



# Food insecurity and body mass index among older people: A systematic review and meta-analysis

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## HIGHLIGHTS

- Food insecurity significantly associated with higher BMI in older adults.
- Meta-analysis included 13 studies with 49,402 participants globally.
- Food-insecure older individuals more likely to be overweight or obese.
- Variation in tools and definitions used to assess food insecurity.

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## ABSTRACT

Food insecurity, characterized by inadequate access to sufficient and nutritious food, poses a significant challenge to the health and well-being of older adults. This systematic review and meta-analysis was aimed to examine the association between food insecurity and body mass index (BMI) in older people, i.e., aging 60 and above. PRISMA 2020 guidelines were followed. The protocol was registered in PROSPERO in advance (ID CRD 42024543271). PubMed/MEDLINE, and Scopus were searched up to February 2024. Out of 5834 retrieved article, a total of 13 studies met the inclusion criteria, encompassing diverse geographic regions and socioeconomic contexts. The meta-analysis revealed a significant association between food insecurity and higher BMI (both obesity and overweight) in older adults. Pooled estimates indicated that food-insecure older individuals were more likely to be overweight or obese (combined) compared to their food-secure counterparts [OR= 1.29 (95% CI= 1.28-1.30),  $p < 0.001$ ;  $I^2 = 94.92$ ]. Results were also confirmed for overweight or obesity alone. Notably, food insecurity was linked to increased consumption of energy-dense, nutrient-poor foods, contributing to higher BMI. These findings underscore the complex relationship between food insecurity and BMI among older adults, emphasizing the need for targeted interventions to address food access and nutritional quality.

## 1. Introduction

Food security and adequate nutrition are vital for the well-being of older adults, helping to mitigate age-related vulnerability to diseases, mental decline, and impaired immune function (Cristina & Lucia, 2021).

Increasing evidence suggests that non-communicable diseases (NCDs) and obesity, particularly in older adults, are linked to food insecurity and unhealthy lifestyle behaviours (Al-Jawaldeh & Abbass, 2022). Food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their

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dietary needs and preferences for an active and healthy life (Clay, 2003).

The cultural, social, and economic practices affecting food consumption, purchasing patterns, and preferences, play a significant role in the dietary habits of older adults. Food insecurity among older adults is often associated with financial vulnerability, low socioeconomic and educational status, functional limitations, living alone, reduced social contact, and lower intake of nutrients (Odunitan-Wayas et al., 2021). Neighbourhood food environments and household food way, such as access to local food retail outlets and the ability to shop and prepare food independently, can reduce the risk of food insecurity. These specific vulnerabilities among elderly can lead to malnutrition, which is associated with longer hospital stays, increased readmissions, and reduced quality of life (Odoms-Young et al., 2024).

Food-insecure older adults frequently consume low-cost, highly processed, and energy-dense foods, which may contribute to obesity, also taking in account that poverty is particularly diffused among older subjects (Woo et al., 2020). Studies in various countries have demonstrated that food-insecure households often lack adequate storage facilities for bulk buying and rely on informal retail food outlets for their convenience (Carvajal-Aldaz et al., 2022). In developing countries, rapid dietary and activity pattern changes have led to a double burden of malnutrition, characterized by the simultaneous presence of underweight and overweight individuals within the same population (Singh et al., 2023). Both underweight and overweight conditions in older adults can lead to serious health consequences, including chronic diseases, disability, and premature mortality (Jiang et al., 2019, Soysal et al., 2022).

Given the rising prevalence of overweight and obesity globally, and specifically among older adults, and the significant proportion of food-insecure populations (Boutari & Mantzoros, 2022), understanding the association between food insecurity and body mass index (BMI) in this demographic is crucial. Previous studies have highlighted the importance of food security in maintaining nutritional balance and preventing malnutrition-related health issues in older adults (Norman et al., 2021). However, results are contrasting with some studies detecting an association between food insecurity and obesity and some other not.

This systematic review and meta-analysis aim to examine the association between food insecurity and BMI in the older adult population (aged 60 and above). By synthesizing existing research, we seek to provide a comprehensive understanding of how food insecurity impacts BMI and identify gap in knowledge. This understanding is essential for developing targeted interventions to improve food security and health outcomes for older adults.

## 2. Methods

This systematic review and meta-analysis adhered to the Cochrane Collaboration guidelines and followed the PRISMA 2020 and MOOSE guidelines for reporting results. The study protocol was pre-established, shared among the research team, and registered in PROSPERO (registration number: CRD 42024543271).

### 2.1. Literature search strategy

The literature search was conducted on PubMed/MEDLINE and Scopus on February 21, 2024. The search aimed to answer the question: "Is the food insecurity associated with body mass index among older people?" The search strategy was developed around three key elements: older population, food security/insecurity, and body mass index. Keywords, including MeSH terms and Title/Abstract, were combined using Boolean operators AND and OR. The PubMed/MEDLINE search strategy was adapted for Scopus. Supplementary Table 1 details the search strategies for each database. Additional articles were retrieved screening references of included studies or consulting experts in the field.

### 2.2. Inclusion and exclusion criteria

Studies were selected based on the PECOS framework: Population (people over 60), Exposure (food insecurity), Comparison (food security), Outcome (body mass index), and Study design (observational epidemiological studies). Eligible studies were those published in English in peer-reviewed journals. Excluded were non-original studies, interventional studies, those not specifically assessing food security (but as for instance food security components or associated factors) or different health outcomes, studies on individuals younger than 60, and non-English publications. Supplementary Table 2 provides a detailed description of the criteria.

### 2.3. Study selection and data extraction

Study selection occurred in two phases: initial screening of titles and abstracts, followed by full-text review of potentially eligible articles. Two reviewers independently assessed the studies at each stage. Disagreements were resolved through discussion, or by involving a third senior researcher if necessary. Data were extracted using a pre-defined spreadsheet in Excel, pre-tested on five randomly selected studies. Extracted data included author, year of publication, the country where the study took place, study period, study design, number of participants, age and gender, main population characteristics, the tool used to assess the level of food security/insecurity and if it was validated or not, definitions of food security/insecurity, method used to measure BMI, maximally adjusted effect size measurements along with the corresponding 95% CI (confidence intervals), number and kind of variables of adjustment in the multivariate analyses, if any funds received for conducting original study and conflict of interests declared. Data extraction was performed in duplicate, and discrepancies were resolved by discussion.

### 2.4. Data synthesis

Following PRISMA 2020 guidelines, the selection process was documented with a flow diagram showing the number of references excluded at each step. Reasons for study exclusion after full-text assessment were detailed. Extracted data were tabulated and summarized in text, with statistical analysis results presented in tables and figures.

### 2.5. Quality assessment

The Newcastle-Ottawa Scale (NOS) assessed the methodological quality and risk of bias of the included studies (Luchini et al., 2017). The scale grades studies on selection, comparability, and exposure or outcome ascertainment giving a score between 0 and 9, higher scores reflecting a higher quality. Studies scoring 7 or more points on the NOS were considered high quality (Nucci et al., 2021).

### 2.6. Statistical analysis

Meta-analysis pooled data to assess the association between food insecurity and body mass index, using odds ratios (OR). Both random and fixed effect models were employed. Heterogeneity was measured using the  $I^2$  test and classified as high ( $I^2 \geq 75\%$ ), moderate ( $50\% \leq I^2 < 75\%$ ), low ( $25\% \leq I^2 < 50\%$ ), or none ( $I^2 < 25\%$ ). Publication bias was assessed using funnel plots and Egger's test, with  $p < 0.10$  indicating bias. If bias was detected, the trim and fill method adjusted for missing studies was applied. Data analyses were performed using Prometa3® software (Internovi, Cesena, Italy).

### 2.7. Subgroup and sensitivity analyses

Subgroup analyses based on gender and geographical location have

been conducted in order to identify any variations in the outcomes that may be attributed to these specific factors. Moreover, to ensure the robustness of our findings, we performed sensitivity analyses considering study design (e.g., cohort studies, cross-sectional studies), quality of the studies included, and based on tools used in the studies to assess exposure and measure outcomes. By conducting these sensitivity analyses, we aim to enhance the reliability and credibility of our review findings, identifying any potential biases or variations due to the study design, quality, or assessment tools.

### 3. Results

#### 3.1. Literature search

A total of 5,834 records were identified by searching PubMed/MEDLINE ( $n = 1873$ ) and Scopus ( $n = 3961$ ). No additional articles were included based on reference screening and expert consultation.

After preliminary exclusion of duplicates ( $n = 1606$ ), a total of 4228 records were screened based on title and abstract. Based on the initial screening, 4198 records were removed because non-original work (review  $n = 334$ , not full-text articles  $n = 345$ ) and focus on different topics ( $n = 3519$ ), leaving 30 records eligible for inclusion. Based on full-text assessment, 17 records were excluded (reasons for exclusion are detailed in the supplementary table 3) (Gajda & Jeżewska-Zychowicz, 2023, Maila, Olayiwola & Ketiku, 2006, Depa et al., 2018, Holben & Pheley, 2006, Ganpule et al., 2023, Kim & Kim, 2020, Kowaleski-Jones et al., 2018, Lee et al., 2021, Leung & Williams, 2012, Liu et al., 2019, Nikniaz et al., 2017, Novin et al., 2022, Pengpid & Peltzer, 2023, Pequeno et al., 2022, Ro & Osborn, 2018, Sarlio-Lähteenkorva & Lahelma, 2001), resulting in 13 records included in the current systematic review (Odunitan-Wayas et al., 2021, Blaney et al., 2009, Brostow et al., 2019, Choi et al., 2022, Encalada-Torres et al., 2022, Fernandes et al., 2018, Gajda, 2023, Ganhão-Arranhado et al., 2018, Grammatikopoulou et al., 2019, Hernandez et al., 2017, Hudin et al., 2017, Kandapan et al., 2022, McClain et al., 2022); however, one record did not provide analytical data and therefore could not be included in the meta-analysis (Blaney et al., 2009), whereas another study reported data as beta coefficient and could not be pooled with the other included studies (Encalada-Torres et al., 2022). The selection process is shown in Fig. 1.

#### 3.2. Descriptive characteristics of included studies

The systematic review included 13 studies encompassing 49,402 participants, predominantly cross-sectional in design. The studies were conducted in various continents, with America the most represented (including three studies in USA, one study in Ecuador and one study in Puerto Rico), followed by Europe with 3 studies (Portugal, Poland, and Greece). Two studies were conducted in Africa (Gabon, and South Africa) and lastly, two studies in Asia (Malaysia and India) (Fig. 2). The participant's age ranged from 60 years and above, with a majority being females (ranging from 52% to 79.9%). The studies focused on community-dwelling older adults, with some from rural settings and others from urban areas or specific health and nutrition surveys (Table 1).

#### 3.3. Methodological aspects of included studies

In this systematic review, various tools were employed to assess food insecurity, each with its own methodology and in some cases validation status (11 studies out of 13). The USDA modules and the Food Insecurity Experience Scale (FIES) were among the most commonly used validated tools. These instruments are crucial for providing standardized measures that facilitate comparisons across different populations and settings. However, the variation in tools reflects the multifaceted nature of food insecurity and the different contexts in which it is studied. Moreover, the heterogeneity in food insecurity definitions highlights the complexity of assessing food insecurity and underscores the importance of selecting appropriate instruments tailored to specific contexts and populations. Regarding food insecurity prevalence, results across these studies shows considerable variation, ranging from as low as 15% to as high as 70%. The majority of studies reported prevalence rates between 17% and 45%. Notably, the studies with higher prevalence rates, such as those by Encalada-Torres et al. (56.8%) and Ganhão-Arranhado et al. (70%)(37 (38), highlight significant levels of food insecurity in certain populations, suggesting that food insecurity remains a critical public health issue that warrants targeted interventions and policy responses.

The methods used to assess BMI in the reviewed studies varied between self-reported and directly measured approaches, as shown in Table 2.

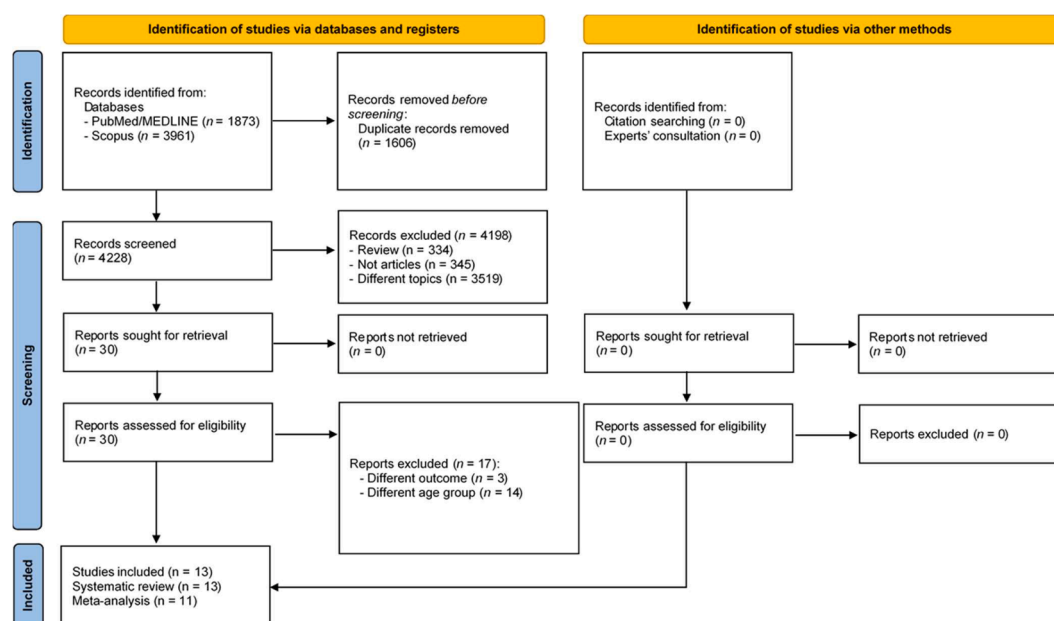


Fig. 1. Flow diagram depicting the selection process.



Fig. 2. Geographical distribution of included studies.

Table 1

Descriptive characteristics of included studies.

Author, year	country	study period	study design	number of participants	age	gender	main population characteristics
Blaney, 2009 (Cristina & Lucia, 2021)	Gabon	n.a.	C-S	301	≥60 y	n= 96 F	rural communities
Brostow, 2019 (Al-Jawaldeh & Abbass, 2022)	USA	2013	C-S	2,868	75.7±7 y	63.0% F	participants from the Health and Retirement Study
Choi, 2022 (Clay, 2003)	USA	2012-2013	C-S	6,203	65.10± 9.61 y	54.2% F	community-dwelling older adults in the Health and Retirement Study Health Care and Nutrition Survey and the National Neighbourhood Data Archive
Encalada-Torres, 2022 (Odunitan-Wayas et al., 2021)	Ecuador	2018	C-S	400	77±7.7 y	60.2% F	community-dwelling older adults living in urban and rural areas
Fernandes, 2018 (Odoms-Young et al., 2024)	Portugal	2015-2016	C-S	1634	74.3±6.8 y	55.5% F	non-institutionalized
Gajda, 2023 (Woo et al., 2020)	Poland	2018-2019	C-S	760	65-74 y 69.9%; >75 y 30.1%	69.3% F	community-dwelling older adults aged 65 y and above living in an area with high level of cultural and economic diversity
Ganhão-Arranhado, 2018 (Carvajal-Aldaz et al., 2022)	Portugal	September 2015 to February 2016.	C-S	337	78.4±7.0 y	62.3% F	non-institutionalized, Senior Centres attendees, aged 65 or more
Grammatikopoulou, 2022 (Singh et al., 2023)	Greece	January to December 2017	C-S	207	72.4±8.5 y	56.5% F	non-hospitalised, non-institutionalised, community-dwelling older adults
Hernandez, 2017 (Jiang et al., 2019)	USA	2011-2012	C-S	5506	71.57±0.15 y	n= 3519, 63.9% F	non-institutionalized
Hudin, 2017 (Soysal et al., 2022)	Malaysia	March-May 2015	C-S	289	69.7 ± 6.0 y	79.9% F	community-dwelling older adults aged 60 y and above without terminal illness, no mute and deaf, and no those who needed assistance for feeding, living a rural area
Kandapan, 2022 (Boutari & Mantzoros, 2022)	India	2017-2018	C-S	28004	79.7% 60-74 y, 20.3% > 75 y	52% F	two-thirds (66.6%) were from rural areas
McClain, 2022 (Norman et al., 2021)	Puerto Rico	2002-2007	C-S	2712	72.8 y	56.7% F	noninstitutionalized older adults (≥60 y)
Odunitan-Wayas, 2021 (Luchini et al., 2017)	South Africa	April-December 2018	C-S	122	67 (64-71) y	only F	non-institutionalized - educated/schooled (only able to read and write) from low-income urban setting

C-S: C-S; F: F; y: years; n.a. not available.

### 3.4. Quality assessment

Based on the results of the risk of bias assessment, the studies included in this review demonstrate varying levels of bias across several key domains. In total five studies demonstrated high quality across all assessed domains, with a total score of 8 (Choi et al., 2022, Fernandes et al., 2018, Hernandez et al., 2017, Kandapan et al., 2022, McClain et al., 2022). A total of seven one study showed a moderate quality (Odunitan-Wayas et al., 2021, Brostow et al., 2019, Encalada-Torres et al., 2022, Gajda, 2023, Ganhão-Arranhado et al., 2018, Grammatikopoulou et al., 2019, Hudin et al., 2017), scoring 5 and indicating

reasonable quality with certain areas of bias, mainly related to limitations in statistical analysis and control variables. Lastly, one study scored the lowest at 3, indicating significant methodological limitations and higher risk of bias (Blaney et al., 2009). These results highlight that while several studies exhibit high methodological quality, a substantial number display moderate to low quality with varying risks of bias. This variability underscores the importance of considering these biases when interpreting the findings and drawing conclusions from the review. Detailed item-by-item quality assessments for each included study are presented in Supplementary Table 4.

The studies included in this systematic review reported varying

**Table 2**

Methodological characteristics and main results of included studies.

author	tool used to assess the level of food insecurity	validated or not	definitions of food insecurity	food insecurity prevalence	method used to measure BMI	maximally adjusted effect size along with the corresponding 95% CI	variables of adjustment	funds	conflict of interests
Blaney (Cristina & Lucia, 2021)	semi-structured interviews	n.a.	Food-secure: mean household adequacy for at least two of the four nutrients was $\geq 75\%$ while $< 50\%$ of income was spent on food.	n.a.	self-reported weight and height	not significantly associated (data not shown)	n.a.	yes	no
Brostow (Al-Jawaldeh & Abbass, 2022)	USDA Six-Item Food Security Module	yes	participants' financial ability to purchase sufficient food (quantity), their perceptions of their ability to afford "balanced" meals (diet quality), meal frequency, and experiences of hunger	17.9% n= 513	measured body mass index	obese food insecure: 185 out of 873; overweight food insecure: 194 out of 1103	none	n.a.	n.a.
Choi (Clay, 2003)	short form of the U. S. Household Food Security Survey Module	yes	self-perceived nutritional inadequacy, household food depletion, disrupted eating patterns, and a repetitive pattern of reduced food intake due to financial constraints over the last 12 months	17.1% (overall)	self-reported weights and heights	obesity: OR= 1.25 (1.03- 1.52)	physical activity, smoking, diet quality	yes	no
Encalada-Torres (Odunitan-Wayas et al., 2021)	Latin American and Caribbean Food Security Scale	yes	n.a.	n= 227, 56.8% (overall)	measured and categorized based on WHO cut-off	underweight: $\beta = 2.971$ (0.326-27.048) p= 0.334	none	yes	no
Fernandes (Odoms-Young et al., 2024)	telephone interview using the Brazilian Food Insecurity Scale	yes	food insecurity within the 3 months before the survey, including mild, moderate and severe food insecurity, defined as anxiety about lack of food to meet dietary needs (mild), food intake reduction and changes in eating patterns (moderate), and experienced the physical sensation of hunger (severe)	30.6% (n= 500); 16.3% mild food insecurity, 4.8% moderate, and 2% severe food insecurity	self-reported weight and height	underweight: OR= 0.421 (0.400-0.443); pre-obesity: 1.388 (1.376-1.401); Obesity: 1.314 (1.300-1.328)	gender, age, education level and health region	yes	no
Gajda (Woo et al., 2020)	US Household Food Security Survey Module developed by Department of	yes	food shortage concerns, lack of basic food, need to change size or	n.a.	self-reported	<b>Food insecurity due to spatial-health issues</b> overweight: OR= 1.04 (0.73- 1.50), p= 0.812;	none	n.a.	n.a.

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Table 2 (continued)

author	tool used to assess the level of food insecurity	validated or not	definitions of food insecurity	food insecurity prevalence	method used to measure BMI	maximally adjusted effect size along with the corresponding 95% CI	variables of adjustment	funds	conflict of interests
	Agriculture 10-item questionnaire		frequency of meals, need to skip meals			obesity: OR= 2.39 (1.59-3.62) p<0.001; <b>Food insecurity due to economic-social issues</b> overweight: OR= 1.34 (0.79-2.27) p= 0.279; obese: OR= 0.82 (0.46-1.48) p= 0.508			
Ganhão-Arranhado (Carvajal-Aldaz et al., 2022)	Food Insecurity Experience Scale (FIES) - 8 short questions referred to the previous 12 months	yes	Food insecurity: anxiety, changes in food quality and quantity	70%; 34.7% mild, 28.8% moderate, 6.5% severe	Measured body height and weight (performed according to International Standards for Anthropometric Assessment - ISAK procedures)	overweight: mild FI= 56 out of 117; moderate FI= 38 out of 97; severe FI= 6 out of 22; obese: mild FI= 35 out of 117; moderate FI= 27 out of 97; severe 3 out of 22	no	no	no
Grammatikopoulou (Singh et al., 2023)	Household Food Insecurity Access Scale	yes	anxiety/ uncertainty about household food access, reduced quality and quantity of food intake and collateral consequences	15% (mild, moderate and severe)	measured at morning hours, with a digital scale and a portable stadiometer	BMI man and (SD) among food secure= 29.5 (6.2) n = 49; food insecure 29.2 (8.6) n= 158	none	no	no
Hernandez (Jiang et al., 2019)	US Department of Agriculture 10-item questionnaire	yes	food insecurity is the lack of availability or access to healthful food because of insufficient money or other resources (Participants who responded affirmatively to three or more items)	19% (overall)	measured on participants' self-reported height and weight	Food insecurity Female: overweight&obese: OR= 1.07 (0.82-1.41), Male: overweight&obese: OR=0.59 (0.41-0.85); Female: overweight OR= 1.17 (0.85-1.61), male: overweight: OR= 0.58 (0.39-0.86)	demographic characteristics (not otherwise specified)	no	no
Hudin (Soysal et al., 2022)	Food Security Tool For Elderly	yes	food insecurity includes those with and without hunger	n= 80, 27.7% (overall)	weight and height were measured using digital weighing scale and stadiometer	OR= 0.911 (0.852-0.974) p=0.006	none	yes	no
Kandapan (Boutari & Mantzoros, 2022)	Food Insecurity Experience scale (FIES) that was developed by the Food and Agriculture Organization (FAO) Voices of the Hungry (VOH) project	yes	<b>Mild:</b> "if the respondent did not eat enough food of his/her choice (excluding fast-ing/food-related restrictions due to religious or health-related reason)". <b>Moderate:</b> "if the respondent reduced the size of your meals or skipped meals because there was not enough food at its household". <b>Severe:</b> "if the respondent 'was hungry but did not eat' or 'did not eat for a	44.6% food insecurity (mild- 37.5%, moderate- 2.1%, and severe-5%)	height and weight of adults were measured using standard procedures. WHO classification was adopted to classify the BMI	<b>RRR: Relative Risk Ratio;</b> <b>Food insecurity-Underweight</b> mild: RRR=1.133 *** (1.066,1.204), moderate: RRR=1.152 (0.952,1.394) severe: RRR=1.503 *** (1.347,1.677) <b>Food insecurity-Overweight</b> mild: RRR=0.977 (0.915,1.044) moderate: RRR=0.671 ** (0.524,0.859) severe: RRR=0.848 * (0.731,0.983)	age, sex, years of schooling, working status, and marital status	no	no

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Table 2 (continued)

author	tool used to assess the level of food insecurity	validated or not	definitions of food insecurity	food insecurity prevalence	method used to measure BMI	maximally adjusted effect size along with the corresponding 95% CI	variables of adjustment	funds	conflict of interests
McClain (Norman et al., 2021)	single-question	no	whole day' because there was not enough food at its household (excluding fasting/food-related restrictions due to religious or health-related reason)". food insufficiency in childhood	n.a.	measured body weight and height	Obesity Male: OR= 0.9 (0.6, 1.2); Female: OR= 1.2 (0.7, 2.2)	age, childhood household economic conditions, self-rated health as child, father's educational attainment, participation in Nutrition Assistance for Puerto Rico program, educational attainment, wealth markers, primary occupation during adulthood, smoking and physical exercise.	yes	n.a.
Odunitan-Wayas (Luchini et al., 2017)	Household food insecurity access scale (HFIAS)	yes	concerns about access to food, insufficient food quality, and insufficient food intake and its physical consequences within the previous 30 days	food insecure (moderate and severe): 36.9%	BMI was calculated based on measured weight and height	Overweight: Food insecurity= 10 out of 24; obese= 31 out of 87	none	yes	no

levels of detail regarding funding sources and conflicts of interest, reflecting transparency in research practices and potential biases that could influence findings. In particular, 7 studies reported funds, whereas four studies declared no funds (Ganhão-Arranhado et al., 2018, Grammatikopoulou et al., 2019, Hernandez et al., 2017, Kandapan et al., 2022), and two studies did not report the information (Brostow et al., 2019, Gajda, 2023). Regarding conflict of interests, only one study among those that reported funds did not specify if any conflict of interest, whereas all the other declared no conflicts (McClain et al., 2022).

### 3.5. Meta-analysis

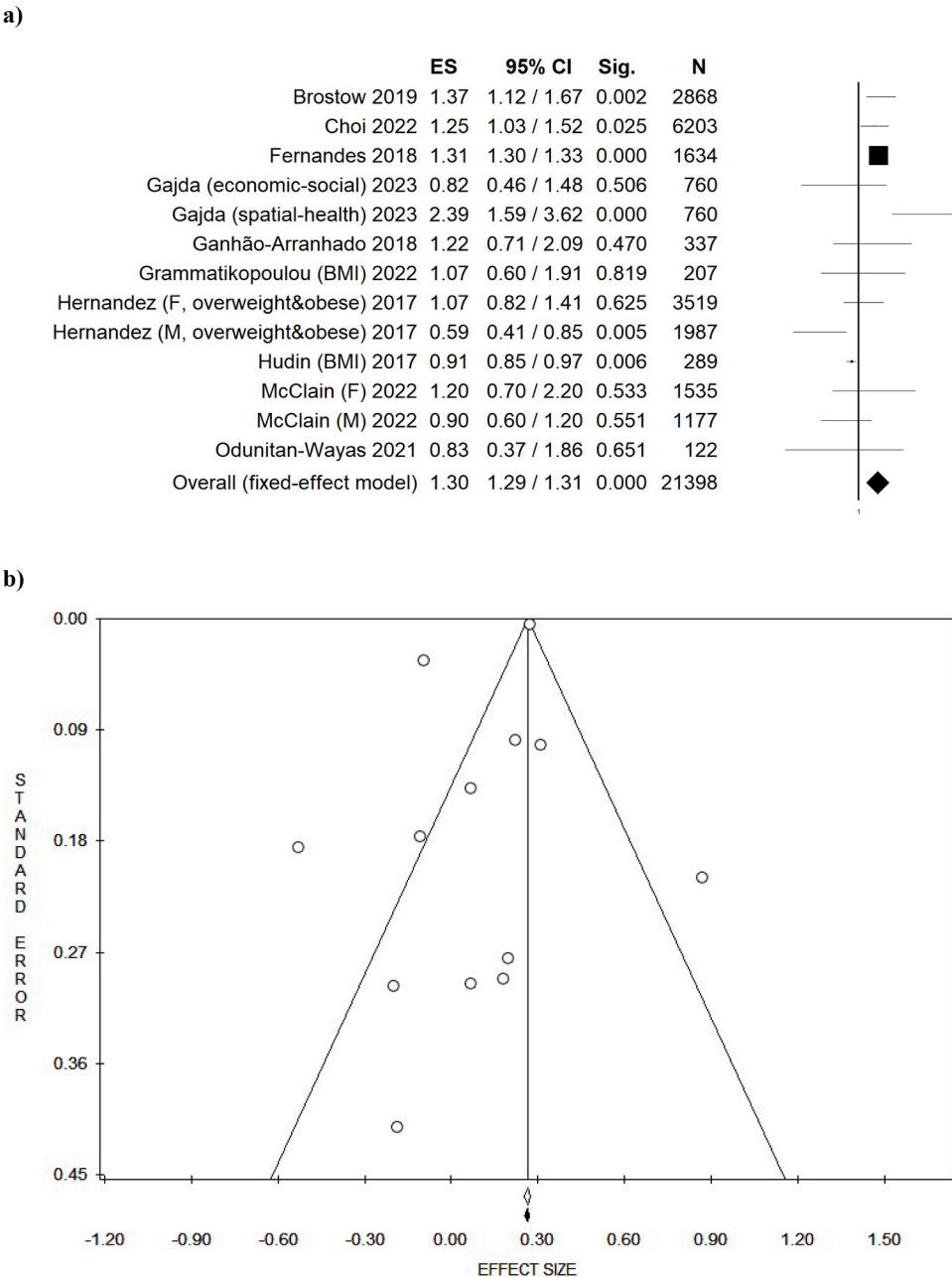
The meta-analysis revealed a significant association between food insecurity and BMI (both considered as categorical or continuous variable) among older people. The fixed effects model yielded an odds ratio (OR) of 1.29 [95% CI = 1.28-1.30],  $p < 0.001$ , based on 49,402 participants, indicating that food insecurity is associated with a higher BMI. However, there was considerable heterogeneity ( $d = 14$ ,  $I^2 = 94.92\%$ ,  $p < 0.001$ ). The random effects model showed an OR of 1.08 (95% CI: 0.91-1.27,  $p = 0.378$ ), suggesting no significant association when accounting for variability among studies. No potential publication

bias was identified by visual assessment of the funnel plot and confirmed by Egger's linear regression test (intercept -2.20,  $p$ -value = 0.092). Results are reported in Fig. 3 a (Forest plot) and b (Funnel plot).

In examining the relationship between food insecurity and obesity, the fixed effects model indicated a significant association with an OR of 1.31 (95% CI: 1.30-1.33,  $p < 0.001$ ) and moderate heterogeneity ( $I^2 = 52.98\%$ ). The random effects model confirmed this significant association with an OR of 1.27 (95% CI: 1.11-1.45,  $p < 0.001$ ). Also in this case, no potential publication bias was identified by visual assessment of the funnel plot (Fig. 2b) and confirmed by Egger's linear regression test (intercept -0.35,  $p$ -value = 0.548). Results are reported in Fig. 4 a (Forest plot) and b (Funnel plot).

For overweight status, the fixed effects model presented an OR of 1.38 (95% CI: 1.37-1.39,  $p < 0.001$ ), with high heterogeneity ( $I^2 = 95.84\%$ ,  $p < 0.001$ ). The random effects model, however, did not find a significant association, with an OR of 1.03 (95% CI: 0.80-1.33,  $p = 0.824$ ). Results are reported in Fig. 5 a (Forest plot) and b (Funnel plot). Forest and funnel plots for random effect models are reported in Supplementary figures 1-3.

It was not possible to assess the pooled OR for underweight, since only two studies specifically estimated the risk associated with food



**Fig. 3.** a) forest plot and b) funnel plot of the fixed effect model assessing the association between food insecurity and BMI (both considered as categorical or continuous variable) among older people.

insecurity; and these studies showed inconsistent results. Specifically, one study found a lower odds of under-nutrition among food-insecure people aged 60 or above (Fernandes et al., 2018), whereas the other found no statistically significant association between under-nutrition and food insecurity (Encalada-Torres et al., 2022). The results for both the fixed and random effect models are shown in Table 3.

3.6. Subgroups analysis

Only two studies stratified by gender, and therefore subgroup meta-analysis by gender was not possible. On the other hand, subgroup analysis by geographical location was performed. Specifically, we categorized studies considering the continents and therefore, two subgroup analyses were conducted: for America and Europe. Studies conducted in Europe (Gajda, 2023, Ganhão-Arranhado et al., 2018, Grammatikopoulou et al., 2019) showed a significant association with

an OR of 1.43 (95% CI: 1.11-1.85,  $p = 0.006$ ) and substantial heterogeneity ( $I^2 = 72.13\%$ ,  $p = 0.013$ ). The random effects model did not support a significant association (OR = 1.30, 95% CI: 0.79-2.14,  $p = 0.297$ ). Studies from the Americas (Brostow et al., 2019, Choi et al., 2022, Hernandez et al., 2017, McClain et al., 2022) indicated a modest significant association with an OR of 1.13 (95% CI: 1.01-1.26,  $p = 0.028$ ) and high heterogeneity ( $I^2 = 73.02\%$ ,  $p = 0.002$ ). The random effects model showed no significant association (OR = 1.05, 95% CI: 0.83-1.31,  $p = 0.700$ ). However, significant bias was detected in this subgroup analysis. After applying the trim and fill method, the estimated effect size did not significantly differ (Table 3). Supplementary figure 4 a and b show the forest plot, respectively for Europe and Americas.

3.7. Sensitivity analysis

Sensitivity analysis by study design was not assessed because all



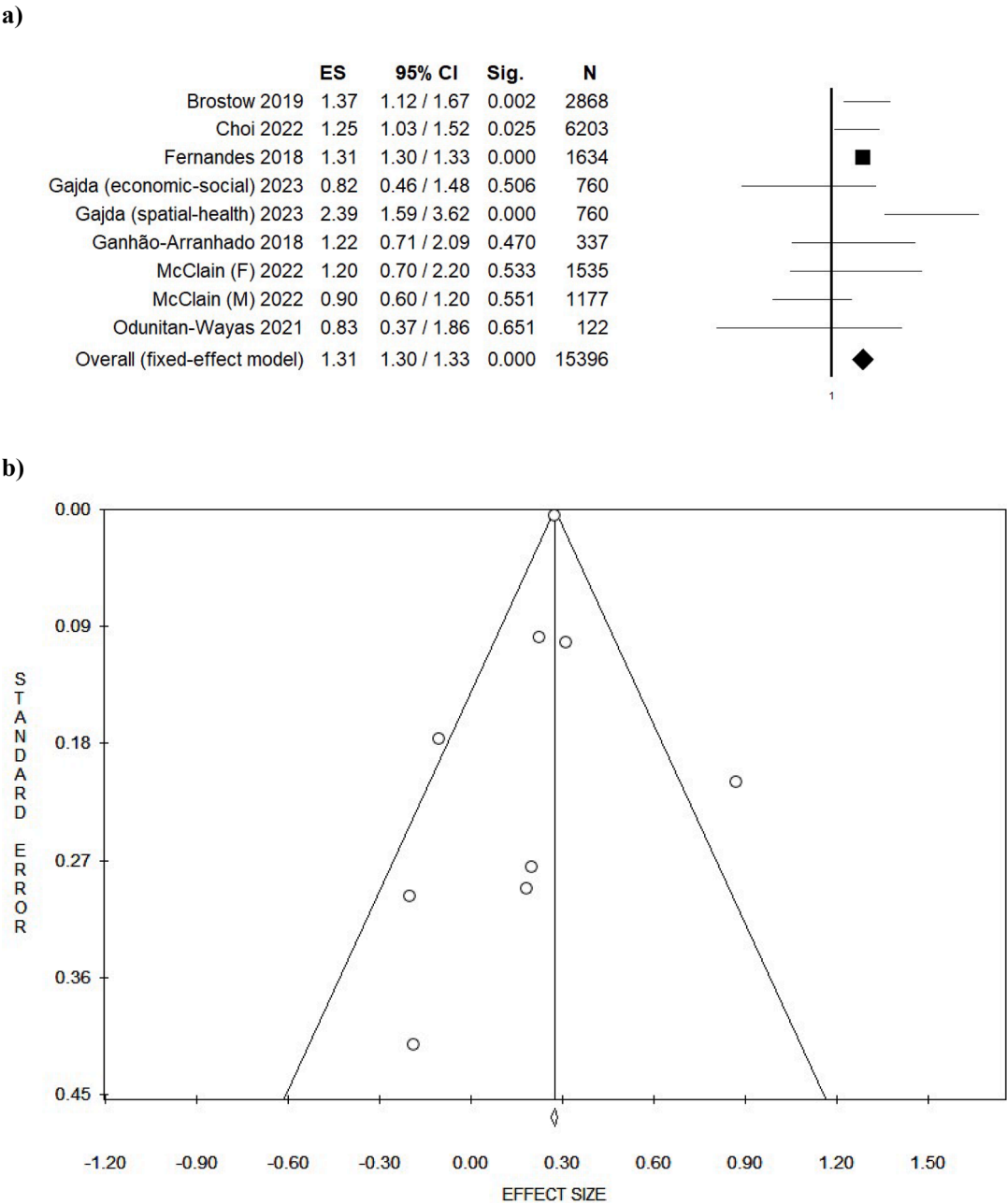


Fig. 4. a) forest plot and b) funnel plot of the fixed effect model assessing the association between food insecurity and obesity among older people.

included studies were cross-sectional. When restricted to studies using validated tools for assessing food insecurity, the fixed effects model showed an OR of 1.29 (95% CI: 1.28-1.31,  $p < 0.001$ ), with high heterogeneity ( $I^2 = 95.63\%$ ,  $p < 0.001$ ). The random effects model showed no significant association (OR = 1.09, 95% CI: 0.91-1.30,  $p = 0.357$ ) (Table 3). For studies using validated BMI measurements, the fixed effects model indicated a protective effect with an OR of 0.91 (95% CI: 0.87-0.96,  $p < 0.001$ ) and moderate heterogeneity ( $I^2 = 66.73\%$ ,  $p = 0.004$ ). The random effects model also suggested a protective effect but was not statistically significant (OR = 0.99, 95% CI: 0.87-1.13,  $p = 0.890$ ).

Sensitivity analysis by quality score (only including high-quality studies, scored 7 and above) revealed that the association was statistically significant only when considering the fixed effect model, but not when the random effect model was used. Details are reported in Table 3. Supplementary figure 4 c show the forest plot of fixed effect model for sensitivity analysis by quality score.

#### 4. Discussion

##### 4.1. Interpretation of results

The findings from this systematic review and meta-analysis indicate a notable association between food insecurity and higher BMI in older people. This association is particularly evident in the context of obesity, where food insecurity significantly correlates with increased odds of being obese. The fixed effects model consistently demonstrated a significant positive association between food insecurity and BMI. This suggests that elderly individuals experiencing food insecurity are more likely to have higher BMI values. The significant association persisted across the specific category of obesity, indicating that food insecurity may be a critical determinant of obesity among older adults. However, the presence of high heterogeneity in many of the analyses suggests substantial variability among the included studies. This variability could be attributed to differences in study populations, settings, and

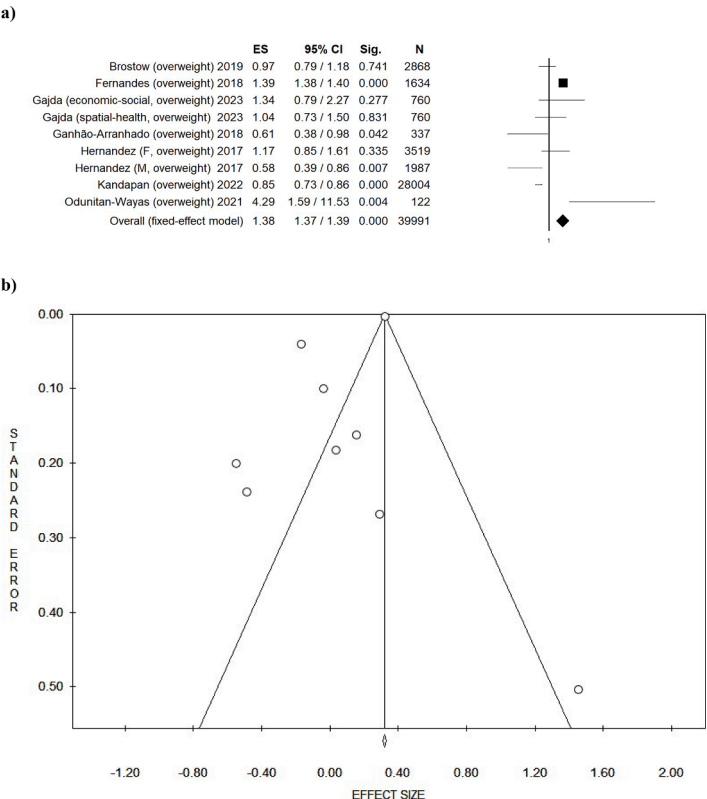


Fig. 5. a) forest plot and b) funnel plot of the fixed effect model assessing the association between food insecurity and overweight among older people.

methodologies to determine both food insecurity and BMI. As for instance, some studies specifically focused on rural or urban areas, moreover, considering methodological aspects, most of the included studies used different tools for assessing food insecurity. Lastly, different levels of food insecurity were considered among studies, contributing in the high detected heterogeneity. Despite this, the random effects models, which account for such variability, still supported a significant association between food insecurity and obesity. This reinforces the robustness of the observed relationship between food insecurity and obesity, although the association with overweight and general BMI under the random effects model was not statistically significant. Sub-group analyses revealed regional differences in the association between food insecurity and BMI. In Europe, a significant association was observed, suggesting that food insecurity might have a more pronounced impact on BMI in Western countries. However, in both the subgroups analyses, the association was weaker and non-significant under the random effects models. When considering studies using validated tools for food insecurity and BMI, the findings were mixed. While the fixed effects model showed significant associations, the random effects model did not. This suggests that methodological rigor and consistency in measurement tools are crucial for accurately assessing the relationship between food insecurity and BMI.

4.2. Public health implications and future research

The findings of this systematic review and meta-analysis have several important implications for public health policies aimed at supporting older people population, particularly those experiencing food insecurity. The observed association between food insecurity and higher BMI, particularly with obesity, underscores the complex interplay between economic, social, and health factors in older people (Carvajal-Aldaz et al., 2022). Addressing the association between food insecurity and higher BMI, including obesity, requires comprehensive and multi-faceted policy interventions (Eskandari et al., 2022). These

findings highlight the need for targeted interventions to address food insecurity as a means to mitigate obesity and related health risks in this vulnerable population. In this perspective, public health policies should prioritize the integration of food security initiatives with nutritional support programs (Durao et al., 2020). Policies that ensure access to nutritious and affordable food can help mitigate the risk of obesity and other related health conditions. Programs such as subsidized grocery vouchers, community gardens, and meal delivery services for older people can play a crucial role in enhancing food security and promoting healthy eating habits (Ziso et al., 2022).

Public health policies should also emphasize tailored nutritional education and counseling for older people, particularly those facing food insecurity. Educational campaigns that provide information on budget-friendly, nutritious meal planning and preparation can empower older adults to make healthier food choices (Teggart et al., 2022). Furthermore, incorporating personalized nutritional counseling into routine healthcare for older people can address individual dietary needs and preferences, thereby improving overall dietary quality and health outcomes (Shyam et al., 2022). Strengthening social safety nets is essential to reduce the economic burden of food insecurity among older people. Policies that enhance income support, such as increasing pension benefits or providing financial assistance specifically for food purchases, can alleviate food insecurity (Khan et al., 2023). Additionally, expanding eligibility criteria and benefits for existing food assistance programs, can ensure broader coverage and support for vulnerable elderly populations. Community-based interventions that foster social support and engagement can also be effective in addressing food insecurity and its health consequences. Public health policies should encourage the development of community centers and programs that provide social interaction, physical activity opportunities, and access to healthy meals (Doustmohammadian et al., 2022). Initiatives such as senior lunch programs, cooking classes, and food sharing networks can create a supportive environment that promotes both food security and healthy lifestyles. Moreover, public health policies should incorporate robust

**Table 3**  
Summary statistics of main analysis, subgroup and sensitivity analyses.

Analysis	Summary statistics					Publication bias	
	Studies Included [Ref.]	No. of Participants	df	ES (95% CI); p-Value	I <sup>2</sup> ; p-value	Intercept <sup>*</sup> ; p-value	Estimated ES <sup>*</sup> ; p-value
BMI	(Al-Jawaldeh & Abbass, 2022), (Clay, 2003), (Odoms-Young et al., 2024), (Woo et al., 2020), (Carvajal-Aldaz et al., 2022), (Singh et al., 2023), (Jiang et al., 2019), (Soysal et al., 2022), (Boutari & Mantzoros, 2022), (Norman et al., 2021), (Luchini et al., 2017)	49,402	14	OR <sup>^</sup> = 1.29 (1.28-1.30); <0.001 OR <sup>''</sup> = 1.08 (0.91-1.27); 0.378	94.92; <0.001	-2.20; 0.092	n.a.
Obesity	(Al-Jawaldeh & Abbass, 2022), (Clay, 2003), (Odoms-Young et al., 2024), (Woo et al., 2020), (Carvajal-Aldaz et al., 2022), (Norman et al., 2021), (Luchini et al., 2017)	15,396	8	OR <sup>^</sup> = 1.31 (1.30-1.33); <0.001 OR <sup>''</sup> = 1.27 (1.11-1.45); <0.001	52.98	-0.35; 0.548	n.a.
Overweight	(Al-Jawaldeh & Abbass, 2022), (Odoms-Young et al., 2024), (Woo et al., 2020), (Carvajal-Aldaz et al., 2022), (Jiang et al., 2019), (Boutari & Mantzoros, 2022), (Luchini et al., 2017)	39,991	9	OR <sup>^</sup> = 1.38 (1.37-1.39); <0.001 OR <sup>''</sup> = 1.03 (0.80-1.33); 0.824	95.84; <0.001	-2.93; 0.106	n.a.
Europe	(Woo et al., 2020), (Carvajal-Aldaz et al., 2022), (Singh et al., 2023)	2,064	3	OR <sup>^</sup> = 1.43 (1.11-1.85); 0.006 OR <sup>''</sup> = 1.30 (0.79-2.14); 0.297	72.13, 0.013	-10.73; 0.015	n.a.
America	(Al-Jawaldeh & Abbass, 2022), (Clay, 2003), (Jiang et al., 2019), (Norman et al., 2021),	17,289	5	OR <sup>^</sup> = 1.13 (1.01-1.26); 0.028 OR <sup>''</sup> = 1.05 (0.83-1.31); 0.700	73.02; 0.002	-3.30; 0.195	n.a.
Quality score		44,059	6	OR <sup>^</sup> = 1.30 (1.29-1.32); <0.000 OR <sup>''</sup> = 1.00 (0.79-1.27); 0.990	95.59; <0.000	-3.23; 0.122	OR <sup>''</sup> = 0.97 (0.76-1.25); 0.825 n.a.
Validated tool for food insecurity	(Al-Jawaldeh & Abbass, 2022), (Clay, 2003), (Odoms-Young et al., 2024), (Woo et al., 2020), (Carvajal-Aldaz et al., 2022), (Singh et al., 2023), (Jiang et al., 2019), (Soysal et al., 2022), (Boutari & Mantzoros, 2022), (Luchini et al., 2017)	46,690	11	OR <sup>^</sup> = 1.29 (1.28-1.31); <0.001 OR <sup>''</sup> = 1.09 (0.91-1.30); 0.357	95.63; <0.001	-2.40; 0.123	n.a.
Validated BMI	(Al-Jawaldeh & Abbass, 2022), (Carvajal-Aldaz et al., 2022), (Singh et al., 2023), (Soysal et al., 2022), (Boutari & Mantzoros, 2022), (Norman et al., 2021), (Luchini et al., 2017)	34,539	7	OR <sup>^</sup> = 0.91 (0.87-0.96); <0.001 OR <sup>''</sup> = 0.99 (0.87-1.13); 0.890	66.73; 0.004	1.10; 0.238	OR <sup>^</sup> = 0.89 (0.85-0.93); <0.001 OR <sup>''</sup> = 0.89 (0.77-1.03); 0.122

<sup>\*</sup> Calculated using Egger's linear regression test; CI: Confident Interval; df: degree of freedom; ES: Effect size; <sup>^</sup> Fixed effects model; <sup>''</sup> Random effects model; n.a.: not applicable; OR: Odds Ratio.

monitoring and evaluation mechanisms to assess the effectiveness of interventions aimed at reducing food insecurity and improving nutritional outcomes among older people (Burgaz et al., 2023). Regular data collection and analysis can help identify gaps, measure progress, and inform the refinement of policies and programs. Collaborating with academic institutions and research organizations can enhance the evidence base for effective public health strategies. By implementing these strategies, policymakers can enhance the well-being and quality of life for older people population, ultimately reducing the burden of obesity and related health conditions.

Further research is needed to explore the causal pathways linking food insecurity and BMI. Longitudinal studies can provide more definitive insights into the temporal relationship and potential mediating factors. Additionally, exploring the impact of regional and cultural contexts will be essential to tailor interventions effectively. Consistent use of validated measurement tools across studies will enhance the reliability of findings and facilitate more robust meta-analyses in the

future.

4.3. Limitations and strengths

One significant limitation of this systematic review and meta-analysis is the high heterogeneity observed among the included studies. Differences in study design, population characteristics, measurement tools, and cultural contexts may contribute to the variability in findings. This heterogeneity can complicate the interpretation of results and limit the generalizability of the conclusions. All the included studies employed a cross-sectional design, which restricts the ability to establish causality between food insecurity and BMI. Longitudinal studies are needed to determine the temporal relationship and potential causal pathways linking food insecurity to changes in BMI and obesity among older people. There were inconsistencies in the measurement tools used to assess food insecurity and BMI across studies. While some studies employed validated instruments, others did not, leading to potential

measurement bias. These inconsistencies can affect the reliability and validity of the pooled estimates. Another potential limitation is that we only limited our research to two scientific databases. Despite including multiple databases might increase the number of retrieved references, we believe that the selection of PubMed/MEDLINE and Scopus provided comprehensive coverage of the relevant literature for our study. Moreover, guidelines set 2 databases as the minimum to perform a systematic review.

The analysis detected significant publication bias in certain subgroups, particularly among American studies. This suggests a potential overestimation of the association due to selective publication of significant results. Moreover, although the review included studies from multiple countries, there was an underrepresentation of certain regions, such as Asia and Africa. This is a notable limitation, as food insecurity is disproportionately prevalent in these regions, which could lead to different patterns in the relationship between food insecurity and BMI compared to other areas. The absence of data from Asia and Africa not only limits the generalizability of our findings but also highlights the urgent need for research that specifically targets these regions. Addressing this gap is essential to gaining a truly global understanding of how food insecurity impacts BMI among the elderly. Future studies should prioritize these underrepresented regions to develop more inclusive and effective interventions. Lastly, while our study provides important insights into the association between food insecurity and BMI in the elderly, we recognize the need to perform a subgroup analyses on vulnerable groups as racial, sexual minorities or migrants. However, the included studies did not provide disaggregated data for specific subgroups, which limited our ability to perform meaningful subgroup analyses. In light of this, we highlight the need for further research to explore these relationships within specific subgroups, which could ultimately contribute to more equitable health outcomes.

Despite some limitations, this review has also important strengths. Firstly, it employed a comprehensive literature search strategy, including multiple databases and a wide range of search terms. Moreover, standard and international guidelines were used to conduct and report data. This approach ensures methodological rigour and contributed in minimizing the risk of missing relevant studies and ensured a broad inclusion of data from various regions and populations. Furthermore, the use of both fixed and random effects models, assessment of publication bias, and evaluation of study quality contributes in enhancing the credibility and reliability of the conclusions drawn from the analysis. Additionally, the meta-analysis included a large overall sample size of 49,402 participants. The substantial sample size enhances the statistical power of the analysis, allowing for more precise estimates of the association between food insecurity and BMI among older people. Moreover, the review conducted detailed subgroup analyses to explore potential sources of heterogeneity and examine the association in different contexts. These analyses provided insights into regional differences and the impact of using validated measurement tools, contributing to a more nuanced understanding of the findings. Lastly, by specifically focusing on older people population, this review addresses a critical and often under-researched group. The findings highlight the unique challenges faced by older adults concerning food insecurity and its impact on BMI, providing valuable information for targeted public health interventions.

In conclusion, this systematic review and meta-analysis provide valuable insights into the association between food insecurity and BMI among older people. The strengths of the review, including its comprehensive approach and large sample size, underscore the importance of addressing food insecurity to improve health outcomes in this vulnerable population. Future research should aim to overcome the identified limitations and further explore the causal relationships and regional variations in this association.

## 5. Conclusions

This systematic review and meta-analysis highlight a significant association between food insecurity and higher BMI among older people, particularly with obesity. The findings varied by region and methodological rigor of the included studies, indicating the complexity of the relationship and the influence of study characteristics. Further research using longitudinal designs and standardized measures of food insecurity and BMI is warranted to better understand the causal pathways and inform interventions.

## CRedit authorship contribution statement

**Vincenza Gianfredi:** Writing – original draft, Formal analysis. **Daniele Nucci:** Writing – original draft, Formal analysis. **Roberta Lattanzio:** Validation. **Sara Piccinelli:** Investigation. **Giovanni Cicconi:** Investigation. **Sheila Jackeline Santisteban Farfan:** Validation. **Alessandro Berti:** Investigation. **Marilena D'Amico:** Investigation. **Noemi Sabatelli:** Validation. **Fabio Guzzardi:** Validation. **Laura Bronzini:** Investigation. **Fabrizio Ernesto Pregliasco:** Investigation. **Stefania Maggi:** Writing – review & editing. **Nicola Veronese:** Writing – original draft. **Pinar Soysal:** Writing – review & editing.

## Declaration of competing interest

None.

## Ethical approval

Not needed.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.archger.2024.105606](https://doi.org/10.1016/j.archger.2024.105606).

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