CLINICAL INVESTIGATION

Protein Intake and Mobility Limitation in Community-Dwelling Older Adults: the Health ABC Study

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OBJECTIVES: The current Recommended Dietary Allowance (RDA) for protein is based on short-term nitrogen balance studies in young adults and may underestimate the amount needed to optimally preserve physical function in older adults. We examined the association between protein intake and the onset of mobility limitation over 6 years of follow-up in older adults in the Health ABC study.

DESIGN: Prospective cohort study.

SETTING: Memphis, Tennessee and Pittsburgh, Pennsylvania.

PARTICIPANTS: Community-dwelling, initially well-functioning adults aged 70–79 years (n = 1998).

MEASUREMENTS: Protein intake (g/kg body weight/d) was calculated using an interviewer-administered 108-item food frequency questionnaire at baseline. Mobility limitation was assessed semi-annually and defined as reporting any difficulty walking one-quarter of a mile or climbing 10 steps on 2 consecutive 6-month contacts. The association between protein intake and incident mobility limitation was examined using Cox proportional hazard regression models adjusting for demographics, behavioral characteristics, chronic conditions, total energy intake, and height.

RESULTS: Mean (SD) protein intake was 0.91 (0.38) g/kg body weight/d, with 43% reporting intakes less than the RDA (0.8 g/kg body weight/d). During 6 years of follow-up, 705 participants (35.3%) developed mobility limitations. Compared to participants in the upper tertile of protein intake (≥1.0 g/kg body weight/d), participants in the lower two tertiles of protein intake (<0.7 and 0.7 –<1.0 g/kg body weight/d) were at greater risk of developing mobility limitation over 6 years of follow-up (RR (95% CI): 1.86 (1.41–2.44) and 1.49 (1.20–1.84), respectively).

CONCLUSION: Lower protein intake was associated with increased risk of mobility limitation in community-dwelling, initially well-functioning older adults. These results suggest that protein intakes of ≥1.0 g/kg body weight/d may be optimal for maintaining physical function in older adults. **J Am Geriatr Soc 2017.**

Key words: aging; mobility limitation; protein

Loss of lean mass with aging, and the associated declines in strength, are well documented,[1–3] and partially account for the aging-related loss of physical function.[4–7] Although a number of underlying mechanisms contribute to age-related declines in lean mass and strength (i.e., sarcopenia), inadequate dietary protein may accelerate this process.[8] In NHANES 2005–2006, 24% of women and 12% of men >70 years consumed less than the Estimated Average Requirement (EAR) for protein (0.66 g/kg body weight/d).[9] However, current Dietary Reference Intakes for protein (i.e., the EAR and Recommended Dietary Allowance (RDA)) are based predominantly on short-term nitrogen balance studies in young adults,[10] and may underestimate the intakes needed to optimally preserve physical function in older adults.[11] An international expert panel recently recommended that older adults should consume 1.0–1.2 g protein/kg body weight/d.[12] However, longitudinal studies of protein intake and relevant health outcomes, including physical function, are needed to establish protein requirements in older adults.[11,12]

We previously showed that lower protein intake was associated with loss of lean mass in Health ABC over 3 years of follow-up.[13] Others have also observed an association between protein intake and change in lean mass.[14–16] Some,[17–20] but not all,[14,15,21] observational studies have shown that that lower protein intake is associated with greater declines in physical performance and strength in older adults, measures that are predictive of subsequent mobility limitations.[22] However, to our knowledge, no

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studies have examined the association between protein intake and the onset of mobility limitation.

The primary objective of this study was to examine the association between protein intake and incident mobility limitation over 6 years of follow-up among older, community dwelling, initially well-functioning black and white men and women. We hypothesized that individuals with lower protein intake would be at greater risk of incident mobility limitation compared to those with higher intakes. We also examined the source of protein (animal vs vegetable) and whether the association between protein intake and mobility limitation was mediated through lean mass.

METHODS

Study Population

Data for this analysis are from the Health, Aging, and Body Composition (Health ABC) study; a prospective cohort study investigating the associations between body composition, weight-related health conditions, and incident functional limitations in older adults. Health ABC enrolled 3,075 community-dwelling black and white men and women aged 70–79 between April 1997 and June 1998. Participants were recruited from a random sample of white and all black Medicare eligible residents in the Pittsburgh, PA, and Memphis, TN, metropolitan areas. Participants were eligible if they reported no difficulty walking one-quarter of a mile, climbing 10 steps, or performing basic activities of daily living, were free of life-threatening illness, planned to remain in the geographic area for at least 3 years, and were not enrolled in lifestyle intervention trials. All participants provided written informed consent and all protocols were approved by the institutional review boards at both study sites.

As the food frequency questionnaire was administered at the 12-month follow-up clinic visit (year 2), this visit served as the study baseline for these analyses and only participants without prevalent mobility limitation at the 12-month follow-up visit were eligible for inclusion (n = 2,270). We excluded participants who were missing the food frequency questionnaire (n = 10), had serious errors on the food frequency questionnaire (n = 44), and reported energy intakes <500 kcal/d or >3,500 kcal/d in women and <800 kcal/d or >4,000 kcal/d in men (n = 43). Participants who were missing pertinent covariates (n = 103) were also excluded for a final analysis sample of 1,998.

Dietary Assessment

To estimate usual nutrient intake, participants completed a 108-item interviewer-administered food frequency questionnaire (FFQ) at year 2 (Block Dietary Data Systems, Berkeley, CA). The Health ABC FFQ food list was developed specifically for Health ABC using 24-hour recalls obtained in NHANES III from older (>65 years) non-Hispanic white and black adults residing in the Northeast or the South. Trained interviewers used wood blocks, food models, standard kitchen measures, and flash cards to help participants estimate portion sizes for each food. Interviews were periodically monitored throughout the study to ensure the quality and consistency of the data collection procedures. The Health ABC FFQ was analyzed for macro- and micronutrient content by Block Dietary Data Systems. Estimated daily intakes of energy and total, animal, and vegetable protein were calculated.

Mobility Limitation

Occurrence of mobility limitation during follow-up was assessed at annual clinic visits alternating with telephone interviews every 6 months. Mobility limitation was defined as 2 consecutive reports of having any difficulty walking one-quarter of a mile or climbing 10 steps without resting due to a health or a physical problem. Incident cases of mobility limitation were ascertained over 6 years.

Potential Confounders

Demographic characteristics (age, gender, race, and study site), smoking status, alcohol consumption, and physical activity were ascertained by an interviewer-administered questionnaire. Smoking and alcohol consumption were categorized as never, former, and current. Physical activity was based on the reported time spent walking over the past 7 days. The original Healthy Eating Index (HEI) score was calculated from the FFQ to assess overall diet quality and compliance with dietary guidelines.[23] Depressive symptoms were measured using the 20-item Center for Epidemiologic Studies Depression Scale (CES-D).[24] Cognitive status was measured using the Modified Mini-Mental State Examination (3MS).[25] Knee pain was assessed by self-report. The prevalence of diabetes, cardiovascular disease (CVD), and chronic obstructive pulmonary disease (COPD) were determined using algorithms based on self-report and medication use. Glomerular filtration rate (eGFR) was estimated from serum creatinine using the Modification of Diet in Renal Disease formula. Serum interleukin-6 (IL-6) was measured using an enzyme-linked immunosorbent assay (ELISA; R&D Systems, Minneapolis, MN). Use of oral steroids was determined from drug data coded using the Iowa Drug Information System ingredient codes. Overnight hospitalizations in the past year were categorized as none or ≥1 hospitalization. Height, as an indicator of body size, was measured using a Harpenden stadiometer (Holtain Ltd., Crosswell, United Kingdom). Body composition was assessed by dual-energy x-ray absorptiometry (DXA; Hologic 4500A, version 8.20a, Waltham, MA).[26,27] Education, smoking status, depressive symptoms, cognitive function, eGFR, and height were measured at the baseline clinic visit; all other covariates were measured at the year 2 clinic visit when diet was assessed.

Statistical Analyses

Descriptive statistics (chi-square tests for categorical variables and analysis of variance (ANOVA) for continuous variables) were used to summarize characteristics of the study population overall and by tertiles of protein intake (in g/kg body weight/d). Kaplan-Meier was used to calculate the cumulative incidence of mobility limitation and the log-rank test used to compare cumulative incidence by gender and race. Cox proportional hazard regression models were used to examine the associations between tertiles of protein intake and incident mobility limitation. Participants who survived with no evidence of incident mobility limitation were censored at their next to the last 6-month contact. Participants who died with no evidence of incident mobility limitation were censored at their time of death; and those who were lost to follow-up were censored at their last visit. Tests for linear trends across tertiles of protein intake were conducted using the median of each category as a continuous variable in the model. Two-way interactions between gender and protein intake and race and protein intake were tested but were not significant (all P for interaction, >.20); thus, risk of mobility limitation is presented in the total sample. Results are also presented by gender and race due to significant differences in the onset of mobility limitation by gender and race. The minimally adjusted model included age, gender, race, study site, education, and total energy intake. The fully adjusted model also included baseline height, smoking status, alcohol intake, physical activity, HEI score, kidney function, cognitive function, depressive symptoms, diabetes, CVD, COPD, knee pain, IL-6, oral steroids use, and hospitalizations in the past year. For models examining animal and vegetable protein intake, animal and vegetable protein intake were included in the model. The proportional hazards assumption was met for all models. All analyses were conducted using SAS version 9.3 (SAS Institute; Cary, NC).

RESULTS

The mean age of the study population (n = 1,998) was 74.6 years, 48.7% were women, and 33.1% were black. Participants excluded from the analysis (n = 200, 9.1%) were more likely to be male, black, a current smoker, and have a lower education and lower Short Physical Performance Battery scores at baseline ($P < .05$). The mean (SD) daily protein intake was 72 (27) g in men and 60 (22) g in women, or 0.91 (0.38) g/kg body weight/d. In the total sample, 27% consumed less than the EAR for protein (0.66 g/kg body weight/d) and 43% consumed less than the RDA (0.8 g/kg body weight/d). Similar proportions of men and women reported consuming less than the EAR (27.3 vs 26.5%) and the RDA (43.4% in both). However, blacks were more likely than whites to report consuming less than the EAR (34.3 vs 23.3%) and the RDA (49.7 vs 40.3%) ($P < .001$). Table 1 shows the descriptive characteristics of the study population by protein intake. Participants with a higher protein intake were older, more likely to be white and a current smoker, less likely to be sedentary, consume no alcohol, or have diabetes or knee pain, and have a lower BMI and a higher HEI score. Participants with a higher protein intake also had a higher percent lean mass and lower percent fat mass than those with lower intakes.

Of the 1,998 participants, 705 reported having mobility limitation over 6.2 years of follow-up for a cumulative incidence of mobility limitation of 45.5%. The cumulative incidence of mobility limitation was higher in men than in women (47.4% vs. 42.8%, $P = .02$) and in blacks than in whites (53.3% vs. 40.8%, $P < .001$). The hazard ratios (95% confidence intervals) of incident mobility limitation by protein intake are shown in Table 2. Participants with protein intake in the lower two tertiles were at significantly increased risk of incident mobility limitation compared to those in the upper tertile in the minimally adjusted model. After adjusting for height, health behaviors and chronic conditions, the association between protein intake and risk of mobility limitation remained significant. To determine whether the association between protein intake and mobility limitation was mediated through lean mass, lean mass was added to the fully adjusted model; the association was attenuated but remained significant. Similar results were observed when fat mass was added to the model to account for the association between adiposity and mobility limitation. In gender and race stratified analyses, lower protein intake was significantly associated with incident mobility limitation in men, women, whites, and blacks in the minimally adjusted model; however, after adjusting for height, health behaviors and chronic conditions, the associations were attenuated and no longer significant in men. In models that also adjusted for lean mass, the associations were attenuated further and no longer significant in men or blacks. In models that adjusted for fat mass, the association between protein intake and mobility limitation was attenuated and no longer significant in any gender or race subgroup. Results were similar when protein intake was categorized using the RDA as the lower cut-point (0.8 and 1.0 g/kg body weight/d) and when protein was expressed per kg of lean mass but not when protein was expressed as percent of total energy intake (data not shown).

Participants with animal and vegetable protein intake in the lower two tertiles were at significantly increased risk of incident mobility limitation compared to those with intakes in the upper tertile in the minimally adjusted model (Table 3). After adjusting for height, health behaviors and chronic conditions, the association between animal and vegetable protein intake and risk of mobility limitation remained significant. Further adjustment for lean or fat mass attenuated the results but the associations remained significant for animal protein. In gender and race stratified analyses, lower animal and vegetable protein intake was significantly associated with incident mobility limitation in men, women, whites, and blacks in the minimally adjusted model; however, after adjusting for height, health behaviors and chronic conditions, the associations were attenuated and no longer significant in men (data not shown).

DISCUSSION

Lower protein intake was associated with greater risk of incident mobility limitation over 6 years of follow-up among initially well-functioning, community-dwelling black and white older adults. After adjusting for demographics, health behaviors and chronic conditions, there was almost a two-fold greater risk of mobility limitation among older adults in the lowest tertile of protein intake (<0.7 g/kg body weight/d) and a 50% greater risk of mobility limitation among older adults with protein intakes in the middle tertile (0.7 to <1.0 g/kg body weight/d) compared to those with protein intakes in the upper tertile (≥1.0 g/kg body weight/d). Lean mass appeared to

Table 1. Descriptive Baseline Characteristics by Protein Intake: The Health ABC study, 1998–1999[a]

	Total sample	Dietary Protein Intake (g protein/kg body weight)			P for trend
		<0.70 g/kg	0.70–<1.00 g/kg	≥1.00 g/kg	
n	1998	644	666	688	
Age	74.6 (0.1)	74.3 (0.1)	74.6 (0.1)	74.8 (0.1)	0.02
Female gender (%)	48.8	48.0	47.9	50.3	0.39
Memphis, TN (%)	49.0	53.0	47.9	46.2	0.01
Black race (%)	33.1	40.8	26.9	32.0	0.001
<HS education (%)	19.3	21.9	17.3	18.9	0.18
Current smoker (%)[b]	7.7	5.9	6.6	10.5	0.002
Alcohol consumption (%)					
None in past year	59.9	63.4	59.6	56.8	0.001
≤7 times/week (%)	29.9	28.7	31.2	29.8	
>1 time/d (%)	10.2	7.9	9.2	13.4	
BMI (kg/m^2)	26.8 (0.1)	28.9 (0.2)	26.7 (0.2)	24.9 (0.2)	<0.001
Body weight (kg)	74.7 (0.3)	81.4 (0.6)	74.5 (0.5)	68.9 (0.5)	<0.001
Physical activity (%)					
0 min/week	34.8	40.4	32.0	32.3	<0.001
1–149 min/week	32.8	33.1	33.0	32.3	
≥150 min/week	32.4	26.6	35.0	35.5	
Cognitive function (3MS score)[b]	91.3 (0.2)	90.9 (0.3)	92.0 (0.3)	91.0 (0.3)	0.01
Depression (CES-D > 15; %)[b]	4.1	3.4	4.2	4.6	0.26
Diabetes (%)	17.6	20.6	16.5	15.8	0.02
CVD (%)	24.7	25.9	26.1	22.1	0.10
COPD (%)	11.4	12.6	10.1	11.6	0.60
Knee pain (%)	21.3	24.8	19.4	19.9	0.03
Hospitalizations in past year (%)	12.3	12.7	9.6	14.4	0.33
Oral steroids (%)	2.4	3.4	2.0	2.0	0.11
eGFR,[b] mL/minute/1.73 m^2	72.7 (0.3)	72.7 (0.6)	72.1 (0.6)	73.4 (0.6)	0.24
IL-6 (pg/mL)	3.3 (0.1)	3.4 (0.1)	3.3 (0.1)	3.1 (0.1)	0.38
Body composition					
Lean mass (kg)	46.7 (0.2)	49.5 (0.4)	46.5 (0.4)	44.2 (0.4)	<0.001
Percent lean mass (%)	62.6 (0.2)	60.8 (0.3)	62.4 (0.3)	64.4 (0.3)	<0.001
Fat mass (kg)	25.8 (0.2)	29.6 (0.3)	25.8 (0.3)	22.4 (0.3)	<0.001
Percent fat mass (%)	34.4 (0.2)	36.3 (0.3)	34.6 (0.3)	32.5 (0.3)	<0.001
Dietary intake					
Total energy (kcals/d)	1849 (14)	1348 (19)	1816 (19)	2348 (19)	<0.001
Fat (% energy)	33.1 (0.2)	32.5 (0.3)	32.8 (0.3)	33.9 (0.3)	0.002
Carbohydrate (% energy)	53.4 (0.2)	55.2 (0.3)	53.8 (0.3)	51.4 (0.3)	<0.001
Protein (% energy)	14.5 (0.1)	13.4 (0.1)	14.4 (0.1)	15.6 (0.1)	<0.001
Protein (g/kg body weight/d)	0.91 (0.01)	0.54 (0.01)	0.85 (0.01)	1.32 (0.01)	<0.001
Protein (g/kg lean mass/d)	1.46 (0.01)	0.90 (0.01)	1.37 (0.01)	2.06 (0.02)	<0.001
Protein (g/d)	66.2 (0.6)	44.0 (0.7)	63.1 (0.7)	89.8 (0.6)	<0.001
Animal protein (g/d)	38.0 (0.4)	23.6 (0.6)	35.5 (0.6)	54.0 (0.6)	<0.001
Vegetable protein (g/d)	28.2 (0.2)	20.4 (0.4)	27.7 (0.4)	35.9 (0.4)	<0.001
HEI score	70.3 (0.3)	66.8 (0.5)	72.3 (0.4)	71.5 (0.4)	<0.001

Abbreviations: 3MS = Modified Mini-Mental State Examination; BMI = body mass index; CES-D = Center for Epidemiologic Studies Depression Scale; COPD = chronic obstructive pulmonary disease; CVD = cardiovascular disease; eGFR = estimated glomerular filtration rate; HEI = Healthy Eating Index.
[a]Means (standard errors) or frequencies with chi-square or analysis of variance (ANOVA) to evaluate the distribution across categories of dietary protein intake.
[b]Smoking status, depressive symptoms, cognitive function, and eGFR assessed in 1997–1998.

partially mediate the association between protein intake and mobility limitation, particularly in men and blacks.

Some observational studies have shown that that lower protein intake is associated with greater declines in physical performance and strength in older adults.[17–20] In the Women's Health Initiative, older women with higher protein intakes had smaller declines in grip strength and repeated chair stands; however, there was no association between protein intake and change in gait speed.[18] Among older women in the Osteoporosis Risk Factor and Prevention Fracture Prevention Study, higher protein intake was associated with less decline in grip strength but was not associated with change in gait speed.[20] Higher protein intake was also associated with less decline in grip strength among older adults in the Framingham Offspring cohort.[19] In the InCHIANTI study, lower protein intake was associated with greater decline in knee extension strength only in older adults with high levels of inflammation.[17] Other studies, however, have not observed an association with dietary protein intake and change in physical performance[15] or strength.[15,21] Furthermore, little is known about the association between protein intake and subjective measures of physical function. In the Women's Health Initiative, older women with higher protein intakes had a

Table 2. Incident Mobility Limitation (HR (95% CI)) by protein intake: The Health ABC Study

	Dietary Protein Intake (g protein/kg body weight)			
	<0.70 g/kg	0.70–<1.00 g/kg	≥1.00 g/kg	*P* for trend
Overall (n = 1998)				
n	644	666	688	
Partial model	2.07 (1.60–2.67)	1.50 (1.22–1.85)	1.00	<0.001
Full model	1.86 (1.41– 2.44)	1.49 (1.20–1.84)	1.00	<0.001
Full model with total lean mass	1.39 (1.03– 1.87)	1.30 (1.05–1.62)	1.00	0.02
Full model with total fat mass	1.34 (1.00–1.81)	1.27 (1.02–1.58)	1.00	0.04
Men (n = 1024)				
n	335	347	342	
Partial model	1.73 (1.19–2.53)	1.41 (1.04–1.90)	1.00	0.004
Full model	1.41 (0.95–2.11)	1.45 (1.06–1.97)	1.00	0.06
Full model with total lean mass	1.17 (0.77–1.79)	1.32 (0.96–1.81)	1.00	0.35
Full model with total fat mass	1.28 (0.84–1.94)	1.38 (1.01–1.89)	1.00	0.18
Women (n = 974)				
n	309	319	346	
Partial model	2.50 (1.74–3.58)	1.62 (1.21– 2.17)	1.00	<0.001
Full model	2.54 (1.73–3.74)	1.70 (1.26– 2.28)	1.00	<0.001
Full model with total lean mass	1.71 (1.11–2.62)	1.42 (1.05– 1.93)	1.00	0.01
Full model with total fat mass	1.49 (0.96–2.30)	1.32 (0.97– 1.80)	1.00	0.06
Whites (n = 1336)				
n	381	487	468	
Partial model	2.16 (1.54–3.02)	1.55 (1.19–2.02)	1.00	<0.001
Full model	1.83 (1.26–2.65)	1.46 (1.11–1.92)	1.00	0.001
Full model with total lean mass	1.56 (1.05–2.33)	1.37 (1.03–1.80)	1.00	0.02
Full model with total fat mass	1.33 (0.88–2.02)	1.28 (0.96–1.69)	1.00	0.12
Blacks (n = 662)				
n	263	179	220	
Partial model	2.05 (1.37–3.08)	1.50 (1.06–2.12)	1.00	<0.001
Full model	1.97 (1.28–3.02)	1.56 (1.09–2.24)	1.00	0.002
Full model with total lean mass	1.26 (0.80–2.00)	1.25 (0.87–1.80)	1.00	0.29
Full model with total fat mass	1.44 (0.92–2.25)	1.30 (0.90–1.87)	1.00	0.11

Abbreviations: CI = confidence interval; COPD = chronic obstructive pulmonary disease; CVD = cardiovascular disease; HEI = Healthy Eating Index; HR = hazard ratio.

Partial model adjusted for: age, gender, race, education, study site, and energy intake.

Full model adjusted for: age, gender, race, education, study site, energy intake, smoking status, alcohol consumption, HEI score, height, physical activity, cognition, depressive symptoms, diabetes, CVD, COPD, knee pain, kidney function, oral steroids, IL-6, and hospitalizations in past year.

slower rate of self-reported physical function decline over 11.5 years as assessed by the Short Form-36, which includes items on climbing stairs and walking different distances.[18] In Health ABC, we observed a greater risk of mobility limitation over 6 years of follow-up in older adults with lower protein intakes.

In subgroup analysis, the association between protein intake and mobility intake differed by gender and race, particularly after adjusting for body composition. While women and whites with lower proteins intakes were at greater risk of mobility limitation even after adjusting for lean mass, the associations, although in the same direction, were attenuated and not significant in men and blacks after adjusting for lean mass. This may be due to differences in body composition by gender and race.[28] However, inferences about subgroup differences should be made with caution as interactions between gender and protein intake and race and protein intake were not significant.

In comparison to vegetable proteins which tend to be deficient in one or more essential amino acids, protein from animal sources provide all essential amino acids and is a source of high biological value protein. However, few studies have examined the effect of protein source on physical function in older adults. Higher animal, but not vegetable, protein intake was associated with less decline in grip strength among older adults in the Framingham Offspring cohort.[19] In Health ABC, lower animal and vegetable protein intake was associated with greater risk of mobility limitation. After further adjusting for lean mass, individuals with lower animal, but not vegetable, protein intake remained at greater risk of mobility limitation. Thus, higher animal protein intake may play a role in physical function beyond maintenance of lean mass, such as improving skeletal muscle quality; however, additional studies are needed to clarify the role of protein source on physical function.

The current RDA for dietary protein in adults (0.8 g/kg body weight/d) is based predominately on short-term nitrogen balance,[10] not on the maintenance of physical function.[11] While some have suggested that the RDA for dietary protein is too low for older adults;[11,12,29,30] others maintain that the RDA does not differ for young vs. older adults.[10,31] In the Health ABC cohort, participants in the lower two tertiles of protein intake were at greater risk of incident mobility limitation over 6 years of follow-up compared to participants in the upper tertile. Similar results were

Table 3. Incident Mobility Limitation (HR (95% CI)) by Animal and Vegetable Protein Intake: The Health ABC Study (n = 1998)

	Dietary Protein Intake (g protein/kg body weight)			
	Tertile 1	Tertile 2	Tertile 3	*P* for trend
Animal protein				
Tertile cutoffs	<0.38 g/kg	0.38–<0.58 g/kg	≥0.58 g/kg	
n	672	655	671	
Partial model	1.74 (1.38–2.18)	1.54 (1.25–1.88)	1.00	<0.001
Full model	1.65 (1.29–2.11)	1.50 (1.22–1.84)	1.00	<0.001
Full model with total lean mass	1.38 (1.07–1.78)	1.39 (1.13–1.71)	1.00	0.006
Full model with total fat mass	1.38 (1.07–1.78)	1.35 (1.09–1.66)	1.00	0.007
Vegetable protein				
Tertile cutoffs	<0.30 g/kg	0.30–<0.43 g/kg	≥0.43 g/kg	
n	677	640	681	
Partial model	2.01 (1.56–2.59)	1.48 (1.20–1.82)	1.00	<0.001
Full model	1.77 (1.35–2.32)	1.36 (1.09–1.69)	1.00	<0.001
Full model with total lean mass	1.28 (0.95–1.73)	1.15 (0.92–1.44)	1.00	0.11
Full model with total fat mass	1.23 (0.91–1.67)	1.12 (0.89–1.41)	1.00	0.18

Abbreviations: CI = confidence interval; COPD = chronic obstructive pulmonary disease; CVD = cardiovascular disease; HEI = Healthy Eating Index; HR = hazard ratio.

Partial model adjusted for: age, gender, race, education, study site, energy intake, and animal or vegetable protein intake.

Full model adjusted for: age, gender, race, education, study site, energy intake, animal or vegetable protein intake, smoking status, alcohol consumption, HEI score, height, physical activity, cognition, depressive symptoms, diabetes, CVD, COPD, knee pain, kidney function, oral steroids, IL-6, and hospitalizations in past year.

observed when protein intake was categorized using established cut-points of 0.8 and 1.0 g/kg body weight/d (data not shown). Thus, our results suggest that protein intakes higher than the current RDA (e.g., ≥1.0 g/kg body weight/d) may be optimal for maintaining physical function.

The strengths of the Health ABC study are that it is a large study of community-dwelling older adults with excellent retention who were extensively characterized providing an unusually rich set of relevant covariates. However, there are important characteristics of Health ABC which limit the generalization of these findings. Participants were recruited to be well-functioning and free of mobility limitation at baseline; thus, these results may not be generalizable to the general older population. Another limitation is the use of self-reported mobility limitation as the primary end point. However, previous studies have shown that self-reported limitations in mobility are valid and have clinical significance.[32] Furthermore, the use of two consecutive reports of mobility limitation reduces the influence of transient mobility limitation. A single, 108-item food frequency questionnaire was used to characterize usual intake of food. Although food frequency questionnaires provide an imprecise estimate of absolute nutrient intake and are prone to systematic bias,[33] they are able to accurately distinguish between individuals with relatively low versus high nutrient intakes. Since dietary intake was assessed at just one time point in Health ABC, we are unable to account for changes in diet that may occur over time. Lastly, the observational nature of this study does not allow us to evaluate a causal association between protein intake and mobility limitation.

To our knowledge, this is the first longitudinal cohort study to examine the role of protein intake on incident mobility limitation. In the Health ABC cohort, lower protein intake was associated with greater risk of mobility limitation. This association appeared to be partially mediated by lean mass. While we cannot establish a causal association, these results suggest that low protein intake may be a modifiable risk factor for mobility limitation, and impaired physical function in general, and that protein intakes of ≥1.0 g/kg body weight/d may be optimal for maintaining physical function in older adults. Thus, dietary protein should be further investigated for its potential to attenuate the age-related loss of physical function in older adults.

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