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Original article

Comparison of protein intake per eating occasion, food sources of protein and general characteristics between community-dwelling older adults with a low and high protein intake

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SUMMARY

Background & aims: Adequate protein intake is required to maintain muscle health in old age, but a low protein intake is very common in older adults. There is little insight in the general and dietary profile of older adults with a low protein intake. Therefore, this study aimed to compare community-dwelling older adults with a low and a high protein intake with regard to protein intake per eating occasion, food sources of protein and general participant characteristics.

Methods: Data were used from 727 Dutch community-dwelling older adults aged ≥70 years. Protein intake at meal and snack moments was measured with two non-consecutive dietary record assisted 24-h recalls. Low protein intake was defined as below the Recommended Dietary Allowance of 0.8 g protein per kg adjusted body weight per day (g/kg aBW/d). Differences in protein and food intakes between those with a low and a high protein intake were assessed with the Mann–Whitney *U* test and Chi-square test. Eating occasions were compared with regard to differences between the low and high protein intake group by using MANOVA. Characteristics of older adults with low protein intake were selected by using a multiple logistic backward elimination procedure.

Results: Low protein intake was present in 15% of the participants. At all eating occasions, median protein intake was lower in the low compared to the high protein intake group (breakfast, 7.8 vs. 10.8 g; lunch, 12.6 vs. 24.3 g; dinner, 21.8 vs. 31.1 g; snack moments, 6.7 vs. 9.7 g; $P < 0.001$), and was also consistently lower relative to energy intake. The contribution of animal protein to total protein intake was lower among the low protein intake group. Both groups obtained most protein from dairy, meat and cereals, but meat contributed less (21.5 vs. 28.2%) and cereals more (21.9 vs. 19.6%) among the low than the high protein intake group (all $P < 0.01$). Differences in protein intake, percentage of energy from protein and contribution of animal to total protein intake between the groups were largest at lunch compared to the other eating occasions. Out of a long list of variables, low protein intake was only associated with following a diet, being obese vs. normal-weight and drinking alcohol on none vs. some but <5 days/week ($P < 0.05$).

Conclusions: At all eating occasions, Dutch community-dwelling older adults with a protein intake <0.8 g/kg aBW/d ate less protein (also relative to their energy intake) and a lower proportion of animal protein compared to those with a high protein intake. These differences were largest at lunch. Major food sources of protein – in both groups – were dairy, meat and cereals. We could only identify following a diet, being obese and not drinking alcohol as general characteristics of older adults with a low protein intake.

Abbreviations: aBW, adjusted body weight; BMI, Body Mass Index; CI, confidence interval; DNFCS, Dutch National Food Consumption Survey; IQR, interquartile range; OR, odds ratio; RDA, Recommended Dietary Allowance; SNAQ^{65+}, Short Nutritional Assessment Questionnaire 65+.

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1. Introduction

A substantial proportion of community-dwelling older adults has a protein intake that is below the current Recommended Dietary Allowance (RDA) of 0.8 g per kilogram body weight per day (g/kg BW/d) [1,2]. To illustrate, the prevalence of low protein intake (i.e., <0.8 g/kg BW/d) was 28% in community-dwelling older adults aged ≥85 years from the UK [3] and 40% in those aged 71–80 years from the US [4].

Previous studies among community-dwelling older adults have shown that lower protein intake is associated with a higher risk of weight loss [5], a greater loss of lean mass over three years [6] and a higher risk of mobility limitations over six years [7]. Especially in old age when muscle mass tends to decline due to an impaired anabolic response to ingested protein and less physical activity [8,9], adequate protein intake is essential to maintain muscle health. Maintenance of muscle health is of great importance for prevention or delay of sarcopenia, disability and mortality [9–11].

In addition to the daily quantity of protein, the amount of protein consumed at one eating moment and its quality are suggested to be important for muscle protein synthesis [10,12–14]. There are some, although weak, indications that an evenly distributed protein intake throughout the day is more effective in stimulating muscle protein synthesis compared to a skewed distribution [13,15]. It is also assumed that animal proteins are more strongly associated with muscle health than vegetable proteins [6,16]. This is likely a result of the higher quality, i.e., higher digestibility and better composition of essential amino acids, of protein from animal than from vegetable sources [17].

The substantial relevance of protein for muscle health and its modifiable nature would make protein intake an appropriate target for interventions aimed at optimizing muscle health. Therefore, older adults with a low protein intake need to be clearly portrayed. Protein intake distribution and food sources of protein among Dutch [18], Spanish [19] and US [20] older adults have been described previously, but no distinction was made between those with a high vs. low protein intake. Recently, Mendonça and colleagues [3] described participant characteristics, protein intake per eating occasion and contribution of food groups to total protein intake according to a low and a high protein intake, but in very old adults (≥85 years) from the UK only.

There is little insight in the general profile, i.e., socio-demographic, lifestyle and health characteristics, and dietary profile, i.e., timing and quality of protein intake, of Dutch older adults with a low protein intake. Therefore, this study aimed to compare community-dwelling older adults aged ≥70 years from the Netherlands with a low and a high protein intake with regard to protein intake per eating occasion, food sources of protein and general participant characteristics.

2. Materials and methods

2.1. Study population

Data for the present study were obtained from the Dutch National Food Consumption Survey (DNFCS)-Older Adults 2010–2012, a nationwide cross-sectional study investigating the diet of community-dwelling older adults aged ≥70 years in the Netherlands. Detailed information on study design and data collection has been described previously [21]. In short, data were collected from October 2010 to February 2012 in 15 municipalities of five different regions in the Netherlands. A total of 3138 older adults were invited to participate, of whom 290 people were not eligible for the following reasons: being institutionalized, using tube feeding or parenteral feeding, having a high-intensity care package, being terminally ill, having no adequate command of the Dutch language or having insufficient cognitive abilities. Of the 2848 eligible older adults, 1624 people refused to participate and 485 people did not respond. Finally, 739 participants were included in the DNFCS-Older Adults 2010–2012. All participants signed informed consent. The Ethics Committee of University Medical Centre Utrecht approved the study protocol.

For the present study, an additional 12 participants had to be excluded due to missing data on body weight, leaving 727 participants for the analytical sample.

2.2. Dietary intake

Dietary intake was measured by means of two non-consecutive dietary record assisted 24-h recalls by trained dieticians. They performed face-to-face interviews during home visits by using the computer directed interview program EPIC-Soft© [22,23]. The two 24-h dietary recalls took place within a period of two to six weeks, with a mean interval of four weeks. Consumption on Sunday to Friday was recalled the next day, while consumption on Saturday was recalled on the following Monday. On the day to be recalled participants filled in a food diary, which was used as a memory aid during the 24-h recall and as a check for the use of household measures to indicate consumption amounts at home. Food products were grouped into 17 food groups [24]. Intakes of energy and nutrients were calculated using an extended version of the Dutch Food Composition Table of 2011 [25].

Dietary intake per individual was calculated as the average intake of the two days assessed. Energy intake was expressed in kcal/d. Total protein intake was expressed in g/d, in percentage of energy per day (En%) and in g/kg body weight (BW)/d. For participants with a Body Mass Index (BMI) outside the healthy range of 18.5–25.0 kg/m^2 for adults aged <71 years or 22.0–27.0 kg/m^2 for adults aged ≥71 years, adjusted body weight (aBW) instead of actual body weight was used. Adjusted body weight is the nearest body weight that would place the participant with an undesirable body weight in the healthy BMI range [20]. Low protein intake was defined as a protein intake below the RDA of 0.8 g/kg BW/d. In addition to daily total protein intake, we expressed intakes (g/d) of animal and vegetable protein, protein intake (g/d) obtained from certain food sources and protein intake (g/d) per eating occasion (breakfast, lunch, dinner and snack moments). Lunch was defined as the meal consumed around noon and was not necessarily a cold meal, while dinner was defined as the main meal consumed in late afternoon or evening and was not necessarily a hot meal. Protein consumed during the snack moments in the morning, afternoon and evening were summed.

2.3. General participant characteristics

Participants were visited at home by a trained dietician twice. During the first home visit, baseline data on socio-demographic, lifestyle, health and diet-related factors were collected by means of a general questionnaire. During one of the two home visits, anthropometric measures were performed following standardized protocols.

2.3.1. Socio-demographic factors

Highest educational level attained was categorized into ‘low’ (primary, lower vocational, or advanced elementary education), ‘intermediate’ (intermediate vocational or higher secondary education) and ‘high’ (higher vocational education or university). Income status was categorized into ‘low’ (<950 euro or <1300 euro when more than one person in the household) or ‘moderate/high’. Participants with missing information on household income were classified as 'low income' when they had old age pension only and as 'moderate income' when they had supplementary pension. Native country was categorized into 'Dutch origin' and 'Not of Dutch origin'. Having a partner was categorized into 'having a partner (inside or outside the household)' or 'not having a partner'. Living independently was categorized into 'living fully independently' (e.g., single-family dwelling, detached house, apartment, flat) or 'living in a home especially intended for older people' (e.g., service flat, elderly commune, living self-reliant near a rest home).

2.3.2. Lifestyle factors

Smoking was categorized into 'never', 'former' and 'current'. Physical activity level was assessed by asking how many days per week the participant performed at least 30 min of moderately intensive physical activity, both in summer and during the rest of the year, taken from the SQUASH (Short QUestionnaire to ASses Health-enhancing physical activity) for adults [26]. Level of physical activity was categorized into 'inactive' (0 days), 'semi-active' (0.5–4.5 days) or 'norm-active' (5 days or more; this latter category refers to the Dutch recommendation for healthy physical activity [27]). The frequency of alcohol consumption was asked for in the general questionnaire and categorized into 'no alcohol', '<1 day/week', '1–5 days/week' and '6–7 days/week'.

2.3.3. Health factors

The presence of chronic diseases was assessed by asking if the participant had any of 17 diseases (e.g., stroke, cancer, osteoporosis) in the past 12 months [21]. Three groups were distinguished according to the number of chronic diseases: 0, 1 and ≥2.

2.3.4. Diet-related factors

The frequency with which a hot meal was prepared by the participant or someone else from the household was categorized into 'never or <1 day/week', '1–4 days/week' and '≥5 days/week'. The frequency with which a hot meal was taken from a company was categorized into '<1 day/week' and '≥1 day/week'. Whether a diet was followed on recall days was asked for 17 diets (e.g., diabetes, energy and/or protein enriched, vegetarian) [21]. Eating difficulties were self-reported and categorized into 'no difficulty' and 'some or great difficulty'. Data on (self-reported) unintentional weight loss, poor appetite and difficulty walking stairs were obtained from the SNAQ^{65+} (Short Nutritional Assessment Questionnaire 65+), a screening tool for determining (risk of) undernutrition in community-dwelling older adults [28]. Unintentional weight loss was assessed by asking if the participant unintentionally lost ≥4 kg within the past six months (yes/no). If unknown, participants were asked if clothes became too big, the belt had to be tightened recently, or the watch became looser around the wrist (yes/no). Poor appetite in the past week (yes/no) was self-reported. Difficulty walking stairs was assessed by asking if the participant could walk up and down a staircase of 15 steps without resting (yes, no, wheelchair user, unknown). If unknown, participants were asked for their ability to walk outside for 5 minutes without resting (yes/no).

2.3.5. Anthropometric measurements

Body weight was measured to the nearest 0.1 kg by using a calibrated weighing scale. Body height was measured to the nearest 0.1 cm by using a wall-mounted stadiometer. If a participant was not able to stand upright or had kyphosis or scoliosis, no measurement of body height was taken. Mid-upper arm circumference (MUAC) was measured by a dietician once on the non-dominant arm at the midpoint between the acromion and the olecranon with a flexible tape meter while the participant was in standing position and had the arm hanging loose. MUAC was measured to an accuracy of 0.1 cm and categorized into <25 and ≥25 cm. Body height and body weight were adjusted for wearing shoes (corrections of 20–29 mm for body height, depending on the height of the shoes; corrections of 0.5 kg for body weight). MUAC was adjusted for wearing clothes (corrections of 5–20 mm). BMI was calculated as body weight (in kg) divided by body height (in m) squared (kg/m^2) and categorized into <22, 22–25, 25–30 and ≥30 kg/m^2.

2.4. Statistical analyses

Continuous non-normally distributed variables were presented as median with interquartile range (IQR) and categorical variables as frequency (*n* (%)). Differences between individuals with a low and a high protein intake were tested by means of the Mann–Whitney *U* test for continuous non-normally distributed variables and the Chi-square test for proportions. Whether differences in protein intake (g/d), percentage of energy from protein (En%) and relative contribution of animal to total protein intake (%) between both groups differed per eating occasion was tested by means of MANOVA. Associations of participant characteristics with low protein intake (i.e., <0.8 g/kg aBW/d) were examined by univariate logistic regression analysis. Linearity of the association between each continuous variable and low protein intake was checked by adding a quadratic term to the model. The presence of multicollinearity among the independent variables was checked by using the Variance Inflation Factor. If this factor was ≤10, multicollinearity was considered weak [29]. All determinants associated ($P < 0.20$) with low protein intake in the univariate analyses were included in the multivariate model, except for those for which the statistically significant category included less than ten participants. We did not include any a priori selected variables. Subsequently, a backward elimination procedure was followed until all remaining variables in the model were associated with low protein intake using a statistical significance level of $P < 0.10$. Effect modification by age (stratified on sample median of 76 years) and sex were checked by adding interaction terms to the univariate models. In case of statistically significant interaction by age or sex ($P < 0.05$), interaction terms were added to the final multivariate model, except for the variables for which stratifying resulted in less than ten participants in a category. Analyses were performed by using SPSS Statistics version 24.0 (IBM Corp., Armonk, NY, USA).

3. Results

Median age of the participants was 76 years, 49.4% were female and 95.6% were from Dutch origin (Table 1). Most participants had a partner (61.5%) and lived fully independently (88.6%). Almost 80% met the Dutch norm for healthy physical activity and 30.9% were free of chronic diseases. Protein intake <0.8 g/kg aBW/d was observed in 15.4% of the participants.

On average, daily energy intake was lower among individuals with a low compared to a high protein intake (median (IQR): 1523 (1310–1783) vs. 1997 (1740–2309) kcal/d). Median (IQR) total protein intake among those with a low and a high protein intake was 52.7 (43.9–59.2) and 78.7 (68.4–90.0) g/d), respectively, which is equal to 0.7 (0.7–0.8) and 1.1 (0.9–1.2) g/kg aBW/d.

3.1. Protein intake per eating occasion

Individuals with a low protein intake consistently ate less protein (g/d) at all eating occasions (Fig. 1). They also had a lower protein intake relative to their energy intake (En%) at all eating occasions (N.S. for breakfast) (Fig. 2) and obtained less protein from animal sources (N.S. for breakfast and dinner) (Fig. 3). The difference in absolute protein intake between those with a low and a

Table 1
Characteristics of the community-dwelling older adults of the DNFCS-Older adults 2010–2012, according to a low and a high protein intake.[a]

	Valid *n*	Total sample	Low protein intake	High protein intake
Number of participants		*727*	*112*	*615*
Age (years)	727	76 (73–80)	76 (73–80)	76 (73–80)
Female gender	727	359 (49.4)	59 (52.7)	300 (48.8)
Education level	724			
Low		398 (55.0)	55 (49.1)	343 (56.0)
Intermediate		159 (22.0)	35 (31.3)	124 (20.3)
High		167 (23.1)	22 (19.6)	145 (23.7)
Low income	719	83 (11.5)	15 (13.6)	68 (11.2)
Dutch origin	727	695 (95.6)	105 (93.8)	590 (95.9)
Having a partner	727	447 (61.5)	76 (67.9)	371 (60.3)
Living fully independently	727	644 (88.6)	98 (87.5)	546 (88.8)
Smoking	727			
Never smoked		248 (34.1)	38 (33.9)	210 (34.1)
Former smoker		404 (55.6)	67 (59.8)	337 (54.8)
Current smoker		75 (10.3)	7 (6.3)	68 (11.1)
Physical activity	726			
Inactive: 0 days/week		27 (3.7)	8 (7.1)	19 (3.1)
Semi-active: 0.5–4.5 days/week		125 (17.2)	21 (18.8)	104 (16.9)
Normal active: ≥5 days/week		574 (79.1)	83 (74.1)	491 (80.0)
Alcohol consumption	727			
None		175 (24.1)	37 (33.0)	138 (22.4)
<1 day/week		111 (15.3)	12 (10.7)	99 (16.1)
1–5 days/week		192 (26.4)	24 (21.4)	168 (27.3)
6–7 days/week		249 (34.3)	39 (34.8)	210 (34.1)
Number of chronic diseases	727			
0		225 (30.9)	30 (26.8)	195 (31.7)
1		247 (34.0)	36 (32.1)	211 (34.3)
≥2		255 (35.1)	46 (41.1)	209 (34.0)
Some or great difficulties eating and drinking	726	27 (3.7)	5 (4.5)	22 (3.6)
Hot meals prepared by participant or someone else in household	726			
Never or <1 day/week		37 (5.1)	5 (4.5)	32 (5.2)
1–4 days/week		54 (7.4)	10 (8.9)	44 (7.2)
≥5 days/week		635 (87.5)	97 (86.6)	538 (87.6)
Uses home-delivered hot meals from company at least once a week	726	30 (4.1)	3 (2.7)	27 (4.4)
Followed a diet on recall days	727	150 (20.6)	33 (29.5)	117 (19.0)
Body Mass Index (kg/m^2)	727			
<22		41 (5.6)	3 (2.7)	38 (6.2)
22–25		152 (20.9)	18 (16.1)	134 (21.8)
25–30		381 (52.4)	56 (50.0)	325 (52.8)
≥30		153 (21.0)	35 (31.3)	118 (19.2)
Unintentional weight loss of ≥4 kg in past 6 months	726	51 (7.0)	7 (6.3)	44 (7.2)
Mid-upper arm circumference <25 cm	723	21 (2.9)	3 (2.7)	18 (2.9)
Poor appetite	727	32 (4.4)	5 (4.5)	27 (4.4)
Difficulties climbing stairs	723	79 (10.9)	17 (15.2)	62 (10.1)
Energy intake (kcal/d)	727	1939 (1663–2249)	1523 (1310–1783)	1997 (1740–2309)
Total protein intake (g/d)	727	75.0 (63.7–88.0)	52.7 (43.9–59.2)	78.7 (68.4–90.0)
Total protein intake (En%)	727	15.4 (13.6–17.4)	13.3 (12.0–15.0)	15.8 (14.0–17.7)
Total protein intake (g/kg aBW/d)	727	1.0 (0.9–1.2)	0.7 (0.7–0.8)	1.1 (0.9–1.2)
Animal protein intake (g/d)	727	47.0 (38.3–57.9)	30.2 (23.3–36.7)	49.9 (41.5–60.1)
Vegetable protein intake (g/d)	727	26.9 (22.1–32.8)	21.6 (17.3–25.6)	27.8 (23.1–34.0)

Data are presented as median (IQR) for continuous variables and as *n* (%) for categorical variables.
[a]Low protein intake: <0.8 g/kg aBW/d; high protein intake: ≥0.8 g/kg aBW/d. Adjusted body weight is the nearest body weight that would place the participant with an undesirable body weight in the healthy Body Mass Index range [20].
Abbreviations: aBW, adjusted body weight; DNFCS, Dutch National Food Consumption Survey.

high protein intake was greater at lunch and dinner compared to breakfast and snack moments (all $P < 0.001$). At lunch, also the difference between those groups with regard to percentage of energy from protein and relative contribution of animal to total protein intake was significantly greater compared to breakfast, dinner (En% only) and snack moments.

3.2. Food sources of protein

The food groups that contributed for at least 5% to protein intake are presented in Table 2. On a daily basis and across the three main eating occasions, the food groups dairy, meat (except breakfast) and cereals contributed most to protein intake among individuals with a low as well as a high protein intake. The magnitude of the relative contribution differed however. Individuals with a low protein intake obtained more protein relative to their total protein intake from cereals, which was most prominent at lunch (median: 34.4 vs. 29.7% among those with a high protein intake, $P < 0.01$). Individuals with a low protein intake obtained less protein relative to their total protein intake from meat, which was most prominent at dinner (32.3 vs. 40.6%, $P < 0.05$).

3.3. General characteristics of individuals with low protein intake

Univariate testing revealed seven variables that were associated ($P < 0.20$) with low protein intake (intermediate vs. high education level, having vs. not having a partner, alcohol consumption on 0 vs. <1 and 1–5 days/week, ≥2 vs. 0 chronic diseases, following vs. not following a diet, BMI of 22–25 vs. <22 kg/m^2 and difficulties vs. no difficulties walking stairs (Table 3).

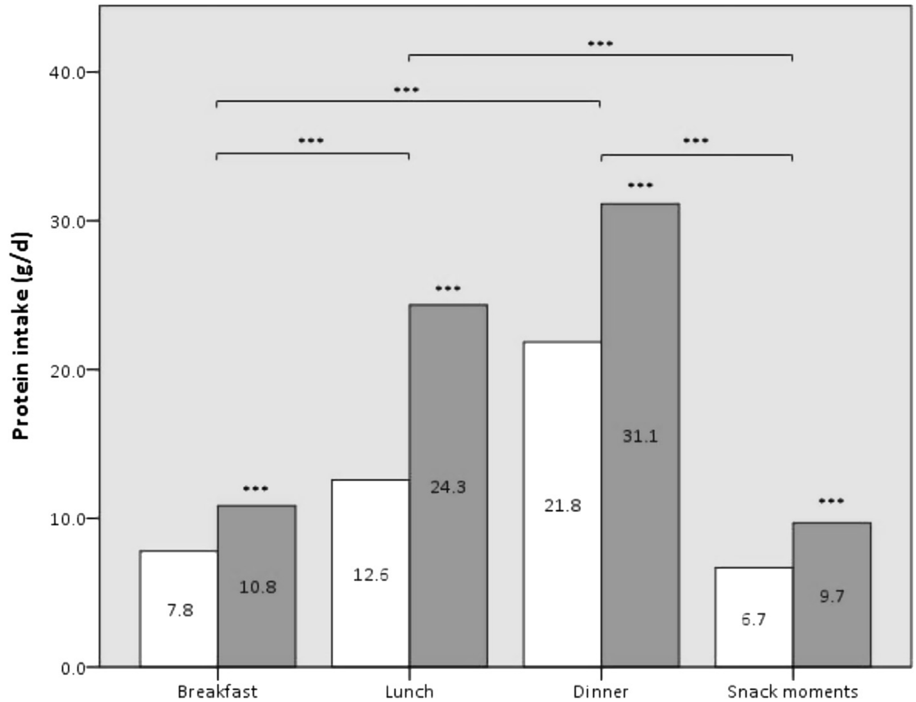

Fig. 1. Median protein intake (g/d) per eating occasion, according to a low (<0.8 g/kg aBW/d) and a high (≥0.8) protein intake. The white bars represent participants with a low protein intake ($n = 112$); the grey bars represent participants with a high protein intake ($n = 615$). *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$, statistically significant difference in protein intake between those with a low and a high protein intake (Mann–Whitney *U* test). The difference in protein intake between those groups was significantly higher at lunch and dinner compared to breakfast and snack moments (MANOVA; all $P < 0.001$).

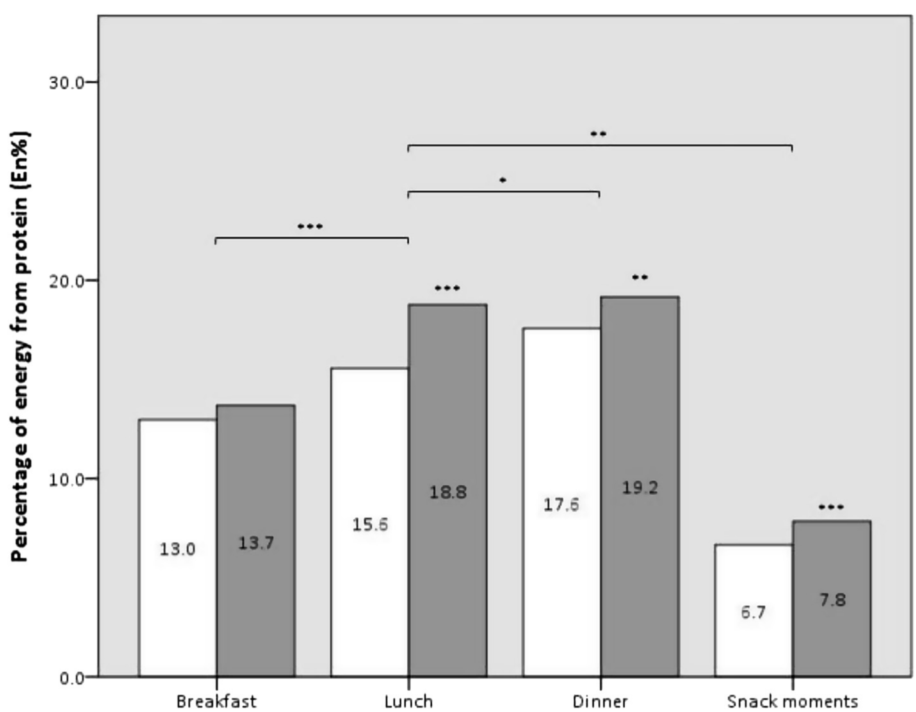

Fig. 2. Median percentage of energy from protein per eating occasion, according to a low (<0.8 g/kg aBW/d) and a high (≥0.8) protein intake. The white bars represent participants with a low protein intake ($n = 106$); the grey bars represent participants with a high protein intake ($n = 600$). *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$, statistically significant difference in energy percentage of protein between those with a low and a high protein intake (Mann–Whitney *U* test). The difference in energy percentage of protein between those groups was significantly higher at lunch compared to breakfast (MANOVA; $P < 0.001$), dinner ($P < 0.05$) and snack moments ($P < 0.01$).

These variables were included in the backward elimination procedure. Due to a very small number of participants ($n < 10$) in the statistically significant categories of physical activity and smoking, these variables were not included. Statistically significant interaction was observed with sex for the univariate association between smoking and low protein intake ($P = 0.048$ for

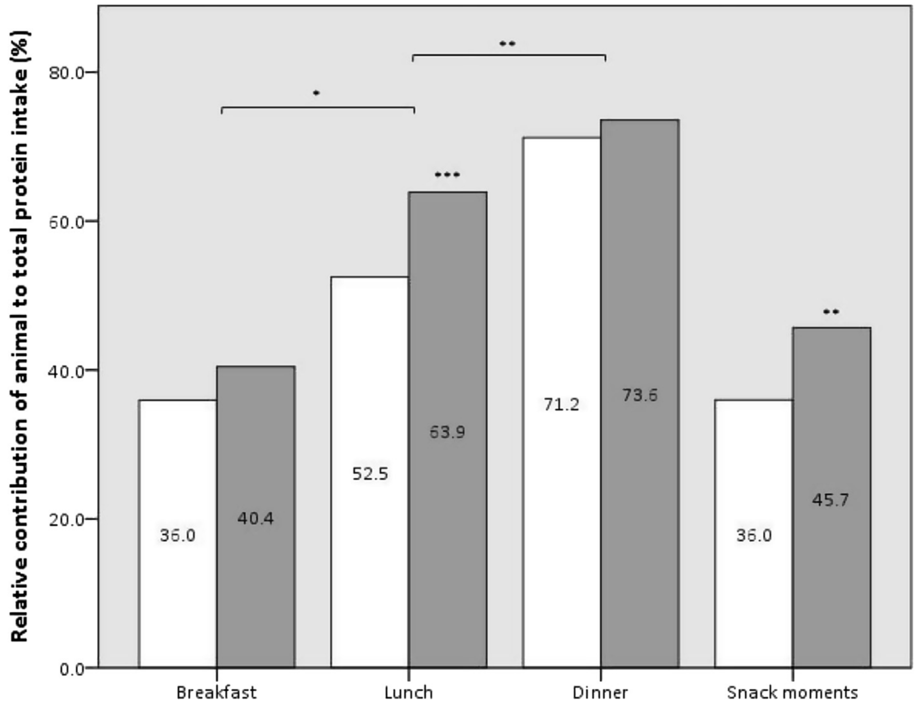

Fig. 3. Median relative contribution (%) of vegetable protein intake (g/d) to total protein intake (g/d) per eating occasion, according to a low (<0.8 g/kg aBW/d) and a high (≥0.8) protein intake. The white bars represent low protein intake ($n = 106$); the grey bars represent high protein intake ($n = 600$). $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$, statistically significant difference in relative contribution of animal to total protein intake between those with a low and a high protein intake (Mann–Whitney U test). The difference in relative contribution between those groups was significantly higher at lunch compared to breakfast (MANOVA; $P < 0.05$) and dinner ($P < 0.01$).

Table 2
Protein delivered by major food groups, presented per day and per eating occasion, in community-dwelling older adults of the DNFCS-Older adults 2010–2012, according to a low and a high protein intake.[a]

	Food group[b]	Low protein intake[a] ($n = 112$)			High protein intake[a] ($n = 615$)		
		% Users[c]	Protein delivered by food group (g/d)	Contribution to daily protein intake (%)[d]	% Users[c]	Protein delivered by food group (g/d)	Contribution to daily protein intake (%)[d]
Whole day	Dairy products	99.1	13.5 (8.3–17.9)[e]	25.4 (16.0–32.9)[e]	99.8	19.5 (13.5–25.5)	24.4 (17.5–30.9)
	Cereal products	99.1	10.8 (8.1–15.5)	21.9 (8.6–26.8)	100*	15.4 (11.7–19.4)	19.6 (15.3–24.1)**
	Meat products	92.9	11.2 (5.3–17.4)	21.5 (11.6–31.4)	96.6	21.9 (14.4–30.1)	28.2 (18.4–38.0)***
Breakfast	Cereal products	89.3	4.1 (1.8–6.5)	54.6 (35.4–73.5)	95.3*	5.3 (3.4–7.8)	49.7 (33.3–68.2)
	Dairy products	61.6	1.4 (0.0–5.4)	20.2 (0.0–53.3)	69.3	3.2 (0.0–6.6)	28.0 (0.0–48.7)
Lunch	Cereal products	85.7	3.7 (1.7–6.5)	34.4 (14.4–50.9)	84.7	5.8 (1.8–8.4)	29.7 (8.3–40.4)**
	Dairy products	73.2	3.1 (0.0–5.4)	24.4 (0.0–36.2)	88.6***	5.7 (3.1–9.4)	23.4 (12.4–40.0)
	Meat products	61.6	1.5 (0.0–5.0)	13.6 (0.0–33.6)	73.8*	3.0 (0.0–11.4)	14.9 (0.0–41.9)
Dinner	Meat products	79.5	7.0 (1.5–12.8)	32.3 (7.8–54.1)	87.2*	12.4 (3.0–21.8)	40.6 (14.1–62.7)*
	Dairy products	76.8	4.0 (0.3–5.5)	17.8 (1.1–28.3)	83.3	4.4 (1.5–7.2)	14.4 (4.5–25.9)
	Cereal products	70.5	1.9 (0.0–4.3)	10.2 (0.0–20.8)	73.3	2.9 (0.0–6.7)	9.1 (0.0–28.2)
	Potatoes, tubers	65.2	1.1 (0.0–2.0)	5.0 (0.0–7.7)	64.6	1.1 (0.0–2.5)	3.4 (0.0–6.9)
Snack moments	Cakes	84.8	1.5 (0.4–2.6)	25.3 (7.6–41.0)	88.8	1.9 (0.8–3.0)	17.5 (7.9–32.3)
	Dairy products	71.4	0.9 (0.0–4.0)	19.1 (0.0–43.4)	80.7*	2.4 (0.5–6.5)	26.8 (5.8–50.1)*
	Non-alcoholic drinks	94.6	0.7 (0.5–1.1)	12.1 (4.8–24.6)	95.1	0.8 (0.5–1.2)	8.1 (4.1–15.2)**
	Fruits, nuts, seeds	68.8	0.3 (0.0–1.0)	5.2 (0.0–17.3)	72.4	0.5 (0.0–1.4)	5.2 (0.0–15.4)

$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$, statistically significant difference between the individuals with a low compared to a high protein intake, as estimated with the Chi-square test (% users) or Mann–Whitney U test (contribution to daily protein intake).

[a] Low protein intake: <0.8 g/kg aBW/d; high protein intake: ≥0.8 g/kg aBW/d. Adjusted body weight is the nearest body weight that would place the participant with an undesirable body weight in the healthy Body Mass Index range [20].

[b] Food groups considered include: *1*) potatoes and other tubers; *2*) vegetables; *3*) legumes; *4*) fruits, nuts, and seeds; *5*) dairy products; *6*) cereals and cereal products; *7*) meat and meat products; *8*) fish and shellfish; *9*) eggs and egg products; *10*) fat; *11*) sugar and confectionary; *12*) cakes; *13*) non-alcoholic drinks; *14*) alcoholic drinks; *15*) dressing sauces; *16*) soups and bouillon; and *17*) miscellaneous.

[c] Proportion of participants consuming the presented food group.

[d] Contribution of protein intake derived from a certain food group to daily protein intake, calculated on individual level as protein intake from a certain food group (g) divided by daily protein intake (g) and multiplied by 100%.

[e] Values are presented as median (interquartile range) due to non-normally distributed data.

Abbreviations: aBW, adjusted body weight; DNFCS, Dutch National Food Consumption Survey.

former smoker vs. non-smoker), but disappeared in the final multivariate model. No multicollinearity was observed.

After the backward elimination procedure (until $P < 0.10$), the following characteristics were associated ($P < 0.05$) with a higher likelihood of a low protein intake: following a diet and being obese vs. normal-weight (BMI ≥30 vs. 22–25 kg/m^2). Alcohol consumption on <1 and on 1–5 vs. 0 days/week were both associated with a lower likelihood of a low protein intake.

4. Discussion

The present study among 727 Dutch community-dwelling older adults showed that 15% of the participants had a protein intake below the RDA of 0.8 g/kg BW/d. At all eating occasions, but most pronounced at lunch and dinner, individuals with a low protein intake consumed less protein than those with a high protein intake. At lunch, the greatest differences in percentage of energy from protein and contribution of animal protein between the groups were observed. Dominant food sources of protein were similar in the low and high protein intake group: dairy, cereals and meat. Low protein intake was associated with following a diet, being obese vs. normal-weight and drinking alcohol on none vs. some but <5 days/week.

The contribution of animal to total protein intake was lower among individuals with a low compared to a high protein intake at all eating occasions, but this was statistically significant only for lunch and snack moments. This finding is relevant as animal protein has a higher quality than vegetable protein [17]. A lower intake of animal protein is not necessarily less beneficial in terms of optimizing protein intake as long as sufficient amounts of vegetable protein from a variety of foods are consumed [17]. It becomes problematic when equal but small portions of animal or vegetable

Table 3
Univariate and multivariate associations of socio-demographic, lifestyle, health and diet-related factors with low protein intake in community-dwelling older adults from the DNFCS-Older adults 2010–2012.[a]

	Univariate		Multivariate	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Age (years)	1.01 (0.97–1.05)	0.573		
Male gender	0.86 (0.57–1.28)	0.448		
Education level				
Low	1.06 (0.62–1.80)	0.838	0.87 (0.50–1.53)	0.628
Intermediate	1.86 (1.04–3.34)	0.037	1.67 (0.92–3.04)	0.091
High	1.00		1.00	
Low income	1.26 (0.69–2.29)	0.456		
Dutch origin	0.64 (0.27–1.51)	0.304		
Having a partner	1.39 (0.91–2.13)	0.133		
Living fully independently	0.89 (0.48–1.63)	0.695		
Smoking				
Never smoked	1.00			
Former smoker, total	–			
Former smoker, men	0.65 (0.31–1.36)	0.251		
Former smoker, women	1.68 (0.94–2.99)	0.080		
Current smoker, total	–			
Current smoker, men	0.37 (0.11–1.26)	0.194		
Current smoker, women	0.71 (0.20–2.52)	0.600		
Physical activity				
Inactive: 0 days/week	2.49 (1.07–5.88)	0.037		
Semi-active: 0.5–4.5 days/week	1.20 (0.71–2.02)	0.506		
Normal active: ≥5 days/week	1.00			
Alcohol consumption				
None	1.00		1.00	
<1 day/week	0.45 (0.22–0.91)	0.026	0.45 (0.22–0.92)	0.030
1–5 days/week	0.53 (0.30–0.93)	0.028	0.56 (0.31–1.00)	0.050
6–7 days/week	0.69 (0.42–1.14)	0.149	0.70 (0.41–1.20)	0.196
Number of chronic diseases				
0	1.00			
1	1.11 (0.66–1.87)	0.698		
≥2	1.43 (0.87–2.36)	0.160		
Some or great difficulties eating and drinking	1.26 (0.47–3.39)	0.651		
Hot meals prepared by participant or someone else in household				
Never or <1 day/week	0.87 (0.33–2.28)	0.772		
1–4 days/week	1.26 (0.61–2.59)	0.528		
≥5 days/week	1.00			
Uses home-delivered hot meals from company ≥1 day/week	0.60 (0.18–2.02)	0.411		
Followed a diet on recall days	1.78 (1.13–2.80)	0.013	1.67 (1.04–2.67)	0.034
Body Mass Index (kg/m^2)				
<22	0.22 (0.03–1.81)	0.160	0.63 (0.17–2.28)	0.481
22–25	1.00		1.00	
25–30	0.96 (0.46–1.98)	0.906	1.36 (0.76–2.42)	0.301
≥30	1.40 (0.64–3.06)	0.400	2.35 (1.24–4.44)	0.009
Unintentional weight loss of ≥4 kg in past 6 months	0.86 (0.38–1.97)	0.727		
Mid-upper arm circumference <25 cm	0.91 (0.26–3.13)	0.877		
Poor appetite	1.02 (0.38–2.70)	0.972		
Difficulties walking or climbing stairs	1.59 (0.89–2.83)	0.119		

[a] Low protein intake: <0.8 g/kg aBW/d; high protein intake: ≥0.8 g/kg aBW/d. Adjusted body weight is the nearest body weight that would place the participant with an undesirable body weight in the healthy Body Mass Index range [20]. Abbreviations: aBW, adjusted body weight; CI, confidence interval; DNFCS, Dutch National Food Consumption Survey; OR, odds ratio.

foods are consumed, because a portion of an animal food contains on average more protein than a similar portion of a vegetable food. Our sample of older adults with a low protein intake seems to consume smaller portions with also a lower animal-to-vegetable protein ratio, and may therefore be at higher risk of protein insufficiency. In this respect, it is important to realize that expert groups suggest that 1.0–1.2 g/kg BW/d is required for optimal stimulation of muscle protein synthesis in older adults [8,11,12]. For that reason, a protein intake below 0.8 g/kg BW/d might be even more problematic than is currently thought.

Dairy, cereals and meat contributed most to daily protein intake in both the low and the high protein intake group, which was similar to findings among UK [3], Spanish [19] and US [20] older adults. However, the magnitude of this (relative) contribution differed between the groups: those with a low protein intake obtained relatively less protein from meat, but more from cereals than those with a high protein intake. The same differences in meat and cereal consumption were found in the Newcastle 85 + Study [3]. Although those with a low protein intake reported higher cereal consumption than those with a high protein intake, this difference might be too small to compensate for the higher amount of protein in a portion of meat than in a similar portion of cereals. This emphasizes the importance of the source of protein in future intervention strategies.

Following a diet was associated with a higher likelihood of a low protein intake, but the association disappeared after adjusting for total energy intake (data not shown). This suggests that it is predominantly the lower energy intake among the individuals who followed a diet that explains the association. In this respect, those following a diet should be warned not to lower their intake of protein-rich foods (except when it concerns a protein-restricted diet). This is particularly important with respect to older adults' body composition, because it has been shown that energy-restricted diets will lead to an accelerated decline in muscle mass [30]. Maintaining a higher level of protein intake in combination with resistance training may prevent further reduction of muscle mass [31].

Obese older adults were more likely to have a low protein intake (expressed by adjusted body weight) compared to those who were normal-weight, but this association disappeared after adjustment for energy intake (data not shown). These results are similar to those of Mendonça and colleagues in the Newcastle 85 + Study [3]. This observation is likely not explained by unrealistic high protein requirements for obese older adults since we used adjusted instead of actual body weight [20], similar to Mendonça. It is more likely that the true protein intakes of the obese individuals are higher than those reported, because overweight people tend to underestimate their dietary intake more often than normal-weight people [32]. The lower energy intake reported by the obese compared to the normal-weight individuals supports this suggestion. Another factor that possibly explains part of the association is the lower physical activity level observed among the obese than the normal-weight individuals, which may result in a lower energy requirement and intake.

More frequent alcohol consumption (up to 5 days/week) was associated with a lower likelihood of a low protein intake compared to no alcohol consumption and remained after adjusting for energy intake. Remarkably, the results of our study differ from those of the Newcastle 85 + Study [3]. In that study, higher alcohol consumption tended to be associated with a higher likelihood of an energy-adjusted low protein intake. This difference is possibly attributable to the fact that the quantity of alcohol consumption was determined in the Newcastle 85 + Study, while the frequency was determined in our study. This idea is supported by a study in NHANES 1999–2000 that showed that a higher quantity of alcohol consumption was associated with poorer diet quality, whereas a higher frequency was associated with better diet quality [33]. It is therefore doubtful whether alcohol consumption is associated with a low protein intake.

Potential dietary strategies aimed at improving daily protein intake depend on an older adult's energy and nutrient requirement and nutritional status, and may include: increasing overall food intake and/or replacing low-protein foods by high-protein foods. The results of our study suggest that implementing any of these strategies at lunch time may be most promising as older adults with a low protein intake seem to consume less protein-rich food products during this meal. The feasibility of these potential strategies is uncertain. It is, for example, unknown how higher intakes at certain eating occasions will influence subsequent food intake, especially considering the fact that among the macronutrients proteins have the highest satiating effect [34]. Although increasing protein intake at breakfast has been shown to be effective for improving daily protein intake [35], research on this topic is scarce. Another aspect to consider is what factors affect older adults' food choice. Motivations and barriers of food intake have been studied previously [36–39], although not all those factors have been thoroughly examined in relation to food sources of (animal) protein [38,39]. Moreover, dietary patterns, food availability and food choice may differ by country, culture and ethnicity [40–42], but research has not been performed yet among a variety of populations. For example, the number and time of the day of hot meals differ from country to country. Furthermore, research has shown that definitions of eating occasions differ per individual and per study and may therefore hamper the interpretation of results [43]. Based on our findings, we can thus not make a statement on the generalizability to other countries. Last, attention has to be paid to the source of protein, especially when both the amount of protein and the proportion of animal protein are low. It would therefore be recommended to advise older adults to compensate a lower animal protein intake by consumption of sufficient amounts of vegetable protein from a variety of foods, in particular at lunch time.

The present study has a number of strengths. The major strength is that the study population is representative for a large part of Dutch older adults with regard to gender, age and region. Furthermore, trained dieticians performed two 24-h recalls to estimate dietary protein intake by using EPIC-Soft®, which is validated and widely used interview software to measure nutritional intake (among older adults as well) [22,23]. In addition, the use of a food diary, that served as a memory aid for the participants, might have yielded more realistic estimates of dietary intake, since some older adults may have a poorer short-term memory. The present study also has limitations. First, the statistical power to find associations might have been insufficient because of the limited size of our study population. Due to some very small (sub)groups, we had to leave out some variables from our multivariate model. This has possibly affected our results in the way that we were unable to investigate certain potential variables for being a characteristic of low protein or for acting as confounder. Second, 24-h recalls are prone to within-subject (day to day) variation [44,45], which we did not take into account to establish habitual protein intake. It is not unrealistic that we misclassified people with regard to their protein intake (i.e., low or high), potentially resulting in attenuation of the associations examined [44,45]. Third, older adults with functional impairments and multimorbidity were underrepresented in our study, so our study sample is relatively healthier than the Dutch older population. The generalizability of our results to the Dutch population as a whole is therefore limited. In addition, the underrepresentativeness of older adults with a poorer health status has most likely attenuated the associations examined.

5. Conclusion

This study showed that Dutch community-dwelling older adults with a protein intake below the RDA of 0.8 g/kg aBW/d (~15%) ate less total protein (also relative to their energy intake) and a lower proportion of animal protein than older adults with a high protein intake at all eating occasions. These differences were largest at lunch. Both the low and the high protein intake group obtained most protein from dairy, meat and cereals. We could only identify following a diet, being obese and not drinking alcohol as general characteristics of older adults with a low protein intake. More research is needed for further specification of risk groups for low protein intake and identification of the best strategy to improve protein intake among the general older population.

CRediT author statement

LMH: Methodology, formal analysis, visualization, writing – preparing original draft, writing – review and editing, data curation; ADAP: formal analysis, writing – preparing original draft, writing – review and editing, data curation; MV: methodology, funding acquisition, supervision, writing – review and editing; JMAB: conceptualization, methodology, resources, supervision, writing – review and editing, data curation; AHN: conceptualization, supervision, writing – review and editing; HAHW: conceptualization, methodology, supervision, writing – review and editing.

Conflict of interest statement

The authors declare to have no conflicts of interest related to this manuscript.

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