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Food insecurity and physical functioning limitations among older U.S. adults

Jennifer A. Jackson[a,*], Adam Branscum[b], Alice Tang[c], Ellen Smit[d]

[a] College of Public Health and Human Sciences, Oregon State University, 204 Milam Hall, Corvallis, OR 97331, United States of America
[b] College of Public Health and Human Sciences, Oregon State University, 127 Milam Hall, Corvallis, OR 97331, United States of America
[c] Public Health and Community Medicine, Tufts University School of Medicine, 150 Harrison Avenue, Jaharis 265, Boston, MA 02111, United States of America
[d] College of Public Health and Human Sciences, Oregon State University, 135 Milam Hall, Corvallis, OR 97331, United States of America

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ABSTRACT

Food insecurity among U.S. older adults has more than doubled since 2001 and is higher in those who are frail. Given the growing aging population and the importance of physical functioning and adequate food intake, the increase in food insecurity is a public health concern. This study examined the association between domains of physical limitations and food security in U.S. older adults. Data were from the National Health and Nutrition Examination Survey (2007–2012) participants 60 years of age and older (n = 5969). Physical limitations were defined as some or much difficulty on 19 activities, categorized into 5 domains and an index score. Food security status was categorized as full, marginal, low, or very low, and also dichotomized into food secure and food insecure (marginal, low, or very low food security). Multinomial and logistic regression models were used to estimate odds ratios (OR) and adjusted ORs (aOR) with food security as the dependent variable and physical limitations as independent variables. Older adults with 4 or more physical limitations were more likely to report very low food security than older adults without limitations (aOR:2.62, 95% CI:1.43, 4.81). The strongest correlates of food insecurity were Instrumental Activities of Daily Living (aOR:1.49; 95% CI:1.10, 2.01), Leisure and Social Activities (aOR:1.56; 95% CI:1.37, 2.14), and General Physical Activities (aOR:1.50; 95% CI:1.08, 2.07). Physical functioning is important for food security among older adults. Interventions should incorporate assessment of physical functioning, and provide resources for food acquisition, preparation, and intake for older adults with physical limitations.

1. Introduction

Food insecurity, or lack of consistent access to enough food to support an active, healthy life, is a major public health problem (Gundersen and Ziliak, 2015; U.S. Department of Health and Human Services, 2013). Between 2007 and 2012, the prevalence of food insecurity in the U.S. increased considerably, with 14.5% of households lacking food security at some point during 2012 (Coleman-Jensen et al., 2013). Although the prevalence of food insecurity decreased significantly between 2013 and 2017, nearly 12% of U.S. households remained food insecure in 2017 (Coleman-Jensen et al., 2018). Food insecurity is associated with health disparities, including disproportionately higher rates among non-Hispanic blacks, Hispanics, and economically disadvantaged groups (Coleman-Jensen et al., 2015). Food insecurity has also more than doubled in older adult populations since 2001, is higher in older adults who are frail, and is associated with chronic health conditions and disability (Smit et al., 2013; Seligman et al., 2007; Seligman et al., 2010; Siefert et al., 2004; Meng et al., 2015; Spotlight on Senior Hunger, 2013; Spotlight on Senior Health, 2013; Senior Hunger Fact Sheet, 2017).

Given the projection that nearly 20% of the U.S. population will be ≥65 years old by 2030 (Vincent and Velkoff, 2010), the ongoing problem of food insecurity observed among older adults (Ziliak and Gundersen, 2018) is concerning. Yet, limited research has examined food insecurity and health outcomes in this population(Gundersen and Ziliak, 2015). Older adults who are food insecure have been shown to have poorer dietary intake, nutritional status and health status compared to those who are food secure(Lee and Frongillo Jr, 2001a; Gundersen and Ziliak, 2017). Food insecurity among older adults has also been associated with functional impairments, which may result in compromised ability to acquire, prepare, or ingest adequate amounts of food(Gundersen and Ziliak, 2017; Lee and Frongillo Jr, 2001b). Further, the likelihood of cost-related medication underuse increases with increasing severity of food insecurity among older adults, which may

* Corresponding author.
E-mail addresses: jenny.jackson@oregonstate.edu (J.A. Jackson), adam.branscum@oregonstate.edu (A. Branscum), alice.tang@tufts.edu (A. Tang), ellen.smit@oregonstate.edu (E. Smit).

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Table 1
Characteristics of adults age 60 years and older and stratified by food security status: National Health and Nutrition Examination Survey, 2007–2012.

Characteristics[a]	Total population (*n* = 5969)		Food secure (*n* = 4811)		Marginal food security (*n* = 493)		Low food security (*n* = 402)		Very low food security (*n* = 263)	
	%	SE[b]	%	SE[b]	%	SE[b]	%	SE[b]	%	SE[b]
Age (n = 5969)										
60–69 years	51.35	0.97	50.45	1.07	53.94	3.14	59.15	2.94	65.14	4.53
70–79 years	30.40	0.67	30.61	0.78	32.25	2.84	27.78	2.99	23.89	3.13
80 years and older	18.24	0.84	18.94	0.88	13.81	1.99	13.07	1.89	10.97	2.93
Sex (n = 5969)										
Male	44.52	0.63	45.27	0.68	38.03	2.31	37.52	2.31	42.38	3.28
Female	55.48	0.55	54.73	0.68	61.97	2.31	62.48	2.31	57.62	3.28
Race/Ethnicity (n = 5969)										
Non-Hispanic white	78.69	1.69	82.48	1.37	53.07	4.38	49.40	6.43	43.95	6.79
Non-Hispanic black	8.88	0.98	7.32	0.80	22.00	2.81	16.92	3.27	24.29	4.23
Hispanic	7.34	1.07	5.40	0.76	19.06	3.80	25.00	4.65	23.55	4.99
Other	5.10	0.59	4.80	0.61	5.86	1.71	8.69	2.70	8.20	3.47
Education level (*n* = 5955)										
< High school graduate	22.97	1.24	19.51	1.19	43.90	3.65	53.43	3.84	53.58	3.72
High school graduate/GED	24.61	1.02	24.83	1.14	23.10	2.55	22.07	2.56	23.97	3.48
> High school graduate	52.42	1.48	55.66	1.61	33.00	3.43	24.50	3.35	22.45	3.85
Family PIR[c] (*n* = 5355)										
< 1.0	10.32	0.75	6.80	0.64	33.02	4.07	38.15	4.42	44.91	4.43
1.0–2.0	24.30	1.11	22.07	1.23	38.07	4.53	45.46	3.83	42.41	4.91
> 2.0	64.38	1.41	71.12	1.50	28.91	3.74	16.39	3.19	12.67	4.17
BMI[d] (*n* = 5566)										
Under/normal weight (BMI < 25)	27.04	0.90	27.19	0.99	25.13	2.85	28.44	3.43	23.47	4.67
Overweight (BMI ≥ 25 and < 30)	36.39	0.87	37.25	0.98	33.44	2.89	23.00	2.65	33.16	3.39
Obese (BMI ≥ 30)	36.57	0.92	35.56	1.01	41.43	3.29	48.56	3.71	43.37	3.91
Smoking (*n* = 5964)										
Never smoker	49.28	0.87	49.82	0.95	46.84	2.97	46.21	3.54	40.01	4.07
Former smoker	39.93	0.88	40.78	0.91	33.64	2.87	33.40	2.69	32.82	3.97
Current smoker	10.80	0.53	9.39	0.54	20.39	2.32	20.39	3.49	27.17	3.84
Chronic Disease Index (*n* = 5778)										
No chronic diseases	18.58	0.92	19.08	1.04	15.64	1.95	16.05	2.33	10.48	2.27
1–2 chronic diseases	52.61	1.07	53.23	1.27	51.35	3.07	47.23	4.56	41.52	4.51
3 or more chronic diseases	28.81	0.78	27.68	0.84	33.00	2.84	36.72	4.17	47.99	4.79

[a] Wald chi square test comparisons for all characteristics and food security were $p < 0.005$.
[b] SE = standard error.
[c] PIR = poverty index ratio.
[d] BMI = body mass index (kg/m^2).

Table 2
Prevalence of physical function limitations by food security status among adults age 60 years and older: National Health and Nutrition Examination Survey, 2007–2012.

Physical Functioning Limitations[a]	Total		Food secure		Marginal food security		Low food security		Very low food security	
	%	SE[b]	%	SE[b]	%	SE[b]	%	SE[b]	%	SE[b]
Activities of Daily Living (ADL) (*n* = 5957)	20.0	0.7	17.8	0.7	32.5	2.9	38.0	3.5	43.9	4.9
Instrumental Activities of Daily Living (IADL) (*n* = 5461)	23.5	0.8	20.9	0.8	41.3	3.2	43.5	3.5	50.1	4.6
Leisure and Social Activities (LSA) (*n* = 5688)	17.5	0.6	15.2	0.6	34.9	2.9	35.6	3.2	39.6	5.1
General Physical Activities (GPA) (*n* = 5895)	60.2	1.1	58.1	1.2	73.2	3.2	77.6	3.5	82.1	2.5
Lower Extremity Mobility (LEM) (*n* = 4721)	24.2	1.0	22.4	1.0	39.2	4.6	42.1	5.5	44.8	5.2
Physical Function Index (%) (*n* = 4001)										
1–3 physical limitations	33.9	1.0	34.3	1.1	31.1	4.1	28.0	3.6	32.1	6.6
4 or more physical limitations	19.0	0.9	17.4	1.0	32.2	4.5	39.6	5.2	40.8	5.2

[a] Wald chi square test comparisons for all categories of physical functioning and food security were $p < 0.005$.
[b] Standard error.

exacerbate functional impairment(Afulani et al., 2015). Decreased physical functioning is a component of frailty (Fried et al., 2001), and we have previously shown that frail older adults were more likely to report being food insufficient than those who were not frail (Smit et al., 2013).

Previous studies examining the relationship between physical functioning and food security among older adults were limited in that they concentrated on only two specific domains of physical functioning (i.e., Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL)), with one recent study including limitations related to obtaining and preparing food (Gundersen and Ziliak, 2017; Lee and Frongillo Jr, 2001b; Goldberg and Mawn, 2015; Chang and Hickman, 2018). Notably, all of these studies defined food security as a dichotomous variable, with marginal food security included in the food secure category. The primary goal of this study was to build on previous research by examining the association between an expanded number of physical functioning domains and marginal, low, and very low food security among a sample of older adults in the U.S.

Table 3
Odds of food insecurity (marginal, low, or very low food security)[a] among adults age 60 years and older for each of the 5 domains of physical function limitations compared to those without physical function limitations: National Health and Nutrition Examination Survey, 2007–2012.

Physical function limitations		Marginal food security[j]		Low food security[j]		Very low food security[j]	
		OR[b]	95% CI[c]	OR[b]	95% CI[c]	OR[b]	95% CI[c]
ADL[d]	aOR[e]	**2.23**	1.66, 2.99	**2.84**	2.10, 3.84	**3.62**	2.37, 5.53
		1.86	1.40, 2.46	**1.98**	1.36, 2.90	**2.29**	1.39, 3.79
IADL[f]	aOR[e]	**2.67**	2.01, 3.54	**2.92**	2.15, 3.95	**3.81**	2.67, 5.45
		2.07	1.55, 2.76	**2.18**	1.58, 3.01	**2.34**	1.52, 3.62
LSA[g]	aOR[e]	**3.00**	2.25, 3.99	**3.09**	2.26, 4.22	**3.66**	2.38, 5.63
		2.31	1.71, 3.12	**2.02**	1.39, 2.95	**2.05**	1.26, 3.34
GPA[h]	aOR[e]	**1.97**	1.41, 2.77	**2.50**	1.64, 3.81	**3.32**	2.35, 4.68
		1.65	1.13, 2.41	**1.97**	1.29, 3.02	**2.57**	1.53, 4.30
LEM[i]	aOR[e]	**2.23**	1.55, 3.20	**2.51**	1.61, 3.92	**2.81**	1.77, 4.45
		1.65	1.08, 2.52	1.65	1.00, 2.74	**1.72**	1.02, 2.91

[a] Reference category = high food security.
[b] OR = odds ratio.
[c] CI = confidence interval.
[d] ADL = activities of daily living; dressing self, walking between rooms on same floor, getting in and out of bed, using a fork knife and drinking from a cup.
[e] aOR = adjusted odds ratio (adjusted for age, sex, race/eth, education, PIR (poverty index ratio), BMI (body mass index (kg/m^2)), smoking, chronic disease index).
[f] IADL = instrumental activities of daily living; managing money, doing household chores, preparing meals.
[g] LSA = leisure and social activities; going out to movies and events, attending social events, performing leisure activities at home.
[h] GPA = general physical activities; stooping, crouching and kneeling, lifting or carrying, standing up from an armless chair, standing for long periods, sitting for a long period, reaching up over head, grasping/holding small objects.
[i] LEM = lower extremity mobility; walking a quarter mile, walking up 10 steps.
[j] Bolded ORs indicate significance at $p < 0.05$.

2. Methods

2.1. Study participants

The study population consisted of adults 60 years of age and older ($n = 6018$) who participated in the continuous National Health and Nutrition Examination Survey (NHANES) during three consecutive 2-year waves (2007–2008, 2009–2010, 2011–2012) and who had complete data on food security ($n = 5969$). NHANES obtains a nationally representative sample of the resident, noninstitutionalized U.S. civilian population by using a complex multistage probability sampling design (Centers for Disease Control and Prevention (CDC), 2015). NHANES was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the National Center for Health Statistics Institutional Review Board. Written informed consent was obtained from all subjects/patients.

2.2. Food security

Food security was measured at the household level over the prior 12 months using the U.S. Food Security Survey Module, an 18-item instrument that was developed and validated by the United States Department of Agriculture (USDA)(Bickel et al., 2000). Because we were interested in food security among older adults, we excluded the 8 items that refer to children. Categories for older adults in U.S. households were generated according to USDA guidelines as follows: high food security (no affirmative responses to any of the 10 items); marginal food security (1–2 affirmative responses); low food security (3–5 affirmative responses); and very low food security (6–10 affirmative responses) (Bickel et al., 2000). Studies have utilized different definitions of food insecurity, with some including marginal food security as food secure (Coleman-Jensen et al., 2013) and others including marginal food security with food insecurity(Strickhouser et al., 2014). Given our specific aim to examine different levels of food insecurity, for our analyses that used a dichotomized outcome, we refer to food insecurity as any category less than high food security (i.e., marginal, low, or very low food security) and food security as fully food secure.

2.3. Physical functioning

Physical functioning was measured using 19 questions designed to assess difficulty in performing a variety of functional activities without the aid of special equipment. Response options for all items were “no difficulty,” “some difficulty,” “much difficulty,” “unable to do,” “do not do this activity,” or “don't know.” Responses of either “do not do this activity” or “don't know” were considered missing. For each item, physical function limitation was defined as report of some or much difficulty or unable to do the activity (Seeman et al., 2010) and was assigned a score of 1, while reporting no difficulty was assigned a score of 0.

A Physical Function Index was created by summing all 19 physical function limitation scores to produce a categorical variable with groupings of no physical limitations, 1–3 physical limitations, and 4 or more physical limitations. We further categorized the activities to assess five domains of physical function limitations: activities of daily living (ADLs), instrumental activities of daily living (IADLs), leisure and social activities (LSAs), general physical activities (GPAs), and lower extremity mobility (LEM) (Xu et al., 2012). ADLs were defined by four activities: dressing oneself; walking between rooms on the same floor; getting in and out of bed; and using a fork, knife and drinking from a cup. IADLs were defined by three activities: managing money; doing household chores; and preparing meals. LSAs were defined by three activities: going out to movies and events; attending social events; and performing leisure activities at home. GPAs were defined by seven activities: stooping, crouching and kneeling; standing up from an armless chair; standing for long periods; sitting for long periods; reaching up over head; and grasping/holding small objects. LEM was defined by two activities: walking a quarter mile and walking up 10 steps. For each domain, physical function limitation was defined as report of any difficulty on at least one functional activity and was assigned a score of 1, while reporting no difficulty on all activities was assigned a score of 0.

For the five domains of physical functioning limitations, our sample size ranged from 5957 for ADL to 4721 for LEM. However, for the Physical Function Index, our sample size was reduced to 4001 participants, (1968 had missing data on one or more physical limitations). We performed a preliminary analysis to compare those with missing data

Table 4
Odds of food insecurity (marginal, low, or very low food security)[a] among adults age 60 years and older with physical function limitations compared to those without physical function limitations: National Health and Nutrition Examination Survey, 2007–2012.

Physical Function Limitation	Marginal food security[h]		Low food security[h]		Very low food security[h]	
	OR[b]	95% CI[c]	OR[b]	95% CI[c]	OR[b]	95% CI[c]
PFI[d]						
0 limitations (referent)	1.20	0.74, 1.93	1.22	0.75, 1.98	1.67	0.89, 3.16
1–3 limitations						
aOR[e]	1.21	0.71, 2.04	1.41	0.84, 2.38	1.78	0.86, 3.68
4 or more limitations	**2.44**	1.44, 4.13	**2.29**	1.93, 5.97	**4.20**	2.71, 6.51
aOR[e]	**2.17**	1.23, 3.82	**2.61**	1.32, 5.17	**2.62**	1.43, 4.81
Covariates						
Age						
60–69 years (referent)						
70–79 years	0.78	0.52, 1.18	**0.51**	0.30, 0 0.85	**0.22**	0.10, 0.46
80 years and older	**0.43**	0.23, 0.81	**0.48**	0.25, 0.93	**0.14**	0.04, 0.53
Sex						
Male (referent)						
Female	1.23	0.85, 1.77	0.99	0.62, 1.58	**0.53**	0.33, 0.84
Race/Ethnicity						
Non-Hispanic white (referent)						
Non-Hispanic black	**3.38**	2.05, 5.58	**3.02**	1.76, 5.19	1.82	0.78, 4.25
Hispanic	**3.12**	1.93, 5.04	**4.70**	2.37, 9.34	**3.44**	1.41, 8.42
Other	1.00	0.35, 2.84	1.77	0.56, 5.60	0.68	0.14, 3.24
Education level						
Less than high school graduate (referent)						
High school graduate/GED	0.93	0.59, 1.48	0.61	0.32, 1.15	0.82	0.38, 1.76
Greater than high school graduate	0.79	0.51, 1.23	**0.47**	0.27, 0.82	0.63	0.25, 1.59
Family PIR[f]						
< 1.0 (referent)						
1.0–2.0	**0.46**	0.27, 0.77	**0.46**	0.31, 0.67	**0.39**	0.20, 0.76
> 2.0	**0.12**	0.06, 0.23	**0.07**	0.04, 0.12	**0.04**	0.01, 0.20
BMI[g]						
Under/normal weight (BMI < 25) (referent)						
Overweight (BMI ≥ 25 and < 30)	1.17	0.70, 1.97	**1.98**	1.18, 3.32	1.37	0.53, 3.51
Obese (BMI ≥ 30)	0.95	0.57, 1.57	1.45	0.89, 2.38	1.11	0.64, 1.91
Smoking						
Never smoker (referent)						
Former smoker	1.02	0.65, 1.61	0.77	0 0.46, 1.27	0.85	0.45, 1.58
Current smoker	1.46	0.78, 2.72	1.38	0.79, 2.39	1.60	0.77, 3.35
Chronic Disease Index						
No chronic diseases (referent)						
1–2 chronic diseases	0.97	0.62, 1.54	1.18	0.66, 2.13	1.97	0.92, 4.24
3 or more chronic diseases	0.82	0.46, 1.44	1.10	0.64, 1.87	**3.44**	1.26, 9.39

[a] Reference category = high food security.
[b] OR = odds ratio.
[c] CI = confidence interval.
[d] PFI = Physical Function Index.
[e] aOR = adjusted odds ratio (adjusted for age, sex, race/eth, education, PIR, BMI, smoking, chronic disease index).
[f] PIR = poverty index ratio.
[g] BMI = body mass index (kg/m^2).
[h] Bolded ORs indicate significance at $p < 0.05$.

on the Physical Function Index to participants with complete data. Participants missing Physical Function Index data were older (73 vs. 69 years), less likely to have education beyond high school (40% vs. 57%), less likely to be non-Hispanic white (71% vs. 82%), more likely to smoke (12% vs. 10%), more likely to be obese (43% vs. 34%), more likely to have a chronic disease (89% vs. 79%), less likely to be food secure (80% vs. 91%), and had a lower family poverty index ratio (PIR) (2.3 vs. 2.6) ($p < 0.05$ for all).

2.4. Covariates

Self-reported covariates included age (years; categorized as 60–69, 70–79, 80 years and older), sex (male or female), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other), and education (less than high school, high school graduate or GED, greater than high school graduate). PIR was categorized as below or above poverty level (ratio of 1.0). Body mass index (BMI) was defined as weight in kg divided by height in m^2 and was categorized as underweight/normal weight (BMI < 25), overweight (BMI ≥ 25 and < 30) and obese (BMI ≥ 30). Smoking status was categorized as current smoker, former smoker and never smoker. Chronic disease index included 14 chronic health conditions (asthma, congestive heart failure, coronary heart disease, angina pectoralis, myocardial infarction, stroke, emphysema, thyroid problem, bronchitis, liver condition, cancer, kidney disease, hypertension, and diabetes) and was categorized as no chronic diseases, 1–2 chronic diseases, and 3 or more chronic diseases.

2.5. Analysis

All descriptive and inferential statistics were obtained using Stata (version 14.1, 2015, StataCorp, College Station, TX, USA) and accounted for sample design and sampling weights. Six-year examination sample weights were created for the combined NHANES cycles following analytical guidelines for the continuous NHANES (National Health and Nutrition Examination Survey, n.d.). Weighted proportions were used to examine participant characteristics and physical

Table 5
Co-occurring physical functioning limitations domains and odds of being food insecure (marginal, low, or very low food security): National Health and Nutrition Examination Survey, 2007–2012.

Domains[a]	Food insecure (marginal, low or very low food security)[h]	
	aOR	95% CI
One Domain[b]		
IADL[c]	**1.49**	1.10, 2.01
LSA[d]	**1.56**	1.37, 2.14
GPA[e]	**1.50**	1.08, 2.07
Two Domains[f]		
IADL + LSA	**2.32**	1.71, 3.14
IADL + GPA	**2.22**	1.51, 3.26
LSA + GPA	**2.33**	1.52, 3.60
Three Domains[g]		
IADL + LSA + GPA	**3.47**	2.42, 4.97

[a] Results include the 3 significant co-occurring domains; GPA (General Physical Activities; stooping, crouching and kneeling, lifting or carrying, standing up from an armless chair, standing for long periods, sitting for a long period, reaching up over head, grasping/holding small objects) and LEM (Lower Extremity Mobility; walking a quarter mile, walking up 10 steps) were not significant.
[b] Older adults with limitations in one domain; ajusted for the two other domains.
[c] IADL = Instrumental Activities of Daily Living; managing money, doing household chores, preparing meals.
[d] LSA = Leisure and Social Activities; going out to movies and events, attending social events, performing leisure activities at home.
[e] GPA = General Physical Activities; stooping, crouching and kneeling, lifting or carrying, standing up from an armless chair, standing for long periods, sitting for a long period, reaching up over head, grasping/holding small objects.
[f] Older adults with limitations in two domains.
[g] Older adults with limitations in all three domains.
[h] Bolded aORs indicate significance at $p < 0.05$.

functioning indicators stratified by food security category.

Multinomial logistic regression analysis was used to estimate separate unadjusted and covariate-adjusted odds ratios (OR, aOR) comparing older adults with physical limitations to those without limitations, with results presented as maximum likelihood estimates and 95% confidence intervals (CI). Because all of the covariates were significantly ($p < 0.05$) associated with at least one of the food insecurity categories in each regression model, all covariates were retained in the models. We performed pre-planned significance tests for increasing aOR with increasing food insecurity to investigate whether the magnitudes of covariate-adjusted associations increased with increasing level of food insecurity. For each of the 5 physical functioning domains and the composite physical function index, we used the corresponding covariate-adjusted multinomial logistic regression model to calculate and compare the average predicted prevalence of being food secure and the prevalence of having marginal, low, or very low food security among adults aged 60 years and older with and without physical functioning limitations. All possible two-way interactions between physical functioning and covariates were examined and none were found to be significant.

To investigate the association between co-occurring physical functioning limitations and food insecurity, we started with a logistic regression model that contained all 5 physical functioning domains, covariates, and two-way interactions; the response variable was dichotomized as food secure or insecure (i.e., marginal, low, or very low food security). All possible two-way interactions between different physical function indicators, and between each indicator and covariates, were considered. Backward elimination of variables based on p values was used for model selection. Statistical significance was set at $p < 0.05$.

3. Results

Among adults aged 60 years and older, approximately 12% reported being food insecure (i.e., marginal, low, or very low food security). Specifically, 2.6% reported very low food security, 4.0% reported low food security, 5.0% reported marginal food security, and 88.4% reported being food secure. The population characteristics by food security status are shown in Table 1. Compared to food secure participants, those with any level of food insecurity were more likely to be younger, female, non-Hispanic black or Hispanic, and less educated. Food insecure participants also had lower income and were more likely to be obese, current smokers, and report three or more chronic diseases than food secure participants.

The prevalence of physical function limitations by food security status are shown in Table 2. As the level of food insecurity increased from food secure to very low food security, participants tended to have greater prevalence of physical limitations in each of the domains of physical functioning. This was consistent for each of the domains and the Physical Function Index with 4 or more physical limitations.

The adjusted multinomial regression models show that the odds of food insecurity were consistently and significantly greater for those with physical limitations compared to those without limitations (Table 3). For example, the odds of very low food security for older adults with ADL limitations was more than double the odds of very low food security for older adults without ADL limitations (aOR: 2.29, 95% CI: 1.39, 3.79). Importantly, the associations were significant for marginal food security as well as low and very low food security.

Table 4 shows the results for the physical function limitations index and the covariates. Similar to the results for the specific domains, participants with 4 or more physical limitations according to the Physical Function Index had significantly higher odds of very low food

Table 6
Average adjusted predictions of prevalence of food security among adults age 60 years and older for those with physical function limitations compared to those without physical function limitations: National Health and Nutrition Examination Survey, 2007–2012.

Physical Function Variable	High food security[c]		Marginal food security		Low food security		Very low food security	
	Estimate, %	95% CI	Estimate, %	95% CI	Estimate, %	95% CI	Estimate, %	95% CI
IADL[a] = 0 limitations	**90.74**	89.34, 92.15	**4.01**	3.25, 4.76	**3.11**	2.41, 3.80	**2.15**	1.36, 2.93
IADL ≥ 1 limitations	**84.31**	82.50, 86.12	**6.72**	5.49, 7.95	**5.19**	3.97. 6.41	**3.78**	2.65, 4.91
Difference (With-Without IADL Limitations)	**−6.43**	−7.33, −4.24	**2.71**	1.32, 3.47	**2.08**	0.86, 2.94	**1.63**	0.54, 2.43
PFI[b] = 0 limitations	**93.56**	92.02, 95.09	**3.15**	1.96, 4.34	**2.06**	1.33, 2.79	**1.23**	0.55, 1.91
PFI = 1–3 limitations	**91.82**	90.13, 93.51	**3.56**	2.51, 4.61	**2.65**	1.77, 3.53	**1.97**	0.90, 3.04
PFI ≥ 4 limitations	**87.91**	85.28, 90.55	**5.58**	3.91, 7.25	**4.09**	2.51, 5.66	**2.42**	1.18, 3.66
Difference (With 4 or more limitations -With 0 limitations)	**−5.65**	−7.53, −2.85	**2.87**	0.47, 3.84	**2.01**	0.24, 3.49	**0.79**	0.10, 2.25

[a] IADL = Instrumental Activities of Daily Living; managing money, doing household chores, preparing meals; similar results for all other domains of physical functioning (ADL, LSA, GPA, LEM).
[b] PFI = Physical Function Index.
[c] Bolded estimates indicate significance at p < 0.05.

security compared to those without limitations (aOR: 2.62; 95% CI: 1.43, 4.81) (Table 4). Associations were not statistically significant for those with 1–3 Physical Function Index limitations. As expected, older adults (> 70 years old), females, and those with higher income had lower odds of being food insecure whereas non-whites and those with > 3 chronic diseases had higher odds. Although all physical functioning domains (Table 3) as well as the index (Table 4) were associated with food insecurity, there was no evidence for a linear increasing trend between the aOR's for the marginal, low, and very low food security groups for any of the measures of physical functioning limitations. (all p-values ≥0.30).

Based on our logistic regression analysis that started with all 5 physical functioning domains, backward elimination resulted in a final model that contained the IADL, LSA, and GPA domains and covariates for age, sex, race/ethnicity, education, PIR, BMI, smoking status, and chronic disease index. These results are shown in Table 5.

Among the 5 domains, those associated with food insecurity were IADL, LSA, and GPA. In addition, older adults with co-occurring limitations in any 2 of these domains were more likely to be food insecure compared to those without limitations (all $p < 0.0001$). For example, the odds of food insecurity for those with IADL and LSA limitations (estimated prevalence = 13%) was 2.32 (95% CI: 1.71, 3.14) times higher than the odds for those without limitations. Similar results were found for older adults with IADL and GPA limitations (estimated prevalence = 22%) and those with LSA and GPA limitations (estimated prevalence = 17%). Older adults with jointly occurring limitations in all 3 domains (IADL, LSA, and GPA; estimated prevalence 13%) had significantly higher odds of food insecurity than those without limitations (aOR: 3.47; 95% CI: 2.42, 4.97). Lastly, the odds of food insecurity were higher for older adults with limitations in more versus fewer domains. Specifically, older adults with limitations in 1 domain were more likely to be food insecure than those without limitations; those with limitations in any combination of 2 domains were more likely to be food insecure than those with limitations in 1 domain; and older adults with limitations in all 3 domains were more likely to be food insecure than those with limitations in any 2 of the domains (all $p < 0.01$).

Table 6 presents average adjusted predictions of prevalence of food security for older adults with physical function limitations compared to those without limitations. Results are presented only for the IADL domain and the composite physical function index because predicted prevalence for the ADL, LSA, LEM, and GPA domains were similar. These findings indicate that the prevalence of high food security was significantly lower among those with physical limitations. For example, older adults with > 3 limitations were nearly 6% less likely to be food secure compared to those without physical limitations ($p < 0.0001$).

4. Discussion

We examined indicators of physical functioning and food security in a population of older adults (aged 60 years and older) in U.S. households. Overall, 12% of older adults reported being food insecure (i.e., marginal, low, or very low food security), consistent with other research that used 2001–2012 NHANES data to examine food insecurity (i.e., marginal, low, or very low food security) among older adults (Strickhouser et al., 2014), yet slightly lower than the estimated 15% of the general adult population that was food insecure in 2012 (Coleman-Jensen et al., 2013). However, the general population estimate was based on a definition of food insecurity that did not include marginal food security. The prevalence of food insecurity declined across increasing age categories in our study, also consistent with other findings (Strickhouser et al., 2014; Ziliak and Gundersen, 2013).

Food insecurity was higher among participants with physical functioning limitations compared to those without limitations. While participants with 4 or more limitations on the Physical Function Index were more likely to be food insecure, the association for those with 1–3 limitations was not significant. This suggests that a greater number of physical limitations (i.e., > 3) is more strongly associated with food insecurity. Each of the physical functioning domains was significantly associated with food insecurity and the association was strongest for those with IADL, LSA, and GPA limitations. Notably, the IADL and GPA domains include functional activities related to food intake, specifically, meal preparation, standing for long periods, and grasping/holding small objects.

Limited research has examined physical functioning in relation to food insecurity. Similar to our findings, Lee and Frongillo Jr (2001b) found that older adults with functional impairments (i.e., ADL and IADL), had higher odds of food insecurity. Chang and Hickman (Chang and Hickman, 2018) also found higher odds of food insecurity among older adults with functional limitations; specifically those with low-income. Gundersen and Ziliak (Gundersen and Ziliak, 2017) found that food insecure seniors were more likely to suffer from at least one ADL limitation. In contrast to our findings, Goldberg et al. (2015) found that physical function limitations were not a significant predictor of food insecurity among adults 60 years of age and older. Differences may be due to differences in the definitions of food insecurity and physical function limitations. Chang and Hickman, Gundersen and Ziliak, and Goldberg et al., defined food security including marginal food security in the high food security category. In contrast, because our findings revealed significant differences in characteristics between marginal and food secure participants as well as a higher prevalence of physical limitations in marginal than food secure participants, we included marginal food security in our definition of food insecurity. Further, our analysis expanded on physical functioning activities examined in the previous studies since we included all 19 activities grouped into 5 domains of physical functioning and an overall index score.

Other studies have examined associations between food insufficiency and frailty, and diet and physical functioning. Using data from the NHANES III, we have previously shown that frail older adults were more likely to be food insufficient and have lower serum nutrient levels than those who were not frail (Smit et al., 2013). Xu et al. (2012) found an inverse association between overall diet quality and self-reported limitations in physical functioning among older adults, suggesting that a healthier diet is important for physical functioning in older adults. Furthermore, Chang and Hickman (Chang and Hickman, 2018) found higher odds of poor diet quality among low-income older adults with physical limitations. Together, these findings and those from this study suggest that it is important to screen for adequate food intake, and physical functioning limitations, in the aging population.

Although food insecurity is strongly associated with income (Coleman-Jensen et al., 2015) and older adults living below the poverty line experience higher rates of food insecurity than their higher income counterparts, many food insecure older adults live above the poverty line (Spotlight on Senior Hunger, 2013). Our study builds on previous research suggesting that physical limitations may be related to altered food access and use, possibly contributing to food insecurity among older adults (Lee and Frongillo Jr, 2001b; Wolfe et al., 2003). For example, older adults with physical limitations may have difficulty preparing meals. Thus, they may become less than food secure not only due to lack of financial resources but potentially also because of limited functional activities related to food intake. This emphasizes that the challenges of food security in the older adult population are multi-dimensional and solutions need to integrate individual barriers to food acquisition, preparation and intake.

Strengths of the present study include detailed food security and physical functioning measures in a sample of the civilian, non-institutionalized older U.S. population. Food security was examined based on four categories, which allowed us to compare different levels of food security. Thus, we were able to examine marginal food security separately and categorize it as food insecure rather than combining marginal with high food security as is the more common approach. Our results point to the importance of treating marginal food security as its

own risk category or consideration for including marginal in the food insecure category, especially as it relates to physical functioning. Physical functioning status was examined using five different domains, including physical and social contexts, as well as an index (total) score. Because those with missing Physical Function Index data were more likely to, for example, have a chronic disease and to be food insecure, our associations between Physical Function Index and food insecurity may be underestimated. Due to temporality in our cross-sectional data, we were limited in our ability to assess directionality and causality in the relationship between food security and physical functioning. Nevertheless, these data were useful for estimating the prevalence of levels of food security and investigating their connection to physical functioning among older adults in the U.S.

5. Conclusions

In conclusion, we found that all categories of physical functioning ability are important in relationship to food security among older adults in U.S. households. Certain domains of physical functioning, namely IADL, LSA, and GPA, appear to be most strongly associated with food insecurity (i.e., marginal, low, or very low food security), and there was statistical evidence of increased odds of food insecurity among older adults with more physical limitations compared to those with fewer or no limitations. Given the aging U.S. population and the importance of physical functioning and adequate food intake, our findings have valuable implications. More research is needed to develop targeted interventions for improving food security in older adults, incorporating assessment of physical functioning related to food acquisition, preparation and intake. In the meantime, our results point to the importance of assessing physical functioning and food security in older adults and of promoting access to sufficient quantity and quality of food to support active, healthy lifestyles among our aging population.

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Conflict of interest

None.

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