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Food insecurity and mobility difficulty in middle-aged and older adults: The importance of bio-psychosocial factors

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ABSTRACT

Objective: Food insecurity has been associated with mobility difficulty (MD) in old age. However, there is a scarcity of research on this topic from low- and middle-income countries, while the bio-psychological factors underlying this association are largely unknown. We investigated the food insecurity-MD link in Ghana and explored how sleep, anxiety, loneliness, and physical activity (PA) mediate the association.
Methods: Community-based, representative cross-sectional data from the Aging, Health, Well-being, and Health-seeking Behavior Study were analyzed (N = 1201; M_{age} = 66.5; women = 63%). MD was assessed with items from the SF-36 of the Medical Outcomes Study. We assessed food insecurity with items on hunger and breakfast-skipping frequency due to lack of food and resources. Adjusted OLS and mediation models via bootstrapping technique evaluated the associations.
Results: Results revealed the expected association between food insecurity and MD, such that greater food insecurity was significantly and positively associated with MD across paths (from β = 0.33 to β = 0.42, $p < .001$). Analyses of indirect effects showed that sleep problems (27.8%), anxiety (15.5%), loneliness (17.5%), and PA (18.0%) mediated the association between food insecurity and MD. Cross-level interactions revealed that food insecurity significantly modified the link between each mediator and MD.
Conclusions: Our data provide novel evidence that bio-psychological mechanisms may underlie the food insecurity-MD link and should, therefore, be considered relevant targets for interventions to prevent/manage MD in later life.

1. Introduction

The global populations are rapidly aging and, for many older adults, mobility difficulty (MD) has increasingly become a growing public health concern, especially in low- and middle-income countries (LMICs), where aging largely occurs in poor socio-environmental conditions and inadequate clinical and long-term care resources [1,2]. Mobility, including the ability to walk, climb stairs, and maintain a proper gait, is an important predictor of quality of life (QoL) in older adults [3,4] and a measure of successful aging [5]. However, MD puts older adults at a greater risk of falls, limited social interactions, poor psychological health, and increased healthcare costs [6–8].

Population-based studies have noted an increasing prevalence of MD, with estimates ranging from 22.5% to 46.7% among older adults [6] and even higher rates (from 35% to 56%) in LMICs [9]. The onset of chronic physical conditions, such as arthritis, stroke, and chronic lung

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problems, are well-known causes of mobility-related disability in older adults [3,10]. Restricted mobility is further associated with adverse health outcomes, including cognitive decline, depression, and increased chronic physical diseases [9,11,12]. Crucially, given the rapid demographic aging in LMICs, MD may significantly burden individual, societal, and healthcare systems due to dependence on others, reduced productivity, and increased hospitalization or nursing home admission [13,14]. Consequently, identifying the potential risk factors for MD and early interventions to prevent the onset and progression of MD may maintain or regain daily activity levels, improve QoL in old age, and promote healthy aging, particularly in LMIC settings.

Food insecurity, defined as having inconsistent access to sufficient, safe, and nutritious food [15,16], affects about 39% of sub-Saharan Africans [17,18]. As a social determinant of health, food insecurity has been linked to adverse health outcomes in later life, including functional declines, frailty, and MD [19–21]. Thus, individuals who are food insecure are more likely to experience higher odds of MD, including difficulty walking or/and climbing a stair and maintaining gait, largely due to a lack of adequate body nutrients to support the body's biological functioning [11,15]. Population-based studies from high-income countries have demonstrated that food insecurity is associated with MD in later life [22–24]. For example, an analysis of longitudinal data among 5986 US adult cohorts found that household food insecurity was strongly associated with worse psychological functioning, including higher odds of mobility challenges [22]. Schwartz et al. [25] observed among 217,094 older Canadian adults that greater food insecurity was associated with greater mobility impairment, including the inability to partake in daily activity. Furthermore, Petersen et al. [26] found a positive association between food insecurity, and increased gait problems, and limited participation in daily activity among American adults. Moreover, a conceptual model may establish a bidirectional relationship between food insecurity and MD, such as MD, and difficulties in daily activities may lead to some levels of food insecurity [65]. This may relate to the view that disability may increase socioeconomic disadvantage and exclusion due to barriers to education, employment, and income/financial security [66,67].

Despite the growing body of research on the food insecurity-MD link, mainly from developed and Asian countries (e.g., [19,27,28], the mechanisms underlying this association are poorly understood, particularly from the LMIC context, where data on this association are scarce. It is, however, hypothesized that food insecurity may lead to greater risks of MD by disrupting sleep patterns due to the deprivation of nutritious foods [29] and impairing psychological functioning, including anxiety and depressive symptoms [11]. Moreover, studies suggest that loneliness and physical inactivity are strongly related to food insecurity [30,31]. For example, Park et al. [32] found among U.S. older adults that individuals who were food insecure experienced a higher incidence of social isolation, loneliness, and depressive symptomatology, which are highly likely to promote MD. Similarly, among 9750 American older cohorts, To et al. [33] observed that older adults with inadequate food supply had higher odds of recording physical inactivity than their food-secure counterparts. However, no previous study has used robust analytic techniques to quantify how much of the association between food insecurity and MD is indirectly attributed to the biopsychosocial pathways (e.g., loneliness, anxiety, sleep, PA, and depressive symptoms). Indeed, the aging process and the concomitant MD are highly differentiated largely by mental and physical/functional health outcomes [68]. The association between food insecurity and MD may be highly likely to vary across biopsychosocial factors, such as sleep, loneliness, anxiety, and PA. However, previous studies have not evaluated the potential effect modification of these biopsychosocial factors in the link between food insecurity and MD. Knowledge of these mechanisms may be crucial for public health planning, developing targeted interventions for MD/functional independence in later life, and promoting healthy aging.

Therefore, this study aimed first to examine the extent to which food insecurity is associated with MD in middle-aged and older adults in Ghana and second to investigate whether biopsychosocial-related factors (i.e., sleep problems, loneliness, anxiety, depressive symptoms, and PA) are mechanisms through which food insecurity influences the odds of MD in this sample. Third, it aimed to extend our knowledge of how biopsychosocial factors moderate the association between food insecurity and MD in Ghana.

2. Methods

2.1. Participants and procedure

This study analyzed cross-sectional data from a community-based sample from a well-characterized Aging, Health, Psychological Well-being, and Health-seeking Behavior study 2016–2018 [34]. The study aimed to comprehensively assess the health outcomes, emotional well-being, and accessibility and utilization of health services among community-dwelling older men and women in Ghana. The study design and selection criteria have been described elsewhere [35]. Briefly, the study devised a multi-staged cluster sampling procedure, and 1247 participants aged ≥50 years who were free from known cognitive incapacitation were recruited from six randomly selected districts in Ghana. Altogether, participants were selected from nine urban and 15 rural randomized communities. The sample size was determined using $N = \rho \times \frac{\left[\left(\mho_{\frac{\alpha}{2}}\right)^2 \times \pi(1-\pi)\right]}{\delta^2}$ [36], (π: expected prevalence; ρ: design effect = 1.5) with a 5% margin of error, 95% confidence interval, 5% type 1, 15% type 2 errors, $p < .05$, and 50% conservative prevalence of adults aged ≥50 years. The model achieved a statistical power of 85% and a 5% (two-sided) significance level to detect an odds ratio of ≥2. Given $\pi = 0.5$ and $\mho_{\frac{\alpha}{2}} = 1.96$, we obtained the required sample size of 901. Also, 38% oversampling accounted for the potential losses or non-responses, yielding 1247 individuals recruited using a systematic random sampling technique. Overall, 28 individuals declined to participate, and three and 15 questionnaires contained outliers and missing data, respectively [34]. The final analytic sample size was 1201 (Fig. 1). Face-to-face interviews were conducted using interviewer-administered questionnaires, and each interview lasted 40 min. Informed consent was obtained from all participants. The protocol was approved by the Committee on Human Research Publication Ethics, School of Medical Sciences, KNUST, and Komfo Anokye Teaching Hospital, Kumasi, Ghana (Ref number: CHRPE/AP/507/16).

2.2. Food insecurity

Two self-reported questions collected data on dietary inadequacies, specifically on hunger and breakfast skipping over the last 30 days: "During the past 30 days, how often did you go hungry because there was not enough food in your home?" and "…how often did you skip breakfast because there was not enough food, and you had no resources to obtain one?" The items were scored on a 5-point response option: 1 = never, 2 = rarely, 3 = sometimes, 4 = most of the time, and 5 = always. The items have been used in other studies in sub-Saharan Africa (SSA) [24] and were adapted from similar food security questionnaires such as the US Household Food Security Survey Module and National Health and Nutrition Examination Survey Food Security module [23]. The overall score for food insecurity was calculated; a high score on the item denotes more food insecurity (M = 3.96; SD = 1.84; range = 2–10; α = 0.782).

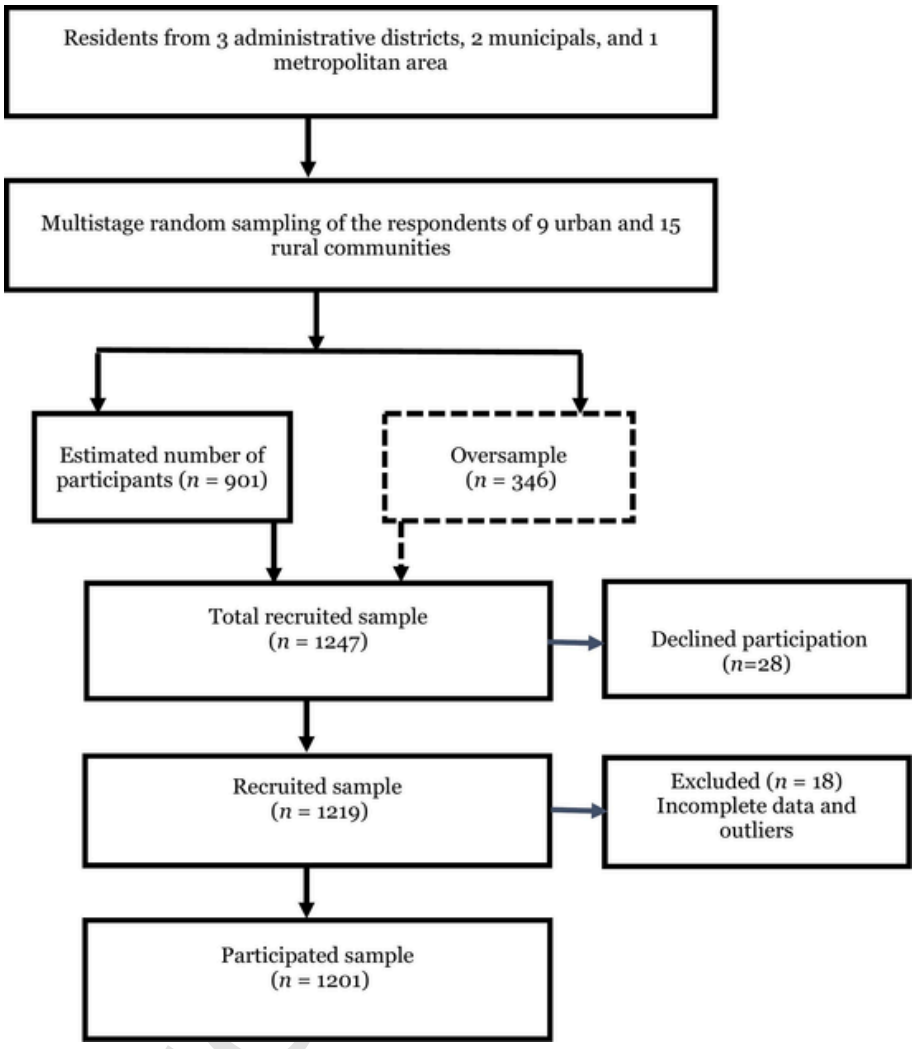

Fig. 1. Flow chart of the selection of study participants.

2.3. Mobility

Mobility was assessed with questions on mobility-related deficiencies from the 36-item Short-Form Health Survey (SF-36) of the Medical Outcomes Study (MOS) [37]. Participants were asked about activities they might do during a typical day to ensure active travel or movement. Does your health now limit you in these activities: (a) climbing about several flights of stairs and (b) maintaining balance and walking more than one kilometer? If so, how much? The responses were scored on a 4-point scale ranging: 1 = much limited, 2 = somewhat limited, 3 = less limited, and 4 = not limited at all. The responses to the two items were reverse-coded and used to compute the MD index (total score 2–8). A high score on this index denotes more MD (M = 4.38; SD = 2.13; range = 2–8; α = 0.908).

2.4. Potential mediators

The mediating variables were selected based on previous research on the association between food insecurity and mobility [21,22,38].

Sleep problems were assessed using two questions: "Overall, in the last 30 days, how much of a problem did you have with sleeping, falling asleep, waking up frequently during the night, or waking up too early in the morning?" and "How much of a problem did you have due to not feeling rested or refreshed during the day?" [39]. Each item had 5-point response options: none = 1, mild = 2, moderate = 3, severe = 4, and extreme = 5. These items have been used in previous SSA studies [11]. A latent sleep quality score was generated with an increasing score indicating higher levels of sleep problems (M = 4.89; SD = 1.89; range = 2–10; α = 830).

Anxiety symptoms were assessed with the two-item questions: "Over the past four weeks, have you been (a) a nervous person?" and (b) "restless person?" with a 4-point response option: 1 = all of the time, 2 = most of the time, 3 = little of the time, and 4 = none of the time [38]. These were reverse-coded such that a high score indicates more anxiety (M = 3.88; SD = 1.56; range = 2–8; α = 830).

Loneliness was assessed with the University of California, Los Angeles 3-item loneliness scale: The questions include: "How often do you (a) lack companionship?" (b) "Feel left out?" and (c) "Feel isolated?" with a 3-point scale: hardly ever/never, some of the time/sometimes, and often/always [40,41]. An overall score was generated with a higher score suggesting higher levels of loneliness (M = 5.30, SD = 3.91; range = 3–9; α = 0.810).

PA was assessed with the International Physical Activity Questionnaire short form (IPAQ-SF) [42,43]. "During the last 7 days, on average, how many days 1) …did you walk for at least 10 minutes at a time, including walking at work, home, and traveling from place to place? 2) … did you do moderate physical activities like gardening, cleaning, bicycling regularly, swimming, or other fitness activities? 3) … did you do

vigorous physical activities like heavy lifting, digging, heavier garden or construction work, chopping wood, aerobics, jogging/running, or fast bicycling?" A high score denotes more PA (M = 9.03, SD = 1.47; range = 0–21; α = 0.846).

Depressive symptoms were assessed using the Center for Epidemiological Studies Depression Scale (CES—D) [63]. The CES-D is a widely used, simple, and validated depressive symptom self-assessment questionnaire that contains 10 items [63]. The participants were asked ten questions about their feelings and behaviors over the past week. Each item was scored on a four-point scale: 0 = rarely (<1 day), 1 = some or a little of the time (1–2 days); 2 = occasionally or a moderate amount of time (3–4 days); and 3 = most or all of the time (5–7 days). The 10 items were summed, generating a CES-D index (range: 0–30), with higher scores indicating the presence of more depressive symptomology. The Cronbach's alpha of the CES-D-10 was 0.806 in this study. The effectiveness of CES-D in older African populations has been shown [64].

2.5. Covariates

The potential confounders were selected based on prior research [22,38]. Age (in years, M = 58.87, SD = 5.88), sex (1 = female = 62.47%, 2 = Male), residence (1 = rural = 42.60%; 2 = urban), income (M = ¢337.00, SD = ¢388.81), marital status (1 = married = 43.40%, 2 = unmarried) and educational status (1 = never/up to primary level = 83.77%, 2 = secondary level, 3 = tertiary level). Self-reported number of diagnosed chronic conditions, including hypertension, diabetes, stroke, arthritis, respiratory disease, chronic kidney disease, asthma, ulcers, and cancers (M = 2.90, SD = 0.74; range = 0–5). Self-related health status was assessed on a four-response scale after collapsing excellent and very good options from the original scale because of fewer counts (1 = excellent/very good; 2 = good; 3 = fair; 4 = poor) (M = 3.30, SD = 0.85; range = 1–5). We assessed pain interference with the question, "During the past four weeks, how much did pain interfere with your normal work (including work outside the home and housework)?" with options: not at all, a little bit, moderately, quite extreme, and very extremely (coded 1–5 respectively) with a higher score indicating higher levels of pain interference (M = 303, SD = 1.26; range = 1–5).

2.6. Statistical analysis

Descriptive statistics were calculated to describe our data. The normality of continuous data was determined using the Kolmogorov–Smirnov test, and the assumptions were confirmed before substantive analysis. We performed Pearson's zero-order correlations to evaluate the interrelationships among the core study variables, adjusting the p-values for multiple comparisons with a Bonferroni correction. Ordinary least squares (OLS) regressions and mediation analyses estimated the hypothesized associations between food insecurity (exposure), MD (outcome), and potential mediators (sleep problems, anxiety symptoms, loneliness, PA, and depressive symptoms) using the Model 4 of Hayes PROCESS macro plug-in version 4.0 software [44] while adjusting for the potential confounding variables. The mediators were tested simultaneously to provide the independent indirect effect of each of the included potential mediators. The PROCESS macro-based mediation analysis relied on bootstrapping with 95% confidence intervals (CI). This model estimated the direct effects of food insecurity on MD (c'), the indirect effects of food insecurity on MD via mediators (a × b), and the total effects (c = [a × b] + c'). Bootstrapping for indirect effects was set at 5000 samples, and if the 95% CI of the mediation effect lay outside zero (0), the mediation effect was deemed statistically significant at the p < .01 threshold. In sensitivity analyses, we estimated the cross-level interactions of food insecurity between the potential mediators and MD. All analyses were performed using SPSS 25.0 (SPSS, Inc., IBM, Armonk, NY, USA) software with α < 0.05 as the statistically significant level.

3. Results

3.1. Sample characteristics

Table 1 presents the sociodemographic and health characteristics of the sample. On average, participants were 66.14(11.85) years of age on average, 63.28% were female, and 13.82% completed some post-secondary education. Slightly over half lived in urban areas, and 56.60% of the sample were unmarried. The mean income was ¢307.98 (¢338.79). On average, the sample reported poor overall health (score of 3.30 out of 5.00). Food insecurity and MD mean scores were 3.96 and 4.38, respectively. Average sleep problems were 4.89, and that of anxiety symptoms was 3.88. The mean loneliness score was 5.30 (range: 0–9), the mean PA score was 9.03 (range: 0–21), the pain interference score was 3.03 (range: 1–5), and the mean number of chronic physical conditions 2.90 (range: 0–5) were reported.

3.2. Correlations

The zero-order correlation matrix for the main variables is shown in Table 2. MD positively correlated with food insecurity (r = 0.185, p < .001), sleep problems (r = 0.308, p < .001), anxiety (r = 0.303, p < .001), loneliness (r = 0.270, p < .001), and depressive symptoms (r = 0.259, p < .001), but negatively correlated with PA (r = −0.497, p < .001). Food insecurity also negatively correlated with PA (r = −0.087, p < .001) but positively correlated with all other variables (r = 0.333–3,79, p<. o01). In addition, sleep problems positively correlated with anxiety (r = 0.249, p < .0o1) and loneliness (r = 0.173, p < .001), but negatively correlated with PA (r = −0.265, p < .001). Anxiety strongly correlated positively with loneliness (r = 0.486, p < .0o1) but negatively with PA (r = −0.228, p < .001), while loneliness correlated negatively with PA (r = −0.174, p < .001). Finally, depressive symptoms positively correlated with food insecurity, sleep problems, anxiety symptoms, and loneliness (range:

Table 1
Descriptive statistics and sample characteristics (N = 1201).

Variable	M(SD): Range or %
Age (in years)	66.14(11.85): 50–111
Sex	
Female	63.28%
Male	36.72%
Residence	
Rural	44.96%
Urban	55.04%
Educational status	
None/Primary	86.18%
Secondary	8.66%
Tertiary	5.16%
Marital status	
Married	43.40%
Not Married	56.60%
Income	¢307.98(338.79): ¢100–¢4000
Number of chronic physical conditions	2.90 (0.74): 0–5
Pain interference	3.03 (1.26): 1–5
Self-rated health	3.30 (0.85): 1–5
Mobility limitation	4.38 (2.13): 2–8
Food insecurity	3.96 (1.84): 2–10
Sleep problems	4.89 (1.89): 2–10
Anxiety symptoms	13.58 (5.46): 7–21
Loneliness	5.30 (3.91): 3–9
PA	9.03 (1.47): 0–21
Depressive symptoms	21.3 (7.7): 10–40

Note: N—Frequency; M—Mean; SD–Standard deviation; PA—Physical activity.

Table 2
Pearson's zero-order correlations between key study variables with Bonferroni Correction for multiple comparisons.

	Variable	1	2	3	4	5	6	7
1	MD	1						
2	Food insecurity	0.185***	1					
3	Sleep problems	0.308***	0.379***	1				
4	Anxiety	0.303***	0.379***	0.249***	1			
5	Loneliness	0.270***	0.333***	0.173***	0.486***	1		
6	PA	−0.497***	−0.087***	−0.265***	−0.228***	−0.174***	1	
7	Depressive symptoms	0.259***	0.340***	0.203***	0.603***	0.580***	−0.174***	1
Mean		4.38	3.96	4.89	13.58	5.30	9.03	21.3
SD		2.13	1.84	1.89	5.46	3.91	1.47	7.7
Range		2–8	2–10	2–10	7–21	3–9	0–7	10–40

*** $p < .001$; *SD*—standard deviation; MD—Mobility difficulty; PA—Physical activity.

$r = 0.203$ to 603, $p < .001$) but negatively correlated with PA ($r = -0.174$, $p < .001$).

3.3. Regression and mediation analyses

In Fig. 2 (Panels A to E), fully adjusted estimates showed that food insecurity was significantly and positively associated with sleep problems (β = 0.717, $p < .001$), anxiety (β = 0.329, $p < .001$), loneliness (β = 0.288, $p < .001$), and depression (β = 0.282, $p < .01$), but negatively associated with PA (β = −0.139, $p < .001$). Moreover, sleep problems (β = 0.176, $p < .001$), anxiety (β = 0.214, $p < .05$), and loneliness (β = 0.277, $p < .01$) were positively related with MD, but PA negatively related to MD (β = −0.589, $p < .001$). Depression was insignificantly related to MD (β = 0.122, $p = .1797$). Finally, the direct association between food insecurity and MD was positive but statistically insignificant (β = 0.062, $p = .3286$), indicating a potential total mediation effect of sleep problems, anxiety, loneliness, and PA in the association between food insecurity and MD.

Estimates of the total, natural direct, and natural indirect effects of food insecurity on MD risk are shown in Fig. 2 and Table 3. The bootstrap-derived 95%CI estimates with 5000 bootstrap samples did not include zero for any outcomes. This suggests that after covariate adjustment, there was a significant indirect effect of food insecurity on MD through sleep problems, anxiety, loneliness, and PA. Thus, sleep problems accounted for 28.0% (indirect effect: β = 0.127, 95%CI = 0.081–0.177) of the total effect (β = 0.4551, 95%CI = 0.3261–0.5840) of food insecurity on MD, anxiety symptoms yielded 15.5% (indirect effect: β = 0.071, 95%CI = 0.015–0.128) of the total effect (β = 0.4551, 95%CI = 0.3261–0.5840) of food insecurity on MD, loneliness accounted for 17.5% (indirect effect: β = 0.080, 95%CI = 0.029–0.134) of the total effect (β = 0.4551, 95%CI = 0.3261–0.5840) of food insecurity on MD, and PA was responsible for 18.0% (indirect effect: β = 0.082, 95%CI = 0.027–0.140) of the total effect (β = 0.4551, 95%CI = 0.3261–0.5840) of food insecurity on MD. However, depressive symptoms were not a significant mediator in the association between food insecurity and MD (indirect effect: β = 0.0344, 95%CI = -0.0158 to 0.0837) of the total effect (β = 0.4551, 95%CI = 0.3261–0.5840).

3.4. Additional analysis

We analyzed the effect modification of the relationship between the mediators and MD by food insecurity (Table 4). The interactions showed that food insecurity significantly moderated the associations of MD with sleep problems (β = 0.071, $p < .001$), anxiety symptoms (β = 0.074, $p < .05$), loneliness (β = 0.110, $p < .01$), PA (β = −0.205, $p < .01$), and depressive symptoms (β = 0.039, $p < .05$). The positive effects of sleep problems, anxiety, and loneliness on MD were further reinforced by food insecurity. Similarly, the negative effect of PA on MD was strengthened by food insecurity.

4. Discussion

4.1. Main findings

Our analyses revealed several notable findings in this population-based study of 1201 middle-aged and older adults from the LMIC context. First, food insecurity was associated with higher odds of MD in a dose-dependent fashion. Second, the association between food insecurity and MD was significantly mediated by sleep problems (27.8%), PA (18.0%), loneliness (17.5%), and anxiety symptoms (15.5%). Finally, food insecurity significantly moderated the association of sleep problems, anxiety, loneliness, and PA with MD in the cross-level interaction estimations. The findings suggest that reducing food insecurity in old age may present opportunities to address mobility challenges in older adults in this setting.

4.2. Interpretation of findings

Our findings help complement the broad spectrum of published reports on associations of food insecurity with functional disability in later life. Several recent studies showed that food insecurity was associated with higher odds of mobility and functional disability. For example, [28] used the cross-sectional National Health Interview Survey (NHIS) and showed among 37,292 older Americans that food insecurity is related to higher odds of mobility impairment, including psychological dysfunction. Fong [45] analyzed a sample of 31,532 community-dwelling older adults in India and reported that food insecurity was associated with higher risks for physical impairment, functional disabilities, and chronic stress. Furthermore, among 72,262 Indian adults from the national cross-sectional population-based dataset, Pengpid & Peltzer [46] reported that food insecurity was significantly associated with functional limitations, including MD. Our study offsets the limitations of some previous studies, such as not providing evidence in SSA, having a smaller sample size, or lacking an indirect association between food insecurity and MD and estimating an interaction effect of proximate variables in this association. Indeed, to the best of our knowledge, our study is the first to examine direct and indirect associations between food insecurity and MD with effect modifications among middle-aged and older adults, particularly in the LMIC context, in concert with a wide range of potential confounders.

We speculate several potential mechanisms to explain the association of food insecurity with MD in later life. First, sleep problems emerged as a significant mediator, explaining nearly 27.8% of the food insecurity-MD association. Prior research suggests food insecurity, marked by hunger and missed breakfasts due to limited access to essential food, can lead to physiological changes like nutritional deficiencies [15,27]. Food insecurity often forces individuals to adopt less nutritious

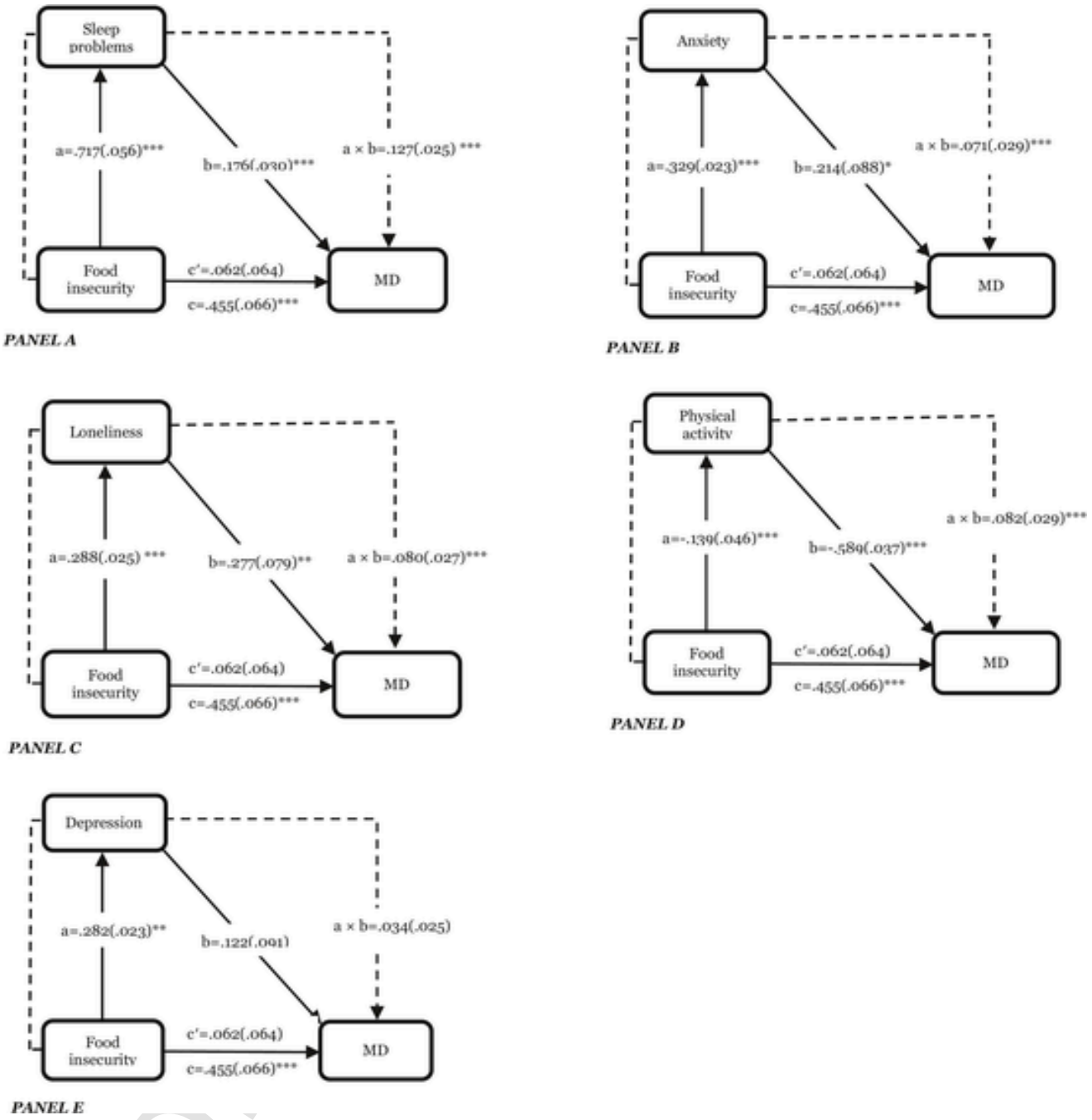

Fig. 2. Bootstrapping mediation analysis of the effect of sleep problems (Panel A), anxiety symptoms (Panel B), loneliness (Panel C), physical activity (Panel D), and depressive symptoms (Panel E) on the association between food insecurity and mobility difficulties among community-dwelling older adults.
Note: a × b = indirect effect of food insecurity and mobility difficulties; c' = direct effect of food insecurity and mobility difficulties; c = total effect of pain interference on functional decline.*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

diets, high in carbohydrates, fats, and oils, while lacking minerals, proteins, vitamins, and micronutrients [27]. Malnutrition can potentially limit the availability of tryptophan, an amino acid crucial for initiating, regulating, and maintaining sleep [47,48]. Research indicates that sleep problems are independently linked with MD in old age [49]. Disrupted sleep patterns can contribute to MD and overall well-being, especially in midlife and later years, via several biological mechanisms, such as changes in body homeostasis, insulin resistance, metabolic syndrome, increased inflammatory inducements, and diabetes [50,51]. Second, anxiety symptoms were a significant mediator, explaining roughly 15.5% of the food insecurity-MD link. Gerontological and clinical research suggests malnutrition, particularly vitamin D deficiency and low calcium intake, increases the risk of mental distress and cognitive impairments [52,53] due to impaired hypothalamic–pituitary–adrenal axis function [54]. Psychological dysfunction, including feelings of anxiety, sadness, and hopelessness, ultimately reduces individuals' motivation to participate in intellectually stimulating activities [55] and, as a result, increases the likelihood of a sedentary lifestyle, leading to MD, particularly in midlife and old age.

Table 3
The direct and indirect effects of food insecurity on MD through sleep problems, anxiety, loneliness, and PA (N = 1201).

Path model		β	Boot*SE*	Boots 95%CI	Proportion mediated
Sleep problems	Indirect effect	0.1265	0.0251	0.0805 to 0.1790	27.8%
Anxiety symptoms	Indirect effect	0.0705	0.0287	0.0148 to 0.1287	15.5%
Loneliness	Indirect effect	0.0798	0.0268	0.0290 to 0.1342	17.5%
PA	Indirect effect	0.0818	0.0277	0.0272 to 0.1369	18.0%
Depressive symptoms	Indirect effect	0.0344	0.0252	−0.0141 to 0.0858	NA
	Total indirect effect	0.3929	0.0481	0.2994 to 0.4893	86.3%
	Total direct effect	0.0621	0.0636	−0.0626 to 0.1869	13.6%
	Total effect	0.4551	0.0657	0.2994 to 0.4893	100.0%

Note: β–Unstandardized regression coefficients are reported; *BootSE*–Bootstrapping standard error; MD—Mobility difficulty; PA—Physical activity.
The models were adjusted for age, sex, residential type, level of education, income, marital status, social isolation, number of chronic physical conditions, self-rated health, pain severity, and pain intensity.
The empirical 95% confidence interval does not overlap with zero.

Third, loneliness also played a crucial role, explaining approximately 17.5% of the association between food insecurity and MD. Prior studies have observed that people who are food insecure are challenged with social withdrawal, limited social support networks, and isolation from relevant others due to feelings of shame, anxiety, or inability to afford nutritious food or outings [27,56]. Loneliness is associated with adverse mental health outcomes like comorbid depressive and anxiety symptoms that could worsen pre-existing health conditions [31], particularly in later life, thereby contributing to physical inactivity rates and, subsequently, declines in mobility levels over time. Fourth, our analysis identified PA as a significant mediator in the association, explaining 18.0%. Thus, older adults who experience inadequate nutrition lack vital body vitamins and minerals and may potentially lack the energy to engage in daily PA [57,58]. Inadequate protein intake can lead to muscle strength loss, decreased bone density, and balance problems, contributing to physical inactivity and ultimately worsening MD [11].

Apart from these crucial mechanistic pathways we estimated in our study, other potential pathways may underpin the food insecurity-MD link in old age. Hunger and nutritional deficiencies are directly associated with an increased risk of chronic health conditions like type 2 diabetes, arthritis, cardiovascular disease, and cancer [12,15]. Chronic diseases can lead to increased hospital admission rates [59] and associated declines in mobility. Additionally, malnutrition in later life weakens the musculoskeletal system [60], potentially leading to increased infections, multimorbidity, and longer healing times, consequently leading to greater disability and MD in old age. Finally, food insecurity has been identified as a well-established risk factor for pain [61,62], which in turn leads to MD via sedentary lifestyles and general muscle weakness [11,54].

Our finding holds several implications for public health, clinical care, and policy intervention. First, healthcare providers could broaden their range of services to encompass dietary and mobility impairment screenings as part of routine healthcare to provide nutritional guidance and promote physical health assistance to individuals. Second, initiating community-based social programs that combat psychological predictors such as social isolation, anxiety, and loneliness in older adults, with social interaction components, can be beneficial, particularly for food-insecure older cohorts in LMICs. Third, educational programs promoting healthy eating habits on a budget can empower older adults to make nutritious choices even with limited resources. Moreover, contextual policy advocacy for social safety nets and support for local agriculture could boost food access and address food insecurity in old age. Pensions, conditional cash transfers, and improved filial transfers and remittances may be viable support policies to address food insecurity for older adults in LMICs. The Livelihood Empowerment Against Poverty (a module of Ghana's cash transfer program) should be expanded to cover many vulnerable older adults. Finally, this study may be relevant to policy and public health efforts to address food insecurity and functional limitations in the context of achieving the United Nations' health-related sustainable development goals through the implementation of evidence-based interventions to increase food supply and improve physical health outcomes of older adults in LMICs.

4.3. Strengths and limitations

The strengths of the current study include using a large and representative sample of older adults in an innovative context, contributing to our understanding of how food insecurity interacts with biopsychosocial factors to exacerbate MD in old age. Also, this study advanced the methodological limitation of previous population-based studies in Western countries and Asian societies to perform a robust interactive analysis between food insecurity, MD, sleep problems, anxiety, loneliness, and PA to disentangle the complex relationship between food insecurity and MD at old age in SSA. However, some limitations exist. Our core variables, including food insecurity, MD, sleep problems, anxiety, loneliness, and PA, were subjectively assessed via self-reports. Indeed, self-reported data may be infused with recall and social desirability biases, which may undermine the veracity of the findings via under- or over-estimation of response. While we employed validated scales to assess the key variables, objectively measured approaches may improve

Table 4
The interaction effects of food insecurity on mobility limitations by food insecurity.

Variable	β	*SE*	95%CI	*p*-value	Constant	*F*-statistics	Adjusted R^2
Potential confounding variables	√						
Food insecurity	†						
Interaction effects							
Food insecurity × sleep problems	0.071	0.015	0.042–0.101	<0.001	−0.918	51.329***	0.331
Food insecurity × anxiety	0.074	0.035	0.005–0.143	0.036	−1.183**	48.361***	0.319
Food insecurity × loneliness	0.110	0.033	0.046–0.174	0.001	−0.1.161*	47.370***	0.323
Food insecurity × physical activity	−0.205	0.017	−0.238–0.172	<0.001	−0.253*	72.234***	0.415
Food insecurity × depressive symptoms	0.031	0.011	0.042–0.151	0.021	−0.124**	39.231***	0.341

Note: β – Unstandardized regression coefficients are reported; *SE* – Robust standard error, CI – Confidence interval; √ – Potential confounders; † – Respective estimates for food insecurity.
Each model was adjusted for age, sex, residential type, level of education, income, marital status, number of chronic physical conditions, self-rated health, pain interference, and sleep problems, or anxiety, or loneliness, or physical activity.
*$p^{<}$0.05; **$p^{<}$0.01; ***$p^{<}$0.001.

our observation in this study. The cross-sectional design did not allow the establishment of causal inferences between food insecurity and MD. We conducted a cross-sectional mediation analysis, which could produce biased estimates even if correct specifications are procured [69,70]. Future research would benefit from longitudinal data to validate these findings. Although MD and food insecurity may be conceptually bidirectional, our mediation models, focus on the direction of food insecurity leading to MD rather than the reverse. Future research may benefit from considering the reverse mediation estimates of the link between MD and food insecurity. Finally, the underlying mechanistic pathways of sleep problems, anxiety, loneliness, and PA in the food insecurity-MD association could be clarified in future studies.

5. Conclusions

These data provide some evidence to suggest that MD may result from food insecurity in later life. This association is largely explained and also modified by biopsychosocial pathways, including sleep problems, anxiety, loneliness, and PA. Interventions to improve MD in old age should include strategies to address food insecurity. Future research using randomized controlled trials and longitudinal data is warranted to establish a causal relationship between food insecurity and MD among older adults.

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CRediT authorship contribution statement

Razak M. Gyasi: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Hubert Bimpeh Asiedu:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Lawrencia Pokuah Siaw:** Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Emmanuel Nyaaba:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Emmanuel Affum-Osei:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Richard Bruce Lamptey:** Writing – review & editing, Writing – original draft, Investigation, Data curation. **Faith Muhonja:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Domonic Degraft Arthur:** Writing – review & editing, Writing – original draft, Investigation, Data curation. **Edward Asamoah:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation. **Michael Nimoh:** Writing – review & editing, Writing – original draft, Investigation, Data curation. **Samuel Adu-Gyamfi:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation.

Declaration of competing interest

The authors declare no conflicts of interest.

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