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Food insecurity and multidimensional healthy aging across 31 countries: pooled longitudinal evidence from four cohorts

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ABSTRACT

Food insecurity is a social determinant of health, yet population level evidence on its relation to multidimensional healthy aging across countries remains limited. We pooled harmonized data from four longitudinal studies conducted in the United States, England, 28 European countries, and Mexico from 2010 to 2019, including 232,228 adults aged 60 years or older. Food insecurity was measured with cohort specific questionnaires. Healthy aging was operationalized across four domains: presence of major diseases, absence of functional limitations, no cognitive impairment, and good mental health. Within cohort associations were estimated using generalized estimating equations and combined using random effects meta-analysis. Food insecurity prevalence ranged from 0.1 % in Denmark to 31.8 % in Mexico. In meta-analysis, food insecurity was associated with lower odds of healthy aging (odds ratio 0.78, 95 % confidence interval 0.72 to 0.85). It was most consistently related to higher odds of functional limitations (odds ratio 1.29, 95 % confidence interval 1.15 to 1.45) and poor mental health (odds ratio 1.56, 95 % confidence interval 1.35 to 1.80). Regional heterogeneity was evident, with stronger associations for cognitive impairment in Europe and for functional limitations in Mexico. Associations were larger among adults younger than 75 years and among those who were physically inactive. Food insecurity is linked to worse multidimensional healthy aging. Routine screening and mitigation of food insecurity within aging and social protection programs, tailored to health system capacity and vulnerable subgroups, may help sustain healthier aging.

1. Introduction

The global aging population is expanding rapidly, with an increasing number of individuals reaching older ages across all regions. As populations age, the focus of public health research has increasingly shifted towards understanding the factors that contribute to "healthy aging."(Dogra et al., 2022). The World Health Organization defines healthy aging as the process of developing and maintaining the functional ability that enables wellbeing in older age (World Health Organization, 2021). Among the many determinants of healthy aging, food insecurity has emerged as a critical yet often overlooked factor that affects older adults worldwide (Pooler et al., 2018). The Food and Agriculture Organization (FAO) defines food insecurity as a situation where an individual lacks consistent access to sufficient, safe, and nutritious food to support normal growth, development, and a healthy, active lifestyle (Food and Agriculture Organization of the United Nations, 2025). Older adults, particularly those in low-income or marginalized communities, are at heightened risk of experiencing food insecurity (Neves Freiria et al., 2024), which may exacerbate age-related health challenges, contribute to chronic diseases, and accelerate activities of daily living decline (Gundersen and Ziliak, 2015). Despite growing recognition of food insecurity as a significant health risk, previous cross-national research has primarily focused on its socioeconomic and structural determinants (Allee et al., 2021; Reeves et al., 2021), with relatively few studies examining its associations with aging health outcomes across countries. Most evidence on the aging health effects of food insecurity comes from the United States (Mavegam Tango Assoumou et al., 2023), with relatively few from low- and middle-income countries

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(Neves Freiria et al., 2024). As a result, evidence on whether food insecurity influences multidimensional healthy aging across global contexts is still insufficient.

Previous epidemiological studies have found significant differences in the prevalence of food insecurity among older people in different countries. While in the United States the prevalence of food insecurity is often reported to be lower among older adults than among working-age adults, largely due to the buffering effect of social programs such as the Supplemental Nutrition Assistance Program (SNAP) and Social Security benefits (Rabbitt et al., 2023; Ziliak et al., 2023), this pattern is not universal. Evidence from low-and middle-income countries indicates that older adults can experience disproportionately high levels of food insecurity, especially in contexts where incomes are limited, household savings are scarce, and intergenerational support is weakening (Neves Freiria et al., 2024). For example, a national survey suggested that nearly one in three older adults aged 60 years or older living in communities in Mexico reports moderate/severe level of food insecurity (Pérez-Zepeda et al., 2016), compared with less than 10 % among those aged 65+ years in high-income countries (Gatton and Gallegos, 2023). Even within high income countries, there is substantial heterogeneity. For example, the rates are relatively low in Nordic countries (such as Norway) with strong welfare states, but considerably higher in Eastern and Southern Europe where social protection systems are more fragile (Gatton and Gallegos, 2023). Beyond these cross-national prevalence variations, it is also important to consider why older adults themselves may be especially vulnerable to the adverse consequences of food insecurity.

From a life-course perspective, older adults may experience greater exposure to food insecurity due to economic, health, and social changes that occur later in life. After retirement, income typically becomes fixed or declines, leaving less flexibility to maintain adequate and nutritious diets (Patriota and Marques-Vidal, 2021). Rising healthcare expenditures further constrain household budgets, while mobility limitations and cognitive decline can make food acquisition and preparation more difficult (Pooler et al., 2018; Wylie et al., 1999). In addition, social changes such as widowhood, living alone, the loss of family caregivers, and reduced household size weaken informal support networks that might otherwise help older adults cope with periods of food scarcity (Lee et al., 2022; Whitelock and Ensaff, 2018).

Beyond higher exposure, older adults are more vulnerable to the health effects of food insecurity. Nutritional deficiencies in later life can exacerbate chronic diseases and accelerate frailty (Shlisky et al., 2017). Limited physiological reserve and multimorbidity reduce the body's capacity to recover from dietary deprivation, while psychosocial stress linked to food insecurity may worsen mental health and functional decline (Pooler et al., 2018). Thus, food insecurity in older age not only occurs more frequently but also may lead to more severe health consequences.

Previous studies have provided evidence supporting these mechanisms, linking food insecurity to a range of adverse health outcomes in older adults, including chronic diseases (Laraia, 2013), functional limitations (Gyasi et al., 2022), brain health (McMichael et al., 2022), and mental health issues (Elgar et al., 2021). However, most existing research has focused on single health domains or specific conditions, and few studies have examined food insecurity in relation to multidimensional healthy aging. As a result, the overall understanding of how food insecurity influences multiple aspects of health and functioning in later life remains limited.

To address these gaps in the literature, this study utilized data from four large, longitudinal cohort studies (involving 31 countries in North America and Europe) to examine the cross-regional association between food insecurity and healthy aging. Specifically, this study investigated the associations between food insecurity and healthy aging, focusing on its four key components: major diseases, functional limitations, cognitive impairment, and mental health, across different cohorts. Furthermore, this study conducted subgroup analysis to determine which populations are more susceptible to the effect of food insecurity on healthy aging. This research not only contributes to our understanding of food insecurity as a determinant of health in older adults but also provides essential evidence for policymakers and healthcare professionals to address the growing issue of food insecurity and its impact on aging populations.

2. Methods

2.1. Study design and participants

This study utilized data from four longitudinal studies, namely the Health and Retirement Study (HRS), the English Longitudinal Study of Ageing (ELSA), the Survey of Health, Ageing and Retirement in Europe (SHARE), and the Mexican Health and Aging Study (MHAS), to enable cross-regional comparisons of food insecurity and healthy aging (see supplementary material, pages 4–5). To ensure temporal comparability, we analyzed data collected between 2010 and 2019 (supplementary material pp 4), excluding data from 2020 onward due to the potential confounding effects of the COVID-19 pandemic. Specifically, the analysis included HRS data from 2010 to 2019 (Waves 10 to 14), ELSA data from 2010 to 2019 (Waves 5 to 9), SHARE data from 2013 to 2019 (Waves 5 to 8, as Wave 4 in 2011 did not assess food insecurity), and MHAS data from 2012 to 2018 (Waves 3 to 5). We used the harmonized dataset developed by Gateway to Global Aging Data Team for four surveys for analysis (Lee et al., 2021). Our study adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)Statement guidelines (supplementary material pp 1–3).

Following the United Nations' age classification for older adults (United Nations Development Programme, 2017), we included participants aged 60 years and older at baseline. Participants with missing data on food insecurity, healthy aging, or covariates were excluded to ensure complete case analysis. The study included 232,228 participants aged $\geq$60 years in final analysis. The study relied on de-identified, publicly available datasets from these cohorts. All four studies had received ethical approval from their respective local ethics committees (supplementary material pp 4–5), and participants provided informed consent prior to enrollment. Supplementary material (pp 6–9) showed the sample selection process for each cohort.

2.2. The measurements of food insecurity

The primary independent variable in this study was food insecurity, which was assessed differently across the cohorts due to variations in survey design and question phrasing. In HRS, it was measured with two questions: (1) "Since the last interview, have you always had enough money to buy the food you need?" and (2) "In the past 12 months, did you ever eat less than you felt you should because there wasn't enough money for food?" Participants responding "no" to the first or "yes" to the second were classified as food insecure; all others were deemed food secure (Lu et al., 2023). In the ELSA, two items were used: (1) "Have meals ever had to be cut or skipped due to insufficient money for food?" and (2) "Does having too little money prevent buying your first choice of food items?" A "yes" to either question indicated food insecurity (Purdam et al., 2019).

In SHARE, a previous study (Nie and Sousa-Poza, 2018) combined the affordability of meat, fish, poultry, fruits, and vegetables to create a proxy measure of food insecurity. However, fruit and vegetable affordability was not consistently assessed across all survey waves, whereas meat, fish, and poultry affordability were available in every wave between 2013 and 2019. To ensure temporal comparability and maintain a consistent analytic sample, we relied on the meat-based affordability measure, although it may underrepresent dietary diversity. In SHARE, household respondents were first asked, "How often does your household eat meat, fish or chicken?" For those reporting less than three times per week, a follow-up question inquired about the reason: (1) "Cannot

afford to eat it more often" or (2) "Other reasons." Respondents selecting option 1 were classified as food insecure; all others were deemed food secure. In the MHAS, food insecurity was evaluated with two questions: (1) "In the last two years, have you always had enough money to buy the food that you need?" and (2) "At any time in the last two years, did you not eat or eat less than you wanted because there was not enough food in your home?". A "yes" to the first or "no" to the second identified participants as food secure, with a "no" to the first item or a "yes" to the second indicating food insecurity (Saenz et al., 2022). Food insecurity was dichotomized (1 = insecure, 0 = secure) across all cohorts for analysis.

2.3. The measurements of healthy aging

The primary outcome, healthy aging, was defined based on prior studies (Rena et al., 2023; Tessier et al., 2025) as the absence of major diseases, functional limitations, cognitive impairment, and the presence of good mental health. Major diseases encompassed diabetes, any cancer or malignant tumor, heart disease, stroke, and chronic lung disease, identified through self-reports diagnosed by a physician across cohorts. Functional limitations were evaluated using five Basic Activities of Daily Living (BADL), namely dressing, bathing, eating, bed transfer, and toileting, to ensure consistency across cohorts. Inability to perform any one of these activities independently classified a participant as having a functional limitation. Cognitive function assessment varied across cohorts, prompting a standardized approach. We evaluated cognition using immediate and delayed recall of 10 words (range 0–20), serial subtraction of seven (five iterations, range 0–5), and three orientation items (year, month, day, range 0–3). Recognizing the strong influence of age and education on cognition, we referred to the aging-associated cognitive decline framework (Levy, 1994) to define impairment. Based on previous reports (Han et al., 2021), participants were grouped into five age categories (60–64, 65–69, 70–74, 75–79, and ≥80 years) and three education levels (less than high school, high school/GED, college and above), yielding 15 age-education strata. For each stratum, mean cognitive scores and standard deviations (SD) were calculated, with cognitive impairment defined as a score below the stratum-specific mean minus 1 SD. Mental health was characterized by the absence of depressive symptoms and self-reported emotional, nervous, or psychiatric conditions diagnosed by a physician. Depressive symptoms were measured differently across cohorts. The HRS and ELSA utilized the 8-item Centre for Epidemiologic Studies Depression Scale (Andresen et al., 1994) (CES-D; range 0–8), with a score ≥3 indicating depressive symptoms. The Mexican Health and Aging Study (MHAS) employed a 9-item CES-D (range 0–9), with a threshold of ≥5 for depressive symptoms. The SHARE used the 12-item Euro-Depression Scale (Prince et al., 1999) (Euro-D; range 0–12), with a score ≥4 denoting depressive symptoms.

2.4. Covariates

Based on previous studies (Behr et al., 2023; Santamaria-Garcia et al., 2023), this study selected age, sex, marital status, education level, family wealth, smoking, alcohol consumption, lack of physical activity, and self-rated health status as potential confounding factors and covariates (supplementary material pp 10). This study used the DAGitty program to create a theoretical model in a directed acyclic graph (supplementary material pp 11) to determine the minimal sufficient adjustment set (MSAS), including age, sex, marital status, education level, and family wealth.

2.5. Statistical analysis

We described continuous variables with mean and SD and described categorical variables with frequencies and percentages. To examine the association between food insecurity and healthy aging, including its components, we applied Generalized Estimating Equations (GEE) with a binomial family, logit link function, and an exchangeable correlation structure, accounting for repeated measures and their correlations. This approach accounted for repeated measures and their correlations across waves. Robust standard errors were estimated using the 'vce(robust)' option in Stata to ensure reliable inference despite potential heteroscedasticity. The strength of associations was quantified using odds ratios (ORs) and their corresponding 95 % confidence intervals (CIs). We fitted three models: Model 1 remained unadjusted; Model 2 adjusted for MSAS; and Model 3 adjusted for all covariates. To synthesize findings across the four cohorts, we conducted pooled analysis by an inverse variance-weighted random-effects meta-analysis, which allowed for between-cohort heterogeneity. The I^2 statistic was reported to quantify the degree of heterogeneity. In addition, we performed subgroup analyses based on covariates to assess variations in associations across population subgroups. Moreover, to explore heterogeneity within SHARE, we performed subgroup analyses at the regional level (Northern, Western, Southern, and Eastern Europe).

To evaluate the robustness of the relationship between food insecurity and healthy aging, we conducted several sensitivity analyses. First, we included wave number as a covariate to address potential time effects across waves. Second, we scored healthy aging continuously (0–4, with higher scores indicating better healthy aging) and estimated its association with food insecurity using GEE with a Poisson distribution, reporting incidence rate ratios (IRRs) and 95 % CIs. Third, we addressed potential attrition bias using Inverse Probability Weighting (IPW). Specifically, we estimated the probability of participants remaining in the study using a logistic regression model, and then assigned weights to each participant based on the inverse of their predicted probability. Fourth, we imputed missing covariate data using multiple imputation by chained equations (MICE) with 10 imputations, applying multinomial logistic regression for categorical variables and logistic regression for binary variables, then re-analyzed the imputed datasets. Fifth, to evaluate whether heterogeneity in food insecurity measurement influenced our findings, we repeated the pooled analysis after sequentially excluding SHARE and ELSA to assess whether the pooled estimates were disproportionately driven by a single cohort's measurement approach.

In addition, to assess the validity of the food insecurity measure in SHARE, we conducted a supplementary analysis using data from Wave 5 (2013), which was the only wave that included additional two-step questions on the affordability of fruits and vegetables. In this wave, respondents were first asked how often their household consumed fruits or vegetables. Those who reported eating them less than three times per week were then asked for the reason, with one response option being "Cannot afford to eat it more often." We then constructed an alternative indicator of food insecurity that classified respondents as food insecure if they reported being unable to afford any of the following: meat, fish, poultry, fruits, or vegetables. This alternative indicator was compared with the original meat-based measure to examine their level of agreement and to test whether associations with healthy aging outcomes and its components were consistent based on logistic regression models. Finally, a sensitivity analysis was conducted using data from the SHARE cohort to examine whether countries with extremely low prevalence of food insecurity influenced the overall findings. Countries were classified according to their national prevalence of food insecurity, with those below 1 % defined as the low-prevalence group (Austria, Germany, Sweden, the Netherlands, Spain, Denmark, Switzerland, Belgium, Luxembourg, Portugal, and Finland). GEE models were re-estimated separately for countries with food insecurity prevalence below 1 % and those with prevalence ≥1 %, adjusting for the same covariates as in the main SHARE analysis. We performed all analyses in Stata 17.0, considering $P < 0.05$ as statistically significant.

3. Results

3.1. Participants characteristics

Table 1 shows the characteristics of participants across the four cohorts: HRS (N = 64,749), ELSA (N = 33,462), SHARE (N = 106,609), and MHAS (N = 27,408). The mean ages of participants in HRS, ELSA, SHARE, and MHAS were 72.7, 71.2, 71.6, and 70.6 years, respectively. Females comprised 54.8 %–58.2 % of participants across cohorts. Education levels varied widely, with 88.8 % of MHAS participants having less than high school education compared to 19.6 % in HRS; college education was highest in HRS (22.4 %) and lowest in MHAS (8.7 %). The proportion of food insecurity and healthy aging varied significantly across the 31 countries studied (Fig. 1 and supplementary material pp 12). Food insecurity ranged from as low as 0.1 % in Denmark to as high as 31.8 % in Mexico. Healthy aging varied from 19.4 % in Lithuania to 50.0 % in Slovakia. The overall proportion of food insecurity was 2.4 % in SHARE, 4.6 % in ELSA, and 7.7 % in HRS. The overall proportion of healthy aging was 24.9 % in HRS, 34.2 % in ELSA, 32.7 % in SHARE, and 31.2 % in MHAS. For the components of healthy aging, major diseases were reported by 45.0 % (MHAS) to 61.4 % (HRS), functional limitations by 12.6 % (SHARE) to 20.4 % (HRS), and cognitive impairment by 14.0 % (HRS) to 16.7 % (MHAS). Good mental health was reported by 66.4 % (SHARE) to 73.8 % (ELSA).

3.2. Association between food insecurity and healthy aging

Table 2 shows the results of the association between food insecurity and healthy aging across four cohort studies. In HRS, food insecurity was associated with lower odds of healthy aging (fully-adjusted model: OR = 0.78, 95 % CI: 0.73–0.84), with similar findings in ELSA (fully-adjusted model: OR = 0.88, 95 % CI: 0.79–0.98). SHARE showed the strongest association (fully-adjusted model OR = 0.67, 95 % CI: 0.60–0.75), while MHAS indicated a slightly weaker but significant link (fully-adjusted model OR = 0.81, 95 % CI: 0.76–0.85). Pooled analysis across cohorts confirmed a consistent inverse relationship (Model 3: OR = 0.78, 95 % CI: 0.72–0.85), though significant heterogeneity was observed (I^2 = 77.1 %, p = 0.004), suggesting variability across populations.

The associations between food insecurity and four components of healthy aging were displayed in Fig. 2. In HRS, food insecurity was significantly associated with increased odds of having major diseases (OR = 1.10, 95 % CI: 1.05–1.14), functional limitations (OR = 1.47, 95 % CI: 1.37–1.58), and poor mental health (OR = 1.32, 95 % CI: 1.25–1.39), but not with cognitive impairment. Similarly, in ELSA, food insecurity was associated with higher odds of functional limitations (OR = 1.26, 95 % CI: 1.11–1.43) and poor mental health (OR = 1.52, 95 % CI: 1.38–1.69), while no significant associations were observed for major diseases or cognitive impairment. In SHARE, food insecurity was strongly associated with cognitive impairment (OR = 1.41, 95 % CI: 1.28–1.55) and poor mental health (OR = 1.81, 95 % CI: 1.66–1.98), while associations with major diseases and functional limitations were not statistically significant. In MHAS, food insecurity was significantly associated with functional limitations (OR = 1.35, 95 % CI: 1.27–1.44), cognitive impairment (OR = 1.25, 95 % CI: 1.17–1.34), and poor mental health (OR = 1.65, 95 % CI: 1.56–1.74), with no significant association observed for major diseases. In the pooled analysis, food insecurity was significantly associated with higher odds of functional limitations (OR = 1.29, 95 % CI: 1.15–1.45) and poor mental health (OR = 1.56, 95 % CI: 1.35–1.80). The associations with major diseases and cognitive impairment did not reach statistical significance. Substantial heterogeneity was observed across cohorts for all outcomes (I^2 ranging from 83.7 % to 94.1 %, all $p < 0.001$).

Table 1

Characteristics of participants in seven longitudinal studies.

Variables	HRS (N = 64749)	ELSA (N = 33462)	SHARE (N = 106609)	MHAS (N = 27408)
Age, mean (sd)	72.7 (8.9)	71.2 (7.8)	71.6 (8.0)	70.6 (7.6)
Sex, n (%)				
Females	37708 (58.2 %)	18339 (54.8 %)	59196 (55.5 %)	15260 (55.7 %)
Males	27041 (41.8 %)	15123 (45.2 %)	47413 (44.5 %)	12148 (44.3 %)
Education, n (%)				
Less than high school or GED	12677 (19.6 %)	10150 (30.3 %)	44289 (41.5 %)	24326 (88.8 %)
High-school or GED	37565 (58.0 %)	17544 (52.4 %)	39247 (36.8 %)	703 (2.6 %)
College and above	14507 (22.4 %)	5768 (17.2 %)	23073 (21.6 %)	2379 (8.7 %)
Marital status, n (%)				
Others	29050 (44.9 %)	11873 (35.5 %)	34433 (32.3 %)	10097 (36.8 %)
Married	35699 (55.1 %)	21589 (64.5 %)	72176 (67.7 %)	17311 (63.2 %)
Family wealth, n (%)				
Q1	13311 (20.6 %)	7802 (23.3 %)	27027 (25.4 %)	6392 (23.3 %)
Q2	15317 (23.7 %)	8505 (25.4 %)	27305 (25.6 %)	6683 (24.4 %)
Q3	17263 (26.7 %)	8600 (25.7 %)	26423 (24.8 %)	6943 (25.3 %)
Q4	18858 (29.1 %)	8555 (25.6 %)	25854 (24.3 %)	7390 (27.0 %)
Self-rated health, n (%)				
Poor	5441 (8.4 %)	2724 (8.1 %)	11852 (11.1 %)	592 (2.2 %)
Fair	14436 (22.3 %)	6704 (20.0 %)	32132 (30.1 %)	978 (3.6 %)
Good	44872 (69.3 %)	24034 (71.8 %)	62625 (58.7 %)	25838 (94.3 %)
Current smoking, n (%)				
No	58182 (89.9 %)	30260 (90.4 %)	88488 (83.0 %)	24653 (89.9 %)
Yes	6567 (10.1 %)	3202 (9.6 %)	18121 (17.0 %)	2755 (10.1 %)
Current drinking, n (%)				
No	31961 (49.4 %)	7456 (22.3 %)	55370 (51.9 %)	21380 (78.0 %)
Yes	32788 (50.6 %)	26006 (77.7 %)	51239 (48.1 %)	6028 (22.0 %)
Physical inactivity, n (%)				
No	20549 (31.7 %)	8950 (26.7 %)	46078 (43.2 %)	8959 (32.7 %)
Yes	44200 (68.3 %)	24512 (73.3 %)	60531 (56.8 %)	18449 (67.3 %)
Food insecurity, n (%)				
No	59758 (92.3 %)	31917 (95.4 %)	104045 (97.6 %)	18700 (68.2 %)
Yes	4991 (7.7 %)	1545 (4.6 %)	2564 (2.4 %)	8708 (31.8 %)
Major diseases, n (%)				
No	24976 (38.6 %)	17972 (53.7 %)	55070 (51.7 %)	15069 (55.0 %)
Yes	39773 (61.4 %)	15490 (46.3 %)	51539 (48.3 %)	12339 (45.0 %)
Functional limitations, n (%)				
No	51547 (79.6 %)	27218 (81.3 %)	93206 (87.4 %)	22031 (80.4 %)
Yes	13202 (20.4 %)	6244 (18.7 %)	13403 (12.6 %)	5377 (19.6 %)
Cognitive impairment, n (%)				
No	55716 (86.0 %)	28501 (85.2 %)	90276 (84.7 %)	22840 (83.3 %)
Yes	9033 (14.0 %)	4961 (14.8 %)	16333 (15.3 %)	4568 (16.7 %)
Mental health, n (%)				
Yes	44787 (69.2 %)	24679 (73.8 %)	70757 (66.4 %)	18531 (67.6 %)

(continued on next page)

Table 1 (*continued*)

Variables	HRS (N = 64749)	ELSA (N = 33462)	SHARE (N = 106609)	MHAS (N = 27408)
No	19962 (30.8 %)	8783 (26.2 %)	35852 (33.6 %)	8877 (32.4 %)
Healthy aging, n (%)				
No	48642 (75.1 %)	22014 (65.8 %)	71734 (67.3 %)	18850 (68.8 %)
Yes	16107 (24.9 %)	11448 (34.2 %)	34875 (32.7 %)	8558 (31.2 %)

Note: GED = General Educational Development.

3.3. Subgroup and sensitivity analyses

Fig. 3 presents the associations between food insecurity and healthy aging across different subgroups. Subgroup analyses revealed substantial heterogeneity in these associations. Notably, consistent findings across the four cohorts indicated that the associations were more pronounced among individuals aged below 75 years and those with insufficient physical activity. In additional subgroup analyses within SHARE, countries were classified into four European regions. Food insecurity was consistently associated with lower odds of healthy aging across regions, with ORs ranging from 0.61 in Southern Europe to 0.79 in Eastern Europe. Associations with mental health were strong in all regions, particularly in Southern Europe. Cognitive impairment was also associated with food insecurity in Northern and Eastern Europe, whereas major diseases showed mixed results across regions. More specific results of subgroup analysis can be found in supplementary material (pp 13–15).

In the first sensitivity analysis, the associations between food insecurity and healthy aging remained significant across all four cohorts after adjusting for time effects. When using a continuous healthy aging score as the outcome variable, food insecurity was associated with lower healthy aging index values. Furthermore, applying IPW in the GEE models yielded consistent results, with food insecurity still significantly associated with healthy aging. Lastly, results after multiple imputation were in line with those of the main analysis. In addition, we conducted sensitivity analyses on food insecurity and four healthy aging components, which is consistent with the results in Fig. 2. Finally, to address heterogeneity in food insecurity measurement, we repeated the pooled analysis after excluding SHARE and ELSA. The pooled association between food insecurity and healthy aging was robust (OR 0.80, 95 % CI 0.76–0.83), and associations with functional limitations and mental health remained evident (Table S10). A supplementary validation analysis based on SHARE Wave 5, the only wave that included additional questions on fruit and vegetable affordability, showed that the extended definition of food insecurity produced slightly higher prevalence estimates than the original meat-based measure (Table S11). The two measures demonstrated almost perfect agreement ($\kappa = 0.92$; SE = 0.0047; $p < 0.001$; Table S12). Logistic regression models using both

Table 2
Association between food insecurity and healthy aging.

Cohorts/ Outcomes	Model 1	Model 2	Model 3
	OR (95 %CI)	OR (95 %CI)	OR (95 %CI)
HRS	0.80 (0.76–0.85)	0.77 (0.72–0.82)	0.78 (0.73–0.84)
ELSA	0.86 (0.79–0.94)	0.83 (0.75–0.91)	0.88 (0.79–0.98)
SHARE	0.52 (0.48–0.57)	0.59 (0.53–0.65)	0.67 (0.60–0.75)
MHAS	0.79 (0.75–0.83)	0.80 (0.76–0.85)	0.81 (0.76–0.85)
Pooled analysis	0.73 (0.61–0.88)	0.74 (0.66–0.84)	0.78 (0.72–0.85)
Heterogeneity	I^2 = 96.6 %, p < 0.001	I^2 = 90.0 %, p < 0.001	I^2 = 77.1 %, p = 0.004

Note: Model 1 remained unadjusted; Model 2 adjusted for MSAS; and Model 3 adjusted for all covariates.

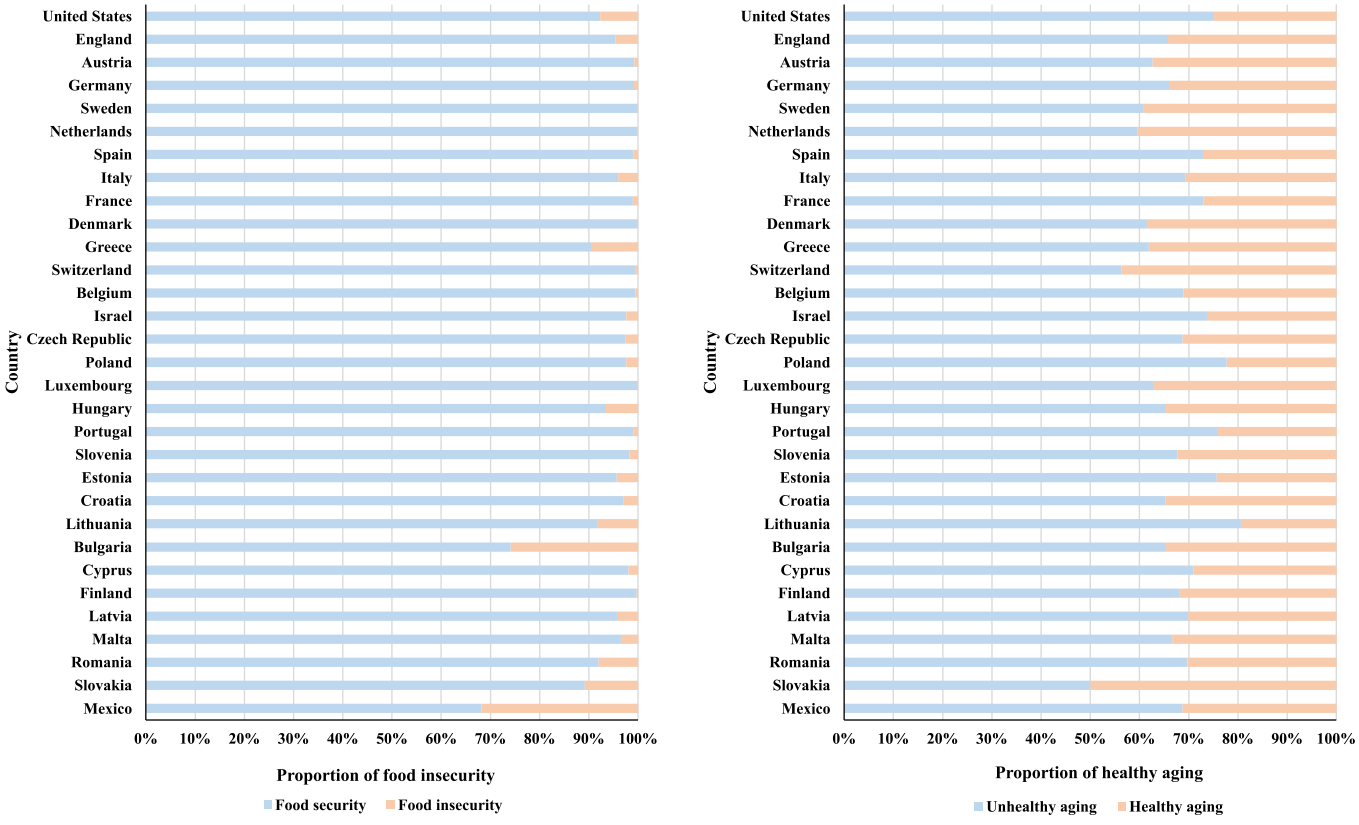

Fig. 1. The proportion of food insecurity and healthy aging across the 31 countries in four longitudinal studies.

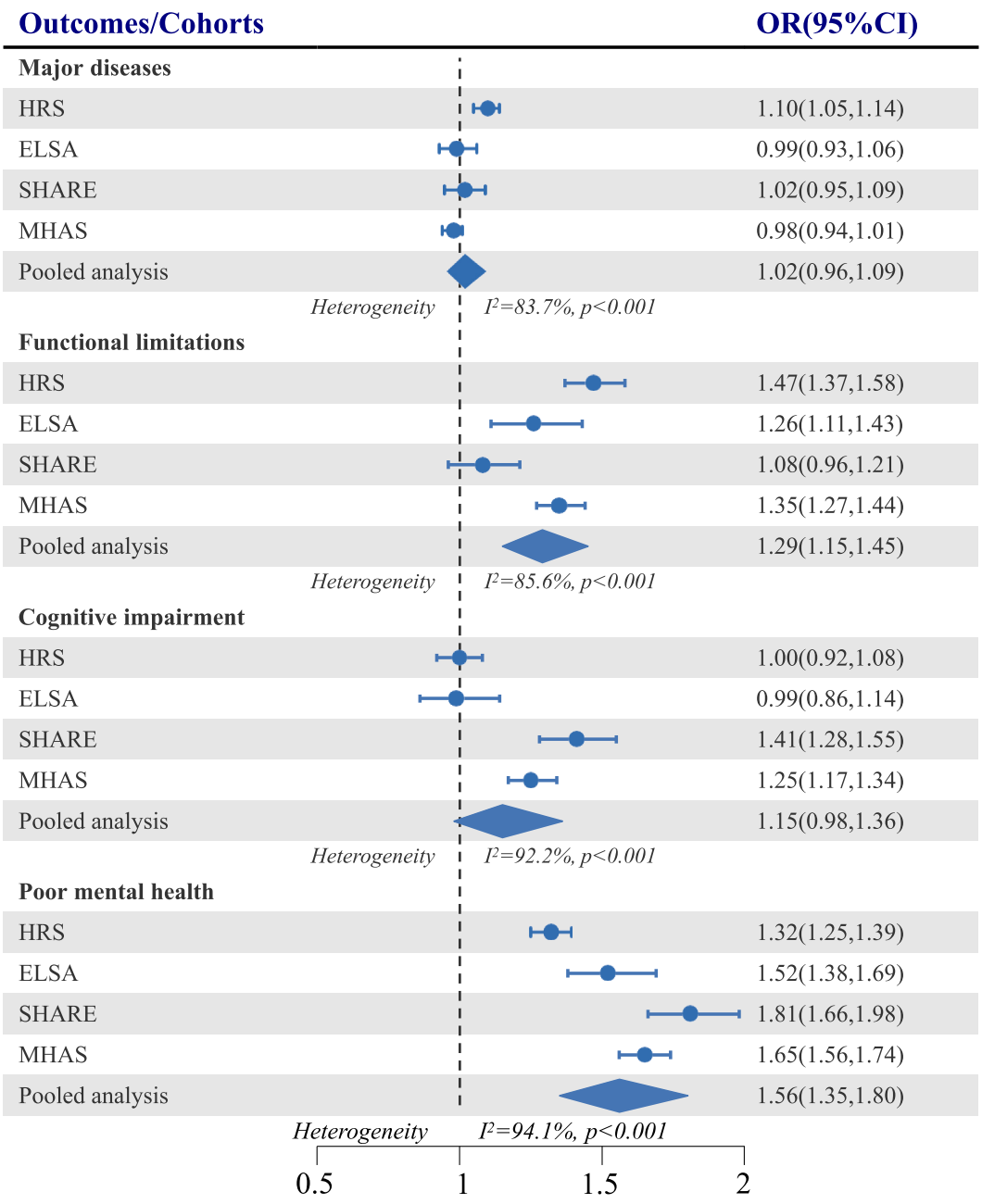

Fig. 2. Associations between food insecurity and four components of healthy aging.

definitions yielded consistent associations with healthy aging outcomes (Table S13), supporting the validity of the single-item indicator applied across other waves. In the SHARE sensitivity analysis, the mean prevalence of food insecurity was 0.5 % among the 11 low-prevalence countries and 4.2 % among the remaining 17 countries. The associations between food insecurity and healthy aging outcomes were consistent across both groups (Table S14). These results suggest that inclusion of countries with minimal food insecurity did not materially affect the overall associations observed in SHARE. More detailed findings from the sensitivity analyses are presented in the supplementary material (pp 16–23).

4. Discussion

This study was the first to explore the association between food insecurity and healthy aging among older adults using four large sample population surveys from diverse regions. In this study, we provided evidence that food insecurity is significantly associated with lower odds of healthy aging. Our analysis revealed that food insecurity was consistently linked to negative outcomes in key components of healthy aging, particularly functional limitations and poor mental health. These findings suggested that food insecurity may play a significant role in exacerbating age-related declines in physical and mental well-being, underscoring the importance of addressing food insecurity in older populations.

The prevalence of food insecurity varied widely across the 31 countries included in this study. In the United States, 7.7 % of older adults were food insecure, a level considerably higher than that observed in most European countries. England reported a prevalence of 4.6 %, which was lower than the United States but higher than many

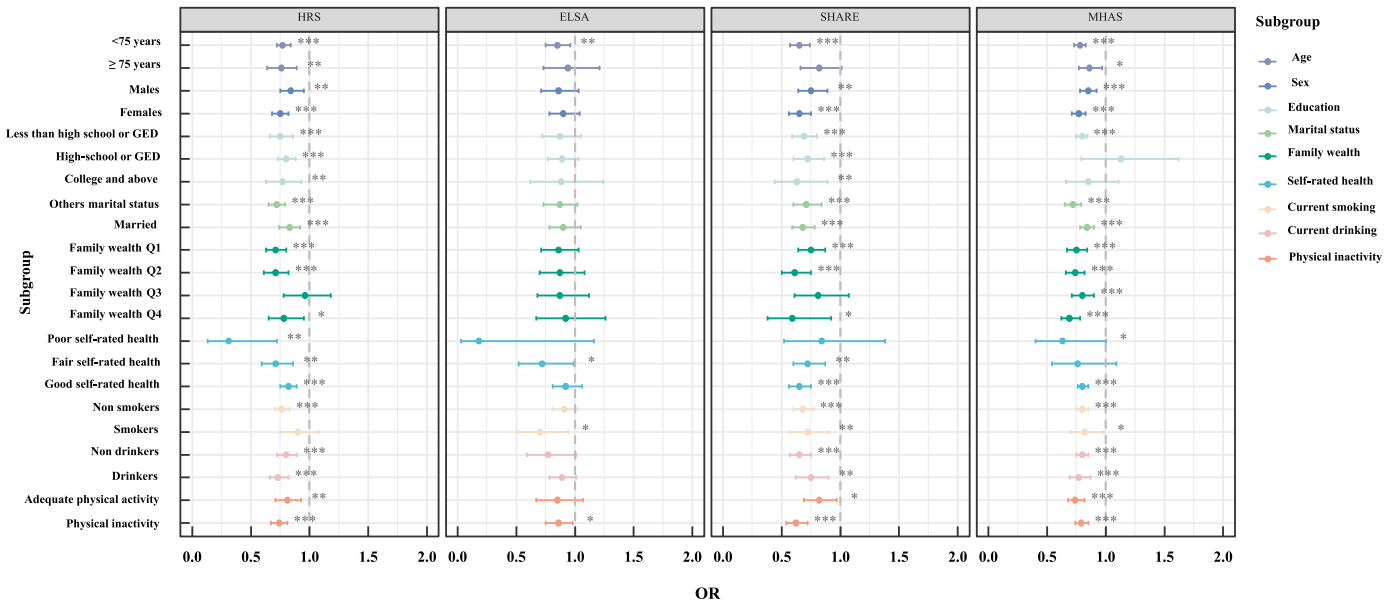

Fig. 3. Associations between food insecurity and healthy aging across different subgroups.

Western European countries. Within continental Europe, Northern and Western countries generally had very low prevalence, often below 1 %, as seen in Denmark, Sweden, the Netherlands, Germany, and Austria. In contrast, Southern and Eastern Europe showed higher levels, with Greece at 9.6 %, Lithuania at 8.2 %, Romania at 8.0 %, and Slovakia at 10.8 %. Mexico recorded the highest prevalence, with nearly one in three older adults classified as food insecure. These variations partly reflect differences in economic resources, welfare systems, and social safety nets, but they are also connected to the instruments applied in each cohort. HRS and MHAS focused on financial barriers and hunger experiences, capturing the sufficiency of quantity and episodes of deprivation (Norwood and Wunderlich, 2006). ELSA emphasized coping strategies such as meal skipping and restricted food choice, which identify earlier stages of constrained food access (Maxwell, 1996). SHARE relied on affordability of meat, fish, and poultry, which reflects access to protein-rich foods and dietary diversity but may also be influenced by cultural or health-related dietary preferences (Penne and Goedemé, 2021; Walker and Baum, 2022). These conceptual differences imply that very low prevalence rates in some countries may not only represent favorable conditions but also the narrower dimension of food insecurity assessed by the instrument. These results mean that direct comparison of prevalence rates across countries should be made with caution, as the instruments do not capture identical domains of food insecurity. The lack of harmonized measures limits the extent to which prevalence estimates can be interpreted as reflecting equivalent experiences across settings. Future research would benefit from the development and application of standardized instruments that incorporate both quantity sufficiency and dietary quality, which would allow for more consistent monitoring and more reliable cross-national comparisons of food insecurity among older adults.

The pooled analysis from the four cohorts demonstrated that food insecurity is associated with a reduced likelihood of healthy aging. A previous study, from the perspective of biological aging, supports the findings of our study, indicating that food insecurity may lead to alterations in DNA methylation across the entire genome and result in accelerated biological aging (Tamargo and Cruz-Almeida, 2024). While the strength of this association in our analysis varied by region, the overall trend of food insecurity negatively impacting aging was clear. Our finding suggested food insecurity can be considered a key driver of poor healthy aging. Several potential mechanisms can explain these associations. The most direct pathway may be through economic stress, where the anxiety and worry about not having enough money to purchase adequate food can increase physiological stress (Ciciurkaite and Brown, 2022). Chronic stress is well-documented to negatively affect both physical and mental health, leading to elevated long-term risk of mental and physical morbidity, weakened immune function, and accelerated aging (Agorastos and Chrousos, 2022; Hansen et al., 2025; Klopack et al., 2022), all of which contribute to a decline in healthy aging. Previous evidence from the United States has provided direct support for our finding that food insecurity is associated with higher allostatic loads and higher levels of inflammation and immune dysfunction (Aljahdali et al., 2024; Pak and Kim, 2021). Additionally, nutritional deficiencies are a central consequence of food insecurity. Older adults are particularly vulnerable to poor nutrition, which can exacerbate existing health conditions or accelerate the onset of age-related diseases (Dent et al., 2023). Inadequate intake of essential nutrients, such as vitamins and minerals, can impair cognitive function, muscle strength, and bone density, leading to functional limitations and increased frailty (Artaza-Artabe et al., 2016; Fekete et al., 2023). Another significant factor is the lack of access to healthcare. Food insecurity often overlaps with other social determinants of health, such as low socioeconomic status, limited healthcare access, and unstable housing (Pirrie et al., 2020). Older adults in food-insecure households may struggle to access regular medical care, preventive services, or necessary medications, which can delay healthcare and result in poorer health outcomes (Ostrer and Seligman, 2025).

Subgroup analyses indicated that this association was more pronounced among individuals aged under 75 years and those with insufficient physical activity. The stronger association observed in individuals aged under 75 years may reflect age-related differences in resilience and compensatory mechanisms (Harvanek et al., 2021). Younger older adults (under 75) likely retain greater metabolic flexibility and adaptive capacity compared to their older counterparts, making them more responsive to both nutrient sensing and nutritional deficiencies (Martemucci et al., 2022). While this group may not yet exhibit advanced chronic conditions, food insecurity could accelerate subclinical pathological processes, such as chronic inflammation or oxidative stress, which are strongly linked to functional decline (Aljahdali et al., 2024; Wells et al., 2020). Conversely, adults ≥75 years may experience accumulated health deficits with aging, where cumulative comorbidities mask the specific effects of food insecurity (Tan et al., 2025). In addition, the amplified association between food

insecurity and healthy aging in those with physical inactivity likely stems from bidirectional pathophysiological interactions. Physical inactivity exacerbates metabolic dysregulation (e.g., insulin resistance, reduced lipid clearance), which may synergize with nutritional deficiencies from food insecurity to accelerate biological aging (Shur et al., 2021; Tamargo and Cruz-Almeida, 2024). This vicious cycle mirrors findings that food-insecure populations are more likely to engage in low physical activity (Maia et al., 2023), which in turn compounds overlapping socioeconomic barriers (e.g., limited access to exercise facilities). These barriers further exacerbate food access difficulties, creating a series of disadvantage. These subgroups heightened vulnerability underscores the need for integrated food insecurity interventions targeting both nutritional support and mobility promotion. Subgroup analyses within SHARE further indicated regional variation. Although food insecurity was associated with reduced odds of healthy aging across all European regions, the magnitude differed, with weaker associations in Southern and Northern Europe and weaker associations in Eastern and Western Europe. Mental health outcomes were consistently affected, with particularly strong associations in Southern Europe, while relationships with major diseases and functional limitations varied across regions. These patterns suggest that both contextual conditions and the measurement dimension captured by SHARE influence the observed associations, reinforcing the need for caution when generalizing findings across diverse welfare and cultural settings. In addition, a supplementary subgroup analysis based on a 1 percent prevalence threshold showed consistent results across countries with lower and higher national levels of food insecurity. This suggests that the observed associations are robust and not driven by countries where food insecurity is nearly absent.

In healthy aging components, this association was particularly strong in relation to functional limitations and mental health issues, which were the most consistently affected outcomes by food insecurity across all cohorts. Food insecurity's strong association with functional limitations is consistent with prior research (Gyasi et al., 2022). Functional limitations in older adults are a key indicator of poor health and increased dependency, leading to diminished quality of life (Gyasi et al., 2022). Food insecurity may exacerbate these limitations by contributing to nutritional deficiencies, and increasing vulnerability to diseases that impair mobility and daily activities (Awuviry-Newton et al., 2022). Similarly, a previous systematic review and meta-analysis also found that food insecurity is related to poor mental health, including depressive symptoms and stress (Pourmotabbed et al., 2020). The psychological stress of not having enough food to meet basic needs can exacerbate feelings of hopelessness and loneliness, significantly diminishing an individual's mental well-being (Gyasi et al., 2024). Food insecurity was also linked to cognitive decline, as shown in the SHARE and MHAS cohorts, where food insecurity was strongly associated with cognitive impairment, although there was no statistical significance in the pooled analysis. A previous systematic review supported our finding, that is, food insecurity is associated with cognitive function across the life course (Royer et al., 2021).

The heterogeneity observed across cohorts is an important aspect of the study's findings. Although the food insecurity measurements in four cohorts emphasized distinct aspects, including financial constraints, hunger experiences, coping behaviors, and affordability of protein-rich foods, the adverse association with healthy aging was observed in all cohorts. Sensitivity analyses confirmed the robustness of these findings. The association between food insecurity and healthy aging remained significant after adjusting for time effects, when using a continuous healthy aging score, when applying inverse probability weighting, and after multiple imputation. Analyses of food insecurity with the four components of healthy aging produced results consistent with the main analysis. In addition, repeating the pooled analysis while excluding SHARE or ELSA yielded similar estimates, indicating that the overall conclusions were not driven by the measurement approach of a single cohort. In a supplementary validation analysis using SHARE Wave 5, where additional information on fruit and vegetable affordability was available, the extended definition of food insecurity produced slightly higher prevalence estimates but yielded consistent associations with healthy aging outcomes. This finding supports the validity and robustness of the single-item measure applied in other SHARE waves. The robustness of the findings across SHARE countries with different food insecurity prevalence supports the stability of the observed associations. These results suggest that despite heterogeneity in measurement, the relationship between food insecurity and healthy aging is stable across alternative specifications. This suggests that food insecurity is a global issue with widespread implications for aging populations, though the severity of its impact may vary depending on local contexts.

The findings from this study carry important implications for public health policy and practice, particularly in countries with high rates of food insecurity among older adults, such as Mexico. Recently, the US Preventive Services Task Force (USPSTF) provided new recommendations and evidence regarding the prevention of food insecurity, and noted that the evidence for screening in healthcare settings remains insufficient (O'Connor et al., 2025; US Preventive Services Task Force, 2025). While the USPSTF's stance on screening remains cautious, our research suggests that targeted interventions for older adults at risk of food insecurity could have a positive impact on aging outcomes. Moreover, as the USPSTF points out, food insecurity is intricately tied to social determinants of health such as poverty and housing instability, factors that extend beyond the healthcare system. Therefore, public health policies should focus on addressing these broader social determinants in addition to increasing access to nutritious food. This aligns with the findings of our study, which suggests that interventions must be multifaceted, targeting not just food access, but also the social and economic factors contributing to food insecurity, particularly in regions like Mexico where these issues are more pronounced. In light of the USPSTF's recommendations, we propose that healthcare systems integrate food insecurity screening into routine assessments for older adults at risk, while simultaneously prioritizing collaboration with community organizations and social services to ensure holistic care. One potential policy recommendation is to expand food assistance programs, such as subsidized grocery schemes or community-based food programs, that target older adults at risk of food insecurity (O'Connor et al., 2025). These programs could be particularly impactful in countries with large low-income populations, where food insecurity is often a direct result of economic hardship.

This study benefits from a longitudinal design, allowing for the examination of the long-term effects of food insecurity on healthy aging. The use of repeated measures across multiple waves enables us to better understand the dynamic relationship between food insecurity and aging outcomes over time. The inclusion of four geographically distinct cohorts, which represent the United States, the England, Europe, and Mexico, enhances the generalizability of the findings and provides valuable cross-cultural insights into the relationship between food insecurity and aging. The study also employed rigorous statistical methods, including Generalized Estimating Equations and random-effects meta-analysis, which ensure robust and reliable estimates of the associations between food insecurity and healthy aging. Sensitivity analyses, such as inverse probability weighting and multiple imputation, further strengthen the validity of the results by addressing potential biases and missing data.

This has several limitations that should be acknowledged. First, food insecurity was measured differently across cohorts, which reduces comparability. Although each food insecurity measurement has validity within its own context, they capture different domains of food insecurity, and the pooled estimates should therefore be interpreted as reflecting a broad vulnerability rather than the same construct across cohorts. In addition, the validation of the food insecurity measure in the SHARE data was limited to Wave 5, which was the only wave that included additional questions on fruit and vegetable affordability. Although the two definitions showed almost perfect agreement, this

validation was based on a single cross-sectional wave and may not fully reflect measurement consistency across other waves or contexts.

Second, although this study controlled for several important covariates, there may be residual confounding from unmeasured factors. For instance, information on the quality of the diet and healthcare access was not available across all cohorts, which could influence both food insecurity and health outcomes. The cohorts included in this study are representative of specific countries or regions but may not fully capture the experiences of food insecure older adults in other settings, particularly in low-income countries without large-scale cohort studies. The generalizability of the findings to non-Western or non-industrialized regions remains an important area for further research. Moreover, another limitation is the aggregation of all 28 SHARE countries. Although this improved statistical power, it inevitably masked between-country heterogeneity. We did not conduct country-specific analyses because in several countries the prevalence of food insecurity was extremely low, leading to insufficient case numbers for stable model estimation of associations with healthy aging and its components. To address this concern, we instead conducted analyses at the regional level (Northern, Western, Southern, and Eastern Europe), which offered a balance between statistical stability and cross-national comparability. In addition, although a sensitivity analysis within the SHARE cohort using a 1 % prevalence threshold suggested that the inclusion of countries with very low food insecurity did not materially affect the results, differences in social and welfare contexts across countries may still limit direct comparability. Finally, the exclusion of data from 2020 onward due to the COVID-19 pandemic may limit the applicability of these findings to the current situation. The pandemic likely exacerbated food insecurity and health disparities, and future research should examine how the COVID-19 crisis has affected food insecurity and healthy aging in older populations.

5. Conclusion

This study demonstrates that food insecurity is a significant predictor of poor health outcomes in older adults, including functional limitations, cognitive impairment, and poor mental health. Despite regional differences in food insecurity prevalence and the social contexts in which these cohorts are situated, the negative association between food insecurity and healthy aging holds across diverse populations. These findings underscore the importance of addressing food insecurity as a public health priority, especially as the global population continues to age. Policymakers and healthcare providers should consider food insecurity as a crucial determinant of health and take steps to ensure that older adults have access to sufficient, nutritious food to support their aging process. Future research should continue to explore the pathways through which food insecurity affects aging and investigate interventions that can improve the health and well-being of older adults.

CRediT authorship contribution statement

Guanghui Cui: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Mingzheng Hu:** Writing – review & editing. **Kaixuan Tang:** Writing – review & editing. **Shaojie Li:** Writing – review & editing, Validation, Conceptualization.

Ethics approval

The study relied on de-identified, publicly available datasets from these cohorts. All four studies had received ethical approval from their respective local ethics committees, and participants provided informed consent prior to enrollment.

The Health and Retirement Study (HRS) has received ethical approval from the University of Michigan Institutional Review Board (IRB Protocol: HUM0061128).

The English Longitudinal Study of Ageing (ELSA) received ethical approvals from various committees, including the Berkshire Research Ethics Committee and the South Central – Berkshire Research Ethics Committee. The specific ethical approval for ELSA is as follows.

ELSA Wave 9 received ethical approval from the South Central – Berkshire Research Ethics Committee on May 10, 2018 (17/SC/0588).

ELSA Wave 8 received ethical approval from the South Central – Berkshire Research Ethics Committee on September 23, 2015 (15/SC/0526).

ELSA Wave 7 received ethical approval from the NRES Committee South Central - Berkshire on November 28, 2013 (13/SC/0532).

ELSA Wave 6 received ethical approval from the NRES Committee South Central - Berkshire on November 28, 2012 (11/SC/0374).

ELSA Wave 5 received ethical approval from the Berkshire Research Ethics Committee on December 21, 2009 (09/H0505/124).

The Survey of Health, Ageing and Retirement in Europe (SHARE) has been reviewed and approved by the Ethics Committee of the University of Mannheim and the Ethics Council of the Max Planck Society, with additional approvals from respective national ethics committees.

The Mexican Health and Aging Study (MHAS) study c had received ethical approval from the Institutional Review Board of the University of Texas Medical Branch, the Instituto Nacional de Estadística y Geografía (INEGI) in Mexico, and the Instituto Nacional de Salud Pública (INSP) in Mexico.

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Declaration of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2025.118758.

Data availability

All original data used in the study can be obtained from the Gateway to Global Aging Data (https://g2aging.org).

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