Kantilafti[1], Konstantinos Giannakou[ID][1], Stavri Chrysostomou[ID][2] *

1 Department of Health Sciences, School of Sciences, European University Cyprus, Nicosia, Cyprus,
2 Department of Life Sciences, School of Sciences, European University Cyprus, Nicosia, Cyprus

* s.chrysostomou@euc.ac.cy

Abstract

Food insecurity is one of the main factors affecting multimorbidity. Previous studies have shown that food insecurity may lead to multimorbidity due to person's inability to consume nutritious diet. However, considering that multimorbidity may cause work-related disabilities and an unstable income, others support the possible effect that multimorbidity has on food insecurity. The purpose of this systematic review and meta-analysis is to examine the relationship between food insecurity and multimorbidity in adults. A systematic literature review of studies was performed using the PubMed, EBSCO and SCOPUS for all articles including adults $\geq$ 18-year-old with multimorbidity living in developed countries published from August 5th until December 7th 2022. Meta-analysis was performed considering results from the fully adjusted model. The methodological quality was assessed using the Newcastle-Ottawa Scale adapted for cross-sectional studies. This systematic review was not registered. This research received no specific grant from any funding agency. Four cross-sectional studies involving 45,404 participants were included in order to investigate the possible impact that food insecurity has on multimorbidity. The study findings showed an increased probability of multimorbidity 1.55 (95% CI:1.31–1.79, p<0.001, I^2 = 44.1%) among people with food insecurity. Conversely, three of the included studies, involving 81,080 participants concluded that people with multimorbidity, have 2.58 (95% CI: 1.66–3.49, p<0.001, I^2 = 89.7%) times higher odds to present food insecurity. This systematic review and meta-analysis provide evidence of a reverse association between food insecurity and multimorbidity. Further cross-sectional studies must be conducted in order to elucidate the association between multimorbidity and food insecurity across age groups and between the two genders.

Introduction

Multimorbidity is a term commonly used to define the coexistence of at least two chronic conditions in the same individual [1] It is estimated that the prevalence of multimorbidity is increasing through the decades, regardless of the individual's race and ethnicity [2]. The global prevalence of multimorbidity is 37.2% [3]. Regarding USA, South America has a higher prevalence (45.7%, 95% CI = 39.0–52.5) compared to North America (43.1%, 95% CI = 32.3–53.8%) [3]. The overall prevalence of multimorbidity in Europe is 39.2% (95% CI = 33.2–45.2%) with

Data Availability Statement: All relevant data are within the paper and its Supporting information files.

some countries reporting higher prevalence, for example: Portugal: 43.9% [4], Ireland: 73.3% [5] and Germany: 39,6% [6] whereas some other countries reporting lower prevalence such as Cyprus: 28.6% [7], and Denmark: 21.6% [8]. It is even more common in the elderly [9], with researchers supporting the claim that prevalence of multimorbidity among the general population older than 75 years is over 80% [10]. However, a previous study showed that people who are younger than 65 years could also present multimorbidity [11] indicating that multimorbidity may appear at any age causing unpleasant effects on people's quality of life. Moreover, multimorbidity is associated with other consequences such as high costs of health care, disability [12], premature death [13] and mortality [14]. Based on the above, multimorbidity must be considered a global public health challenge.

Several factors have been identified that contribute to multimorbidity, including age [15], a low educational level [16], living in a deprived area [17], low levels of physical activity [18], and unhealthy lifestyle [16]. Another potential factor that has been reported is food insecurity, defined as the result of limited or inadequate access to nutritionally and safely sound food, due to individual factors such as low income, mobility limitations, and other factors such as limited access to grocery stores or transportation barriers [19]. Notably, some researchers support the possible reverse causation between multimorbidity and food insecurity [20] On one hand, food insecure people, due to lack of money, consume unhealthy food that are cheaper and more readily available than healthy alternatives [21], which may have a negative impact on a person's quality of life affecting both mental and physical health [22–24]. On the other hand, people with multiple chronic conditions may be unable to work, thus having an unstable income. Furthermore, having multiple chronic conditions increases expenditures for medications, physiotherapy, and transportation to doctors [20]. Also, people with chronic diseases often need to follow a specific nutritional therapy related to their illness which is often expensive and non-affordable [25, 26]. Based on the above, multimorbidity may cause an economic burden on individuals, resulting in food insecurity. Many researchers support the potential relation between food insecurity and chronic diseases including obesity [24], diabetes mellitus [27], hypertension [28] and cancer [29]. The main literature gap the present meta-analysis attempts to achieve is related to the investigation whether food insecurity may be responsible for the presence of more than two chronic conditions in the same individual. As both food insecurity and multimorbidity are characterized with high prevalence [10, 30] and also have an impact on a person's quality of life, identifying an association between them could contribute to more targeted programs and policies.

As mentioned above, there is a scarcity of evidence regarding the possible association between food insecurity and multimorbidity. Furthermore, studying the association between food insecurity and multimorbidity vice versa, the extent of the impact that multimorbidity has on food insecurity is unknown. The above literature gap is highlighted with the preliminary search for published systematic reviews or protocols in PROSPERO, MEDLINE, Cochrane Database of Systematic Reviews and the Joanna Briggs Institute Evidence synthesis, that has been conducted and found nothing related to food insecurity and multimorbidity. To the best of our knowledge, this is the first systematic review and meta-analysis to investigate the association among food insecurity and multimorbidity in developed countries. Thus, the purpose of this systematic review and meta-analysis is to investigate the relationship between food insecurity and multimorbidity in adults living in developed countries, as well as vice versa. Therefore, identifying the exact association among multimorbidity and food insecurityand measuring the impact of the possible reverse causation between multimorbidity and food insecurity would be extremely important for public health actions related to multimorbidity and food insecurity. Taking into account the possible impact that food insecurity has on multimorbidity public health policies will be more effective controlling multimorbidity and vice versa.

Methods

The systematic review is conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [31]. The PRISMA 2009 checklist is shown in S1 Table. This systematic review was not registered. However, we conducted a preliminary search for published systematic reviews or protocols in PROSPERO, MEDLINE, Cochrane Database of Systematic Reviews and the Joanna Briggs Institute (JBI) Evidence synthesis and didn't find any protocol related to our systematic review and meta-analysis. This research received no specific grant from any funding agency.

Search strategy and eligibility criteria

A systematic literature search was conducted through the international databases, including PubMed, EBSCO and Scopus using Medical Subject Headings (MeSH) terms. The references cited in the selected articles were also searched manually. The literature search was conducted independently by two researchers (MK and KG) from August 5th until December 7th 2022. The search was limited to papers published in English; there was no date restriction on the studies included. Any discrepancies between reviewers were resolved in consultation with a third author (SC). The search strategy used is presented in (S2 Table).

To identify included studies, we used the Participants, Interventions, Comparisons, Outcomes, and Study Design (PICOS) method. This method provides a structured approach for formulating research questions and identifying key elements of a study. It ensures that the research question is clearly defined, relevant studies are identified and included, and facilitates the development of a focused and comprehensive search strategy. Participants were $\geq$ 18-year-old adults with multimorbidity. Multimorbidity was considered both the intervention/exposure and the outcome of interest, defined as the presence of at least two chronic conditions in the same individual as described by Fox et al [1] For the comparison, we used participants with 0–1 chronic conditions. The outcome of interest as well as exposure was food insecurity, which is defined as the result of limited or inadequate access to nutritionally and safe food [19]. Any study design was eligible for inclusion. We did not include studies conducted with samples of institutionalized adults (e.g., hospitalized or residents of nursing homes) because their nutrition is based on institution's nutrition plan and all residents and hospitalized patients are able to consume food that it is offered to them by the institution. Furthermore, we did not include studies conducted in developing countries because it is possible that the mechanisms which are accounted for the association between food insecurity and multimorbidity are different compared to those in developed countries. Published conference abstracts, dissertations, narrative reviews, and case reports were also excluded.

Study selection and data extraction

Following the elimination of duplicate records, the study selection process was implemented in a two-fold approach, consisting of: 1) identification of possibly pertinent articles based on the examination of their titles and abstracts, and 2) identification of pertinent articles based on a comprehensive assessment of their full texts, which were evaluated against predetermined eligibility criteria. Study selection was carried out independently by two reviewers (MK and KG). Any discrepancies between reviewers were resolved in consultation with a third author (SC). A standardized data extraction table was used in Microsoft Office Excel. The study extracted the following variables from each study: author, year, and country; study design and population; main measures; multimorbidity definition and occurrence, food insecurity definition and occurrence; comparison group; multimorbidity and food insecurity assessment;

confounders and main findings assessed. The extraction was performed independently by MK and KG and any disagreements were discussed by all three reviewers until consensus.

Quality assessment

The Newcastle-Ottawa scale assesses the quality of the studies in three sectors, with the maximum number of stars awarded being ten: 1) the selection of the study group (representativeness of the sample, sample size, non-responders, and ascertainment of the exposure) scores up to five stars, 2) the comparability of subjects in different outcome groups on the basis of design or analysis scores up to two stars, and finally 3) the aspects of the outcome such as the assessment of the outcome and the statistical test score up to three stars. "Very good studies" and "good studies" were defined as those that scored nine or ten points and seven or eight points, respectively. Studies with five or six stars were categorized as satisfactory, and studies with less than four points were categorized as unsatisfactory. Any disagreement was resolved by discussion with a third author [SC].

Statistical analysis

The association between food security and multimorbidity was assessed using the odds ratios (OR) and corresponding 95% confidence intervals (CI). For the meta-analysis, we considered results from the fully adjusted model. We assessed heterogeneity between variables, and we reported the P-value of the χ^2-based Cochran Q test and the I^2 metric for inconsistency [32]. If $I^2 > 50\%$, a random effects model was used; otherwise, a fixed-effect model was applied [32]. The publication bias was examined by visual inspection of funnel plots and evaluated formally with Egger's regression asymmetry test [32]). All statistical analyses were performed by STATA 14.0 software (STATA Corp, College Station, TX), and a two-tailed P value <0.05 was deemed statistically significant.

Results

Study selection and characteristics

The flow chart of selection studies regarding the systematic review is presented in Fig 1. After the search, 8 articles were included for qualitative analysis [20, 33–39] whereas 7 articles were enrolled in the quantitative meta-analysis [20, 33–35, 37–39]. (Fig 1). The study by Fernandes et al (2018) [36] was excluded from the meta-analysis since the researchers didn't use direct comparisons in order to compare their results (e.g., 1 condition vs. none) as it was done in the other studies. The above studies were selected among 559 articles out which 302 were duplicate and were removed from the search.

For the investigation of the potential effect that food insecurity has on multimorbidity, more than 45,000 adults > 18 years of age were included in the systematic review. All studies included employed a cross-sectional design, were published between 2003 and 2022, and conducted in United States [35, 38, 39] while one study was conducted in many countries [37] (Smith, et al., 2022). Food insecurity was measured using the 6-item [38] or the 18-item US Household Food Security Survey Module [39], two questions about food insecurity [37], and four self-reported food insecurity risk situations questions [35]. In all studies included, the presence of multimorbidity, as the outcome of interest, was assessed using self-reported chronic conditions questionnaires.

For the investigation of the potential impact that multimorbidity has on food insecurity, we included four studies with almost 83, 000 adults > 18 years of age All cross-sectional studies, were published between 2013 and 2020, and contacted in United States [33, 34], Canada [20]
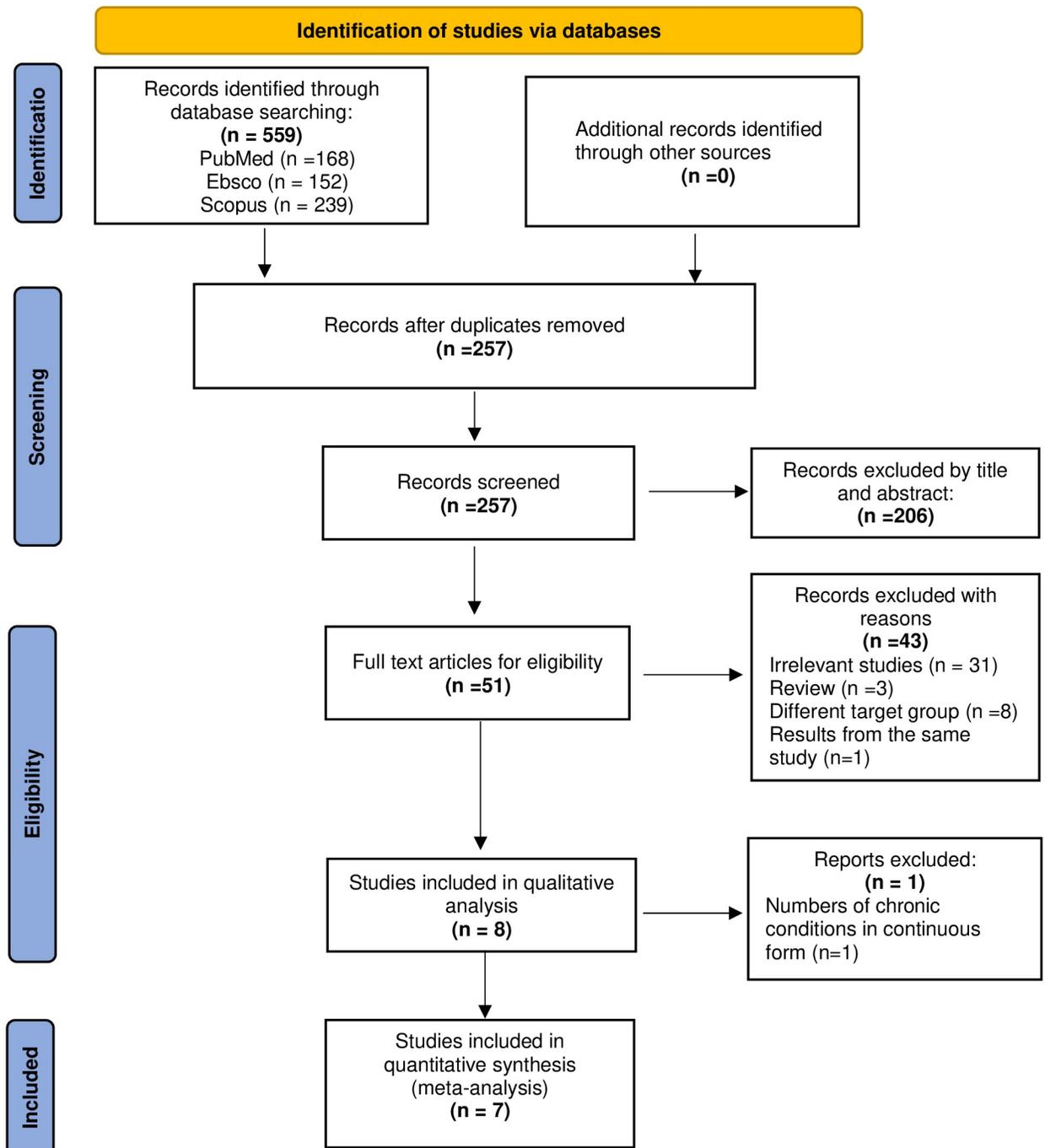
Identification of studies via databases

Records identified through database searching:
(n = 559)
PubMed (n =168)
Ebsco (n = 152)
Scopus (n = 239)

Additional records identified through other sources
(n =0)

Records after duplicates removed
(n =257)

Records screened
(n =257)

Records excluded by title and abstract:
(n =206)

Full text articles for eligibility
(n =51)

Records excluded with reasons
(n =43)
Irrelevant studies (n = 31)
Review (n =3)
Different target group (n =8)
Results from the same study (n=1)

Studies included in qualitative analysis
(n = 8)

Reports excluded:
(n = 1)
Numbers of chronic conditions in continuous form (n=1)

Studies included in quantitative synthesis (meta-analysis)
(n = 7)

Identificatio — Screening — Eligibility — Included

Fig 1. Flow chart of the selected studies.

https://doi.org/10.1371/journal.pone.0288063.g001

and Portugal [36]. Multimorbidity, was assessed using self-reported chronic conditions questionnaires. Food insecurity, the outcome of interest, was measured using the 6-item [34] or the 18-item US Household Food Security Survey Module [20], the 10-item US Adult Food Security Survey Module [33] and a psychometric scale adapted from the Brazilian Insecurity Scale, adapted from the US Household Food Insecurity Survey Module [36].

Quality assessment and publication bias

Six studies had scored 5 out of 10, classified as "satisfactory studies") and the remaining two studies had scored 4 out of 10 indicating "unsatisfactory" (Table 1). The funnel plots showed reasonable symmetry, with no evidence of publication bias. Likewise, no evidence of publication bias was observed according to Egger asymmetry test ($P_{Egger's\ test}$ P > 0.05) except for studies on the association between food insecurity and multimorbidity ($P_{Egger's\ test}$ <0.05) (S1 and S2 Figs).

The effect of food insecurity on multimorbidity

Using the fixed effect model, four studies found that people with food insecurity have 1.55 (95% CI: 1.31–1.79, p<0.001) times higher odds for multimorbidity. There was no significant statistical heterogeneity among study results (I^2 = 44.1%, p = 0.097) (Fig 2).

The effect of multimorbidity on food insecurity

A random-effect model was applied to analyze the data and compared to people without multimorbidity (0–1 chronic conditions), those who present ≥ 2 chronic conditions have 2.58 (95%

Table 1. Quality assessment using Newcastle-Ottawa scale adapted for cross-sectional studies.

	Selection[a]				Comparability[b]	Outcome[c]		Total quality score	Results
Studies defined multimorbidity as the outcome of interest									
Author, year	**Selection[a]**				**Comparability[b]**	**Outcome[c]**		**Total quality score**	**Results**
	(1) Representativeness of the sample	(2) Sample size	(3) Non responders	(4) Ascertainment of the exposure	(1) Comparability of subjects on the basis of the design or analysis	(1) Assessment of outcome	(2) Statistical test		
Leung et al, 2020	*	-	*	-	**	-	*	5/10	Satisfactory
Sharkey R. 2003	*	-	*	-	**	-	*	5/10	Satisfactory
Smith et al, 2022	*	-	*	-	**	-	*	5/10	Satisfactory
O'Neal et al, 2022	*	-	*	-	**	-	*	5/10	Satisfactory
Studies defined food insecurity as the outcome of interest									
Author, year	**Selection[a]**				**Comparability[b]**	**Outcome[c]**		**Total quality score**	**Results**
	(1) Representativeness of the sample	(2) Sample size	(3) Non responders	(4) Ascertainment of the exposure	(1) Comparability of subjects on the basis of the design or analysis	(1) Assessment of outcome	(2) Statistical test		
Jih et al, 2018	-	-	*	-	**	-	*	4/10	Unsatisfactory
Tarasuk et al, 2013	*	-	*	-	**	-	*	5/10	Satisfactory
Jih et al, 2020	-	-	-	*	**	-	*	4/10	Unsatisfactory
Fernandes et al, 2018	*	-	*	-	**	-	*	5/10	Satisfactory

Abbreviations:

[a].A maximum of 5 stars can be awarded for the selection.

[b].A maximum of 2 stars can be awarded for the comparability.

[c].A maximum of 3 stars can be awarded for the outcome.

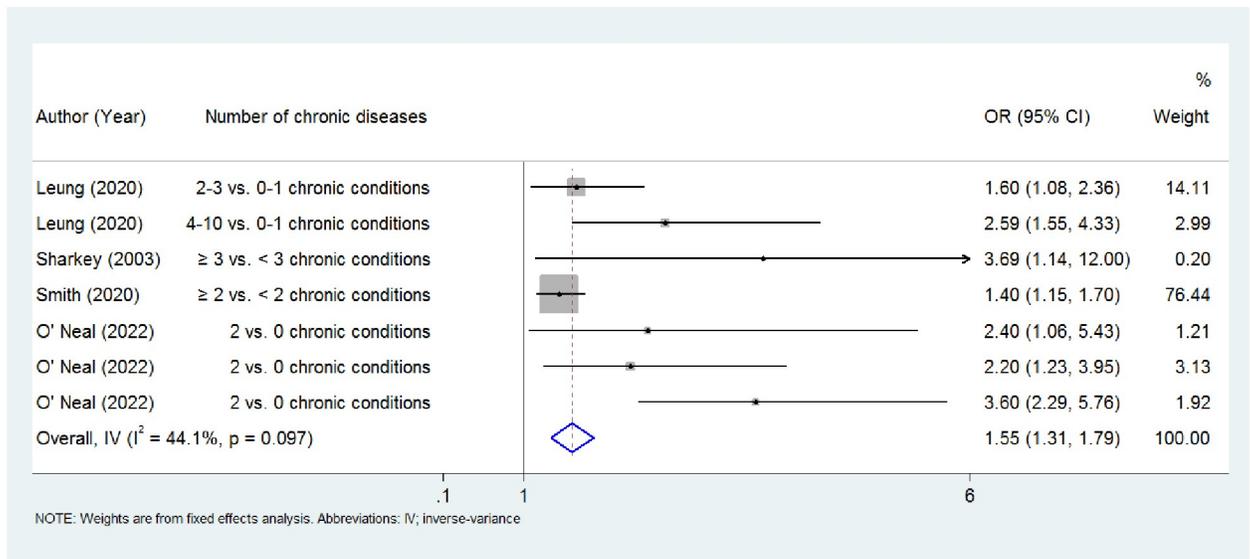https://doi.org/10.1371/journal.pone.0288063.t001

Fig 2. Forest plot for the meta-analysis for the association between food insecurity and multimorbidity. Abbreviations: IV: inverse variance.

CI: 1.66–3.491, p<0.001, I^2 = 89.7%, p = 0.000) times higher odds for food insecurity (Fig 3). The results of the study that was not included in the meta-analysis [36] is presented in Table 2.

Discussion

Four cross-sectional studies involving 45,404 participants were included in order to investigate the possible effect that food insecurity has on multimorbidity. Our findings suggested that, compared to being food secure, food insecurity was associated with 1.55 (95% CI:1.31–1.79)
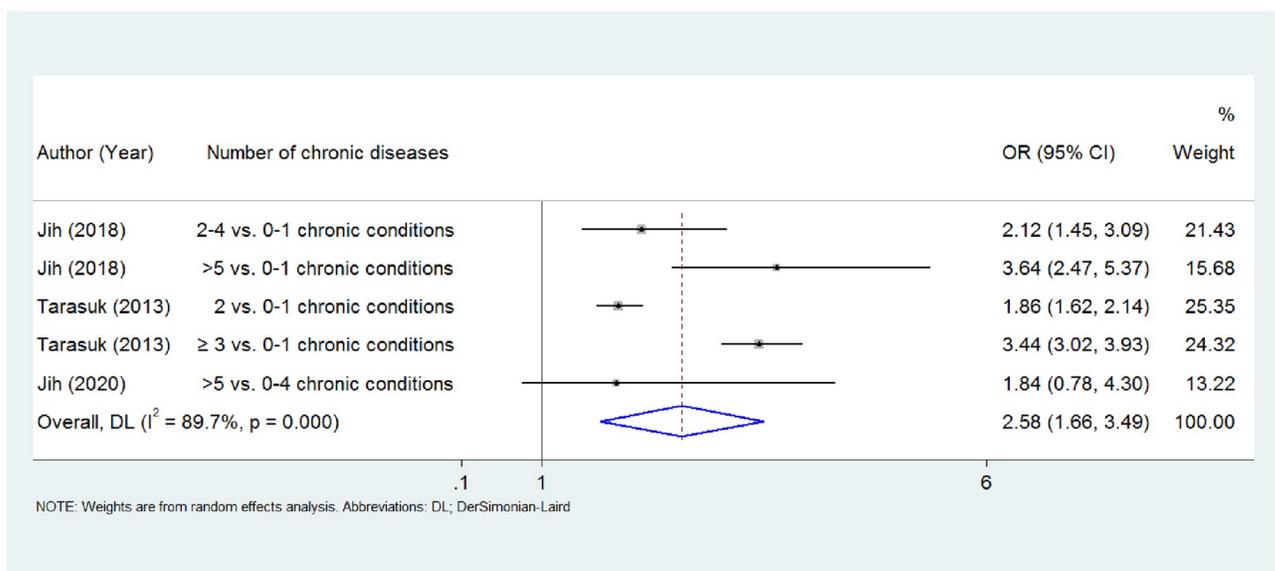

Fig 3. Forest plot for the meta-analysis for the association between multimorbidity and food insecurity. Abbreviations: IV: inverse variance, DL: DerSimonian and Laird.

Table 2. Characteristics of the observational studies.

Studies defined multimorbidity as the outcome of interest

Author / Year Country	Study Design population	Main measures	Multimorbidity definition / occurrence	Food insecurity definition / occurrence	Comparison group	Multimorbidity assessment	Food Insecurity assessment	Confounders	Main findings
Leung et al, 2020 U.S.	Cross-sectional study N = 2048 50–80 y	FI Multiple chronic conditions	NR / 94,4%	>2 affirmative responses from 6-item short form US Household Food Security Survey Module / 14%	0–1 condition	Self-reported diagnosis	6-item U.S. Household Food Security Survey Module	age, sex, race ethnicity, educational attainment, marital status, annual, household income, employment health insurance	FI was associated with multimorbidity. 2–3 chronic conditions: (RRR 1.60, 95% CI 1.08, 2.36) ≥4 chronic conditions (RRR 2.59, 95% CI 1.55, 4.33)
Sharkey R. Joseph 2003 U.S.	Cross-sectional study N = 279 Women >60 y Home-delivered meal recipients	FI Multimorbidity	≥3 disease conditions / 47,3%	Responded yes, to either absence of food situation / 10%	<3 disease conditions	Self-reported diagnosis	Four self-reported FI risk situations questions	Race, income, education, age, living arrangement, marital status, tobacco use, Food Stamp, Program participation, IADL, BMI	FI was associated with greater than three times higher odds of multimorbidity (OR:3.69, 95% CI 1.14–12.00)
Smith et al, 2022 China Ghana India Mexico Russia South Africa	Cross-sectional study N = 34 129 > 50 y	FI Multimorbidity	≥2 chronic conditions / 45.5%	Positive answers in two questions / 11.8%	< 2 chronic conditions	Self-reported diagnosis	Two questions about FI	Country, age, sex, education, wealth	FI was associated with multimorbidity (OR:1.40, 95% CI 1.15–1.70)
O'Neal et al, 2022 US	Cross-sectional study N = 8 948 > 18 y	FI chronic conditions	≥ 1 chronic cardiometabolic condition and depression / 49.2%	>1 affirmative responses from 18-item form US Household Food Security Survey Module / 25.1%	0 chronic conditions	Self-reported diagnosis	18-item US Household Food Security Survey Module	Age, sex, and race, ethnicity	FI was associated with multimorbidity. Very low FI: OR: 2.4 (95% CI 1.06–5.43) Low FI: OR: 2.2 (95% CI 1.23–3.95) Marginal FI: OR: 3.6 (95% CI 2.26–5.76)

Studies defined food insecurity as the outcome of interest

Author / Year Country	Study Design population	Main measures	Multimorbidity definition / occurrence	Food insecurity definition / occurrence	Comparison group	Multimorbidity assessment	Food Insecurity assessment	Confounders	Main findings

(Continued)

Table 2. (Continued)

Study	Design	Exposure / Outcome	Prevalence	Cut-off / Prevalence	Reference	Outcome ascertainment	Food security measure	Covariates	Results
Jih et al, 2018 U.S.	Cross- sectional study N = 3552 > 50 y Annual household income < 300% of the FPL	FI Multiple chronic conditions	NR / 83,5%	>2 affirmative responses from 6-item short form US Household Food Security Survey Module / 27.8%	0–1 affirmative responses	Self-reported diagnosis	6-Item U.S. Household Food Security Survey Module	Age, sex, race, ethnicity, marital status, health insurance status, self-rated health, employment status, household size, education, wealth, household size, smoking status and BMI	Multimorbidity was associated with FI. 2–4 chronic conditions: (OR 2.12, 95% CI 1.45, 3.09) > 4 chronic conditions (OR 3.64, 95% CI 2.47, 5.37)
Tarasuk et al, 2013 Canada	Cross- sectional study N = 77053 18–64 y	FI Multimorbidity	NR	1 affirmative response from18-item US Household Food Security Survey Module / 11.8%	0 affirmative responses	Self-reported diagnosis	18-item US Household Food Security Survey Module	household sociodemographic.	Multimorbidity was associated with FI. 1 chronic condition: OR: 1.43 (95% CI 1.28–1.59) 2 chronic conditions: OR:1.86 (95% CI 1.62–2.14) 3 chronic conditions: OR: 3.44 (95% CI 3.02–3.93)
Jih et al, 2020 U.S.	Cross- sectional study N = 475 > 60 y	FI Multiple chronic conditions	≥ 2 chronic conditions / 98,3%	3+ affirmative responses from 10-item U.S. Adult Food Security Survey Module / 8.2%	NR	Diagnoses from the Elixhauser Comorbidity Index	10-item U.S. Adult Food Security Survey Module	Age, sex, race ethnicity, presence of behavioral health diagnosis, multiple chronic conditions, BMI, number of primary care visits in the last year that were significantly different between older adults with and without FI	Multimorbidity was associated with FI. ≥1 chronic conditions: OR: 4.1 (95% CI 1.9–9.0) ≥5 chronic conditions: OR: 1.84 (95% CI 0.78–4.3)
Fernandes et al, 2018 Portugal	Cross- sectional study N = 1885 > 65 y	FI Multiple chronic conditions	NR	1 affirmative response from Psychometric scale / 23%	0 affirmative response	Self-reported diagnosis	Psychometric scale adapted from the Brazilian Insecurity Scale	Age, gender, education level, health region	The presence of ≥ 1 chronic conditions was associated with FI OR: 1.161 (95% CI 1.158–1.164)

Abbreviations: N: Sample, FPL: Federal Poverty Level, FI: Food Insecurity, U.S.: United States, NR: Not Reported, BMI: Body Mass Index, IADL: Instrumental Activities of Daily Living, OR: Odd Ratio, AOR: Adjusted Odd Ratio

https://doi.org/10.1371/journal.pone.0288063.t002

times higher odds for multimorbidity. Conversely, three of the included studies examined the possible association between multimorbidity and food insecurity, and we found that people with multimorbidity have 2.58 (95% CI:1.66–3.49) times higher odds of experiencing food insecurity.

It is noteworthy that, up to date, no review or meta-analysis has systematically investigated the association between food insecurity and multimorbidity. However, two previous studies have partially examine this topic. A data analysis form the National Health and Nutrition Examination Survey for the years 2007–2014 found that food insecure obese adults were more likely to have more comorbidities conditions than food secure obese adults [40]. Another study, conducted in Portugal, concluded that food-insecure households had greater odds of having one or more comorbidities [36].

It is worth mentioning that among factors associated with multimorbidity, age seems to have an impact on this global challenge [9, 16–18]. Based on the latest data from United Nations, worldwide, life expectancy, reached 72.8 years in 2019, showing an increase of almost 9 years since 1990. Further reductions in mortality will lead to even more increase in life expectancy reaching 77.2 years in 2050 [41]. According to WHO data, the proportion of the global population aged 60 years and older will almost double from 12% to 22% between 2015 and 2050 [42]. Based on the above and keeping in mind that multimorbidity is more common among the elderly population, it is obvious that health systems will have to face an increasing number of people living with multimorbidity [43]. Furthermore, it is worth mentioning that the prevalence of multimorbidity in populations is difficult to be measured, due to the use of different definitions and classifications. For example, a systematic review of 39 observational studies across 12 countries reported the prevalence of multimorbidity to be between 13% and 95%. Although most of the studies were defined multimorbidity as the presence of at least 2 chronic diseases in the same individual there were studies that considered multimorbidity as the presence of at least 3 chronic diseases [44]. Another systematic review reported similar results with multimorbidity varying from 3.5% to 98.5% in primary care patients and between 12% and 71.8% among the general population. According to researchers [9], the most important factor responsible for the above variation is the definition of multimorbidity, with some studies to defined multimorbidity as having 2 or more chronic conditions and other to defined multimorbidity as the presence of 3 or 4 chronic conditions. Notably, recent data by FAO support that the prevalence of food insecurity has also increased from 22.6% in 2014 to 29.3% in 2021 globally. Regarding Europe, 8.0% of the population are food insecure with 1.5% of them being severe food insecure [45]. Therefore, taking into account the significant number of people suffering from food insecurity on one hand and the continues increase in the prevalence of multimorbidity on the other hand, further studies examining the association among food insecurity and multimorbidity are emerged.

In order to investigate the potential mechanisms for the association between food insecurity and multimorbidity we cannot exclude the possibility of reverse causation [20]. On one hand, controlling multimorbidity requires additional expenditures for medications, physiotherapy, transportation and doctor's visits. As a results of the above, people with multimorbidity face an additional strain on the household budget leading to an increased risk of developing food insecurity [20, 46]. At the same time, multimorbidity can affect adults ability to garner income in order to minimize experiences of food insecurity due to their physical and mental limitations [20]. On the other hand, due to lack of money, food insecure people are characterized with increased consumption of unhealthy food which is typically cheaper and more readily available than healthy alternatives leading to obesity and other obesity-related diseases [21, 47–49]. Moreover, based on previous research, it seems that food insecurity is ever more severe among low-income population. Particularly, a previous study in Cyprus indicated that families

would need to spend up to two-thirds of their monthly income to eat healthily [50]. Thus, a poor diet due to food insecurity may lead to inadequate nutritional status. As a result of that, people present a systematic low-grade inflammation which elevates acute phase proteins in the body such as C-reactive protein (CRP) [51, 52]. During inflammation, molecular and cellular manifestations are observed in the body leading to the loss of tissue function and tissue homo-eostasis [53]. For example in case of lipid metabolism, inflammation can cause decrease in HDL cholesterol, increase in triglycerides, lipoprotein(a) and LDL levels resulting in dyslipide-mia and increase risk of atherosclerosis [54]. Therefore, inflammation may be a mechanism by which food insecurity leads to multiple chronic diseases including heart disease, hypertension and diabetes mellitus [55, 56].

Notably, food insecurity is associated with unhealthy body weight including both obesity and underweight [23, 57]. As for obesity, food insecure people consume cheaper but high energy density foods leading to a much higher energy intake compared to energy expenditure [23] Therefore, food insecure people are in a high risk of developing obesity and the relative adverse outcomes [54, 56]. Based on the above, food insecurity could lead to multimorbidity through obesity given that obesity is the main leading cause of many chronic non-communicable diseases [58]. The risk of hypertension and coronary heart diseases is more than two fold higher in obese people compared with people with normal body weight [59, 60]. Furthermore, the risk of type two diabetes, insulin resistance and dyslipidemia is more than threefold higher and the risk of cancer is over one fold higher in obese people than in those with normal body weight [60, 61]. Regarding being underweight, food insecurity may lead to inadequate food consumption due to financial barriers which can cause negative energy balance and under-nourishment [57]. A recent study suggest that people with Body Mass Index (BMI) < 18 kg/m^2 were significantly more likely to suffer from five or more chronic conditions [62]. There-fore, unhealthy body weight could be the key factor for the association between food insecurity and multimorbidity and thus, controlling body weight could eliminate both conditions.

It is worth mentioning that food insecurity could also result to poor chronic disease man-agement. For example, in regards to diabetes, Seligman et al. concluded that food insecure peo-ple with diabetes reported poor glycemic control, as defined by hemoglobin A(1c) ≥8.5% because of increased difficulty in following a diabetic nutritional therapy characterized by high consumption of fruits and vegetables and low intake of carbohydrate and fat-rich foods and emotional distress due to their weakness for successful diabetes self-management [25]. Based on the literature, uncontrolled diabetes may lead to other chronic diseases such as kidney dis-eases and other cardiovascular diseases [63]. Moreover, a study in Cyprus has shown that the Cypriot gluten-free Healthy diet is costly and not affordable among low-income Cypriots diag-nosed with celiac disease. In case of low-adherence to a prescribed diet, patients are likely to experience disease's relapses, compromising their long-term health [26]. In contrast, regarding diabetes, the same researchers found that the diabetic nutritional therapy is more affordable compared to other diets such as the healthy diet or the gluten free healthy diet [64]. Therefore, it could be assumed that not all chronic diseases lead to food insecurity and that each disease may cause different level of food insecurity. However, more research is required for identifying the size effect of each disease on food insecurity.

The current study has some limitations. Despite the effort to find all eligible articles on this subject, gray literature and studies published in language other than English were not included in our search. Another potential limitation of our study is that we did not search beyond Pubmed, EBSCO, and Scopus databases, which may have resulted in missing relevant studies. In addition, we excluded a study from the meta-analysis due to the number of comorbidities found in a continuous form [36]. Another limitation is the fact that some studies used different questionnaires in order to evaluate food insecurity which may restrict their comparability.

Finally, most of the studies evaluated multimorbidity using self-report methods which may increase the risk of recall bias. However, it is worth mentioning that self-report method for multimorbidity can provide reliable results compared to data originating from primary health care system records [65].

Conclusions

To the best of our knowledge, this is the first systematic review and meta-analysis that examine the bidirectional association between food insecurity and multimorbidity in developed countries. providing evidence of reverse association between food insecurity and multimorbidity. Food insecure people have 1.55 higher odds of presenting multimorbidity. At the same time people with multimorbidity have 2.58 higher odds to present food insecurity. Our findings emphasize the need for further research in order to better clarify the determinants of multimorbidity and food insecurity. Furthermore, more studies are needed to increase comparability between them and reach to more accurate results due to the fact that the existing literature is limited. At the same time, future studies should investigate the relationship between multimorbidity and food insecurity considering the possible disparities may exist between males and females and also between age groups. Moreover, future studies could focus on examining food insecurity in particular group of patients such as patients with obesity or diabetes or other chronic diseases. Considering the above, it is expected that at one hand, public health policies should implement strategies assessing food insecurity in their population especially for people who are at high risk being food insecure like the elderly people and people with financial barriers. At the other hand, public health policies should conduct well-structured strategies for multimorbidity evaluation. Conclusively, considering the above findings, the relative authorities, will be able to develop successful public health programs for controlling multimorbidity and food insecurity such as programs and strategies aiming to target multimorbidity and addressed to people visiting food banks or are on food allowance due to socioeconomic status and income.

Supporting information

S1 Table. PRISMA checklist.
(DOCX)

S2 Table. Summary of the search strategy.
(DOCX)

S1 Fig. Funnel plot in the meta-analysis on the association between food insecurity and multimorbidity.
(TIF)

S2 Fig. Funnel plot in the meta-analysis on the association between multimorbidity and food insecurity.
(TIF)

Author Contributions

Methodology: Konstantinos Giannakou.

Software: Konstantinos Giannakou.

Supervision: Stavri Chrysostomou.

Validation: Konstantinos Giannakou.

Writing – original draft: Maria Kantilafti.

Writing – review & editing: Stavri Chrysostomou.

References

1. Fox R, Fletcher J. Alarm symptoms in primary care. British Medical Journal. 2007. https://doi.org/10.1136/bmj.39212.467037.BE PMID: 17510105

2. Caraballo C, Herrin J, Mahajan S, Massey D, Lu Y, Ndumele CD, et al. Temporal Trends in Racial and Ethnic Disparities in Multimorbidity Prevalence in the United States, 1999–2018. Am J Med [Internet]. 2022 Sep 1 [cited 2023 Mar 1]; 135(9):1083–1092.e14. Available from: https://pubmed.ncbi.nlm.nih.gov/35472394/ https://doi.org/10.1016/j.amjmed.2022.04.010

3. Chowdhury SR, Chandra Das D, Sunna TC, Beyene J, Hossain A. Global and regional prevalence of multimorbidity in the adult population in community settings: a systematic review and meta-analysis. eClinicalMedicine [Internet]. 2023 Mar 1 [cited 2023 Mar 17]; 57:101860. Available from: http://www.thelancet.com/article/S2589537023000378/fulltext https://doi.org/10.1016/j.eclinm.2023.101860 PMID: 36864977

4. Laires PA, Perelman J. The current and projected burden of multimorbidity: a cross-sectional study in a Southern Europe population. Eur J Ageing [Internet]. 2018 Jun 15 [cited 2023 Mar 21]; 16(2):181–92. Available from: https://pubmed.ncbi.nlm.nih.gov/31139032/

5. Hernández B, Reilly RB, Kenny RA. Investigation of multimorbidity and prevalent disease combinations in older Irish adults using network analysis and association rules. Sci Reports 2019 91 [Internet]. 2019 Oct 10 [cited 2023 Mar 21]; 9(1):1–12. Available from: https://www.nature.com/articles/s41598-019-51135-7 https://doi.org/10.1038/s41598-019-51135-7 PMID: 31601959

6. Puth MT, Weckbecker K, Schmid M, Münster E. Prevalence of multimorbidity in Germany: impact of age and educational level in a cross-sectional study on 19,294 adults. BMC Public Health [Internet]. 2017 Oct 18 [cited 2023 Mar 21]; 17(1). Available from: https://pubmed.ncbi.nlm.nih.gov/29047341/

7. Kyprianidou M, Panagiotakos D, Faka A, Kambanaros M, Makris KC, Christophi CA. Prevalence of multimorbidity in the Cypriot population; A cross-sectional study (2018–2019). PLoS One [Internet]. 2020 Oct 1 [cited 2023 Mar 21]; 15(10). Available from: https://pubmed.ncbi.nlm.nih.gov/33104700/

8. Frølich A, Ghith N, Schiøtz M, Jacobsen R, Stockmarr A. Multimorbidity, healthcare utilization and socioeconomic status: A register-based study in Denmark. PLoS One [Internet]. 2019 Aug 1 [cited 2023 Mar 21]; 14(8). Available from: https://pubmed.ncbi.nlm.nih.gov/31369580/ https://doi.org/10.1371/journal.pone.0214183

9. Fortin M, Stewart M, Poitras ME, Almirall J, Maddocks H. A systematic review of prevalence studies on multimorbidity: Toward a more uniform methodology. Annals of Family Medicine. 2012.

10. Koné Pefoyo AJ, Bronskill SE, Gruneir A, Calzavara A, Thavorn K, Petrosyan Y, et al. The increasing burden and complexity of multimorbidity. BMC Public Health. 2015;

11. Barnett K, Mercer SW, Norbury M, Watt G, Wyke S, Guthrie B. Epidemiology of multimorbidity and implications for health care, research, and medical education: A cross-sectional study. Lancet. 2012; https://doi.org/10.1016/S0140-6736(12)60240-2 PMID: 22579043

12. McPhail SM. Multimorbidity in chronic disease: Impact on health care resources and costs. Risk Management and Healthcare Policy. 2016. https://doi.org/10.2147/RMHP.S97248 PMID: 27462182

13. Gijsen R, Hoeymans N, Schellevis FG, Ruwaard D, Satariano WA, Van Den Bos GAM. Causes and consequences of comorbidity: A review. J Clin Epidemiol. 2001; https://doi.org/10.1016/s0895-4356(00)00363-2 PMID: 11438406

14. Menotti A, Mulder I, Nissinen A, Giampaoli S, Feskens EJM, Kromhout D. Prevalence of morbidity and multimorbidity in elderly male populations and their impact on 10-year all-cause mortalitym: The FINE study (Finland, Italy, Netherlands, elderly). J Clin Epidemiol. 2001;

15. Fabbri E, An Y, Zoli M, Simonsick EM, Guralnik JM, Bandinelli S, et al. Aging and the burden of multimorbidity: Associations with inflammatory and anabolic hormonal biomarkers. Journals Gerontol—Ser A Biol Sci Med Sci. 2015; https://doi.org/10.1093/gerona/glu127 PMID: 25104822

16. Nagel G, Peter R, Braig S, Hermann S, Rohrmann S, Linseisen J. The impact of education on risk factors and the occurrence of multimorbidity in the EPIC-Heidelberg cohort. BMC Public Health. 2008; https://doi.org/10.1186/1471-2458-8-384 PMID: 19014444

17. Pathirana TI, Jackson CA. Socioeconomic status and multimorbidity: a systematic review and meta-analysis. Aust N Z J Public Health. 2018; https://doi.org/10.1111/1753-6405.12762 PMID: 29442409

18. Delpino FM, de Lima APM, da Silva BGC, Nunes BP, Caputo EL, Bielemann RM. Physical Activity and Multimorbidity Among Community-Dwelling Older Adults: A Systematic Review With Meta-Analysis. Am J Heal Promot. 2022; 0(0):1–15. https://doi.org/10.1177/08901171221104458 PMID: 35621359

19. Barrett CB. Measuring food insecurity. Science. 2010. https://doi.org/10.1126/science.1182768 PMID: 20150491

20. Tarasuk V, Mitchell A, McLaren L, McIntyre L. Chronic physical and mental health conditions among adults may increase vulnerability to household food insecurity. J Nutr. 2013; https://doi.org/10.3945/jn.113.178483 PMID: 23986364

21. Rosas LG, Guendelman S, Harley K, Fernald LCH, Neufeld L, Mejia F, et al. Factors associated with overweight and obesity among children of Mexican descent: Results of a binational study. J Immigr Minor Heal. 2011; https://doi.org/10.1007/s10903-010-9332-x PMID: 20217234

22. Summit WF. Rome Declaration on World Food Security and World Food Summit Plan of Action Rome Declaration on World Food Security. World Food Summit. 1996;

23. Farrell P, Thow AM, Abimbola S, Faruqui N, Negin J. How food insecurity could lead to obesity in LMICs. Health Promot Int. 2018;

24. Moradi S, Arghavani H, Issah A, Mohammadi H, Mirzaei K. Food insecurity and anaemia risk: A systematic review and meta-analysis. Public Health Nutr. 2018; https://doi.org/10.1017/S1368980018001775 PMID: 30021665

25. Seligman HK, Tschann J, Jacobs EA, Fernandez A, López A. Food insecurity and glycemic control among low-income patients with type 2 diabetes. Diabetes Care. 2012; https://doi.org/10.2337/dc11-1627 PMID: 22210570

26. Chrysostomou S, Andreou SN, Andreou C. The development of the gluten free healthy food basket in Cyprus. Is it affordable among low-income adults diagnosed with celiac disease? J Public Health (Oxf) [Internet]. 2020 [cited 2023 Feb 25]; 42(2):270–6. Available from: https://pubmed.ncbi.nlm.nih.gov/31329915/ https://doi.org/10.1093/pubmed/fdz034

27. Gucciardi E, Vogt JA, DeMelo M, Stewart DE. Exploration of the Relationship Between Household Food Insecurity and Diabetes in Canada. Diabetes Care [Internet]. 2009 Dec [cited 2023 Feb 11]; 32 (12):2218. Available from: /pmc/articles/PMC2782980/ https://doi.org/10.2337/dc09-0823 PMID: 19720843

28. 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 Public Health. 2018; https://doi.org/10.3390/ijerph15092016 PMID: 30223555

29. Gany F, Lee T, Ramirez J, Massie D, Moran A, Crist M, et al. Do our patients have enough to eat? Food insecurity among urban low-income cancer patients. J Health Care Poor Underserved. 2014; https://doi.org/10.1353/hpu.2014.0145 PMID: 25130231

30. FAO, IFAD, UNICEF W and W. The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Rome, FAO. 2021.

31. Moher D, Liberati A, Tetzlaff J, Altman DG, Altman D, Antes G, et al. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Medicine. 2009.

32. Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med [Internet]. 2002 Jun 15 [cited 2023 Mar 22]; 21(11):1539–58. Available from: https://pubmed.ncbi.nlm.nih.gov/12111919/ https://doi.org/10.1002/sim.1186

33. Jih J, Nguyen TT, Jin C, Seligman H, Boscardin WJ, Ritchie CS. Food Insecurity Is Associated with Behavioral Health Diagnosis Among Older Primary Care Patients with Multiple Chronic Conditions. J Gen Intern Med [Internet]. 2020 Dec 1 [cited 2023 Mar 1]; 35(12):3726–9. Available from: https://pubmed.ncbi.nlm.nih.gov/31808129/ https://doi.org/10.1007/s11606-019-05569-4

34. Jih J, Stijacic-Cenzer I, Seligman HK, Boscardin WJ, Nguyen TT, Ritchie CS. Chronic disease burden predicts food insecurity among older adults. Public Health Nutr [Internet]. 2018 Jun 1 [cited 2023 Mar 1]; 21(9):1737–42. Available from: https://pubmed.ncbi.nlm.nih.gov/29388533/ https://doi.org/10.1017/S1368980017004062

35. Sharkey JR. Risk and Presence of Food Insufficiency Are Associated with Low Nutrient Intakes and Multimorbidity among Homebound Older Women Who Receive Home-Delivered Meals. In: Journal of Nutrition. 2003. https://doi.org/10.1093/jn/133.11.3485 PMID: 14608062

36. Fernandes SG, Rodrigues AM, Nunes C, Santos O, Gregório MJ, de Sousa RD, et al. Food Insecurity in Older Adults: Results From the Epidemiology of Chronic Diseases Cohort Study 3. Front Med [Internet]. 2018 [cited 2023 Mar 1]; 5(JUL). Available from: https://pubmed.ncbi.nlm.nih.gov/30050904/ https://doi.org/10.3389/fmed.2018.00203

37. Smith L, Il J, Louis S, López GF, Felipe S, Mark S, et al. Food insecurity and physical multimorbidity among adults aged ≥ 50 years from six low - and middle - income countries. Eur J Nutr. 2022; (0123456789).

38. Leung CW, Kullgren JT, Malani PN, Singer DC, Kirch M, Solway E, et al. Food insecurity is associated with multiple chronic conditions and physical health status among older US adults. Prev Med Reports. 2020; https://doi.org/10.1016/j.pmedr.2020.101211 PMID: 32983850

39. O'neal LJ, Jo A, Scarton L, Bruce MA. Food Insecurity Is Associated with Mental–Physical Comorbidities among U.S. Adults: NHANES 2013 to 2016. Int J Environ Res Public Health. 2022; https://doi.org/10.3390/ijerph19031672 PMID: 35162697

40. 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; https://doi.org/10.1007/s11606-019-05081-9 PMID: 31161567

41. Gaigbe-Togbe V, Bassarsky L, Gu D, Spoorenberg T, Zeifman L. World Population Prospects 2022. 2022. 1–54 p.

42. World Health Organization. Ageing and health. 2018. p. https://www.who.int/news-room/fact-sheets/detail/a.

43. Nunes BP, Flores TR, Mielke GI, Thumé E, Facchini LA. Multimorbidity and mortality in older adults: A systematic review and meta-analysis. Archives of Gerontology and Geriatrics. 2016. https://doi.org/10.1016/j.archger.2016.07.008 PMID: 27500661

44. Violan C, Foguet-Boreu Q, Flores-Mateo G, Salisbury C, Blom J, Freitag M, et al. Prevalence, determinants and patterns of multimorbidity in primary care: A systematic review of observational studies. PLoS One. 2014; https://doi.org/10.1371/journal.pone.0102149 PMID: 25048354

45. FAO. The State of Food Insecurity and Nutrition in the World. 2022.

46. Valtorta NK, Hanratty B. Socioeconomic variation in the financial consequences of ill health for older people with chronic diseases: A systematic review. Maturitas. 2013. https://doi.org/10.1016/j.maturitas.2013.01.015 PMID: 23415927

47. Jafari F, Ehsani S, Nadjarzadeh A, Esmaillzadeh A, Noori-Shadkam M, Salehi-Abargouei A. Household food insecurity is associated with abdominal but not general obesity among Iranian children. BMC Public Health. 2017;

48. Gubert MB, Spaniol AM, Bortolini GA, Pérez-Escamilla R. Household food insecurity, nutritional status and morbidity in Brazilian children. Public Health Nutr. 2016; https://doi.org/10.1017/S1368980016000239 PMID: 26893101

49. Eckel RH, Jakicic JM, Ard JD, De Jesus JM, Houston Miller N, Hubbard VS, et al. 2013 AHA/ACC guideline on lifestyle management to reduce cardiovascular risk: A report of the American college of cardiology/American heart association task force on practice guidelines. J Am Coll Cardiol. 2014;

50. Chrysostomou S, Andreou S. Do low-income Cypriots experience food stress? The cost of a healthy food basket relative to guaranteed minimum income in Nicosia, Cyprus. Nutr Diet. 2017; https://doi.org/10.1111/1747-0080.12322 PMID: 28731637

51. González-Fernández D, Pons E del C, Rueda D, Sinisterra OT, Murillo E, Scott ME, et al. C-reactive protein is differentially modulated by co-existing infections, vitamin deficiencies and maternal factors in pregnant and lactating indigenous Panamanian women. Infect Dis Poverty. 2017; https://doi.org/10.1186/s40249-017-0307-1 PMID: 28571565

52. Zhou A, Hyppönen E. Vitamin D deficiency and C-reactive protein: a bidirectional Mendelian randomization study. Int J Epidemiol. 2022;1–12.

53. Legein B, Temmerman L, Biessen EAL, Lutgens E. Inflammation and immune system interactions in atherosclerosis. Cell Mol Life Sci [Internet]. 2013 Oct 21 [cited 2023 Mar 19]; 70(20):3847–69. Available from: https://link.springer.com/article/10.1007/s00018-013-1289-1 PMID: 23430000

54. Feingold KR, Grunfeld C. The Effect of Inflammation and Infection on Lipids and Lipoproteins. Endotext [Internet]. 2022 Mar 7 [cited 2023 Mar 19]; Available from: https://www.ncbi.nlm.nih.gov/sites/books/NBK326741/

55. Vozoris NT, Tarasuk VS. Household food insufficiency is associated with poorer health. J Nutr. 2003; https://doi.org/10.1093/jn/133.1.120 PMID: 12514278

56. Mendis S, Puska P, Norrving B. Global atlas on cardiovascular disease prevention and control. World Heal Organ. 2011;

57. Gowda C, Hadley C, Aiello AE. The association between food insecurity and inflammation in the US adult population. Am J Public Health. 2012; 102(8):1579–86. https://doi.org/10.2105/AJPH.2011.300551 PMID: 22698057

58. Safaei M, Sundararajan EA, Driss M, Boulila W, Shapi'i A. A systematic literature review on obesity: Understanding the causes & consequences of obesity and reviewing various machine learning approaches used to predict obesity. Computers in Biology and Medicine. 2021.

59. Zatońska K, Psikus P, Basiak-Rasała A, Stępnicka Z, Gaweł-Dabrowska D, Wołyniec M, et al. Obesity and Chosen Non-Communicable Diseases in PURE Poland Cohort Study. Int J Environ Res Public Health [Internet]. 2021 Mar 1 [cited 2023 Mar 19]; 18(5):1–10. Available from: /pmc/articles/PMC7967430/ https://doi.org/10.3390/ijerph18052701 PMID: 33800151

60. WHO. Obesity: Preventing and Managing the Global Epidemic. Geneva, Switzerland; 2000.

61. Boyle P, Anderson BO, Andersson LC, Ariyaratne Y, Auleley GR, Barbacid M, et al. Need for global action for cancer control. Ann Oncol. 2008; 19(9):1519–21. https://doi.org/10.1093/annonc/mdn426 PMID: 18723552

62. Cwirlej-Sozanska AB, Wisniowska-Szurlej A, Wilmowska-Pietruszynska A, Sozanski B, Mazur A. Effect of body weight on disability and chronic disease rates in the elderly in south-eastern poland. Ann Agric Environ Med. 2020; https://doi.org/10.26444/aaem/108542 PMID: 32588600

63. Kazancioğlu R. Risk factors for chronic kidney disease: An update. In: Kidney International Supplements. 2013.

64. Chrysostomou S, Koutsampelas C, Andreou SN, Pittas C. The purchase of the Diabetic Healthy Food Basket in Cyprus results in cost savings: Is it affordable among the low-income population? Public Health Nutr. 2020; https://doi.org/10.1017/S1368980020001184 PMID: 32466821

65. Violán C, Foguet-Boreu Q, Hermosilla-Pérez E, Valderas JM, Bolíbar B, Fàbregas-Escurriola M, et al. Comparison of the information provided by electronic health records data and a population health survey to estimate prevalence of selected health conditions and multimorbidity. BMC Public Health. 2013; https://doi.org/10.1186/1471-2458-13-251 PMID: 23517342