




Associations of protein source, distribution and healthy dietary pattern with appendicular lean mass in oldest-old men: the Helsinki Businessmen Study (HBS)

S. K. Jyväkorpi¹  · A. Urtamo¹ · M. Kivimäki¹ · T. E. Strandberg^{2,3}Received: 4 March 2020 / Accepted: 29 April 2020 / Published online: 22 May 2020
© The Author(s) 2020

Key summary points

Aim To investigate how food and dietary intakes, protein daily distribution and source were associated with appendicular lean mass (ALM)/m² in the oldest-old community-dwelling men.

Findings ALM/m² was associated with total protein intake, source and distribution as well as fruit and vegetable intakes.

Message Not only protein intake, but also source and distribution as well as healthy overall diet characterized by abundant amounts of fruits and vegetables were important in maintaining muscle mass in the oldest-old men in our study.

Abstract

Purpose We explored how food and dietary intakes, protein daily distribution and source are associated with appendicular lean mass (ALM)/m² of the oldest-old community-dwelling men.

Methods Cross-sectional analyses of Helsinki Businessmen Study (HBS, mean age 87 years) participants who came to clinic visit in 2017/2018. Nutritional status, physical performance and fasting blood samples were measured. Food and dietary intakes were retrieved from 3-day food diaries. Body composition was measured and appendicular lean mass (ALM) per m² was dichotomized as ALM/m² < 7 kg/m² and ≥ 7 kg/m². Differences between lower and higher ALM were analyzed using *t* test or Mann–Whitney *U* test. Analysis of covariance was used to investigate independent associations with ALM/m².

Results Random sample of 130 participants took part in the medical examinations, 126 returned food diaries, and 102 underwent DXA-scan. ALM/m² was associated with total protein (*p* = 0.033), animal protein (*p* = 0.043) and meat protein (*p* = 0.033) intakes. Protein distribution between daily meals differed at lunch; those with higher ALM/m² ate more protein (*p* = .047) at lunch. Consumption of fruits, vegetables (*p* = 0.022) and meat (*p* = 0.006) was associated with ALM/m².

Conclusion Protein intake, source and distribution as well as fruit and vegetable intakes were associated with higher ALM in oldest-old men.

Study registration The study is registered with ClinicalTrials.gov identifier: NCT02526082.

Keywords Appendicular lean mass · Protein intake · Protein distribution · Protein source · Fruits and vegetables · Animal protein · Meat intake

Introduction

Skeletal muscle is highly important for metabolic health and maintenance of physical function in older age [1]. Skeletal muscle mass and strength decline steadily after the fourth decade of life and the rate of decline are accelerated with aging [2]. Loss of skeletal muscle mass is an independent risk factor for osteoporosis, falls and fractures, impaired functioning and mortality [3].

✉ S. K. Jyväkorpi
satu.jyvakorpi@gery.fi

¹ University of Helsinki, Clinicum and Helsinki University Central Hospital, Unit of Primary Health Care, Tukholmankatu 8 B, 00014 Helsinki, Finland

² University of Helsinki, Clinicum, and Helsinki University Hospital, Helsinki, Finland

³ University of Oulu, Center for Life Course Health Research, Oulu, Finland

Skeletal muscle is also a major organ of glucose metabolism and thus low skeletal muscle may impair glucose tolerance and insulin resistance [4]. For these reasons, there has been a great interest to define lifestyle-related risk factors of skeletal muscle loss. Of nutritional factors, especially inadequate protein intake has been associated with accelerated loss of lean mass, and an increased risk of functional impairments, whereas adequate protein intake has been linked to muscle protein balance and slower rate of muscle mass decline [5]. Higher protein intake has also been associated with increase in muscle mass especially in relation to exercise [6]. Of dietary patterns, Mediterranean diet has been positively associated with muscle mass in older adults [7, 8]. However, data on the fastest growing age group of the oldest old (> 85 years) are very limited with respect to nutrition and muscle mass.

To address this limitation, we explored detailed food and nutrition intakes, distribution of daily protein intake and source between lower and higher appendicular lean mass (ALM) groups in oldest old, community-dwelling men.

Methods

In the Helsinki Businessmen Study (HBS) socioeconomically homogenous cohort of men, born between 1919 and 1934, have been followed-up since the 1960s [9]. In the present cross-sectional analysis, we report findings from the most recent clinic visit including a random sub-cohort of home-living survivors of HBS in 2017–2018 (mean age 87 years of age). At the clinic visit, body mass index (BMI) was calculated as weight (kg/height (m) squared), Mini Nutritional Assessment (MNA) [10] and Short Physical Performance Battery (SPPB) [11] were performed as instructed, body composition measured with DXA-scans, and appendicular lean mass (ALM) per m^2 was calculated. ALM/ m^2 was dichotomized as $< 7 \text{ kg}/m^2$ and $\geq 7 \text{ kg}/m^2$ according to the classification of Gould et al. [12]. Blood insulin and glucose levels were analyzed from blood samples after the 12 h fast. Food, energy and nutrient intakes, daily protein distribution and protein source (amounts of vegetable, animal; milk, meat, fish, and egg proteins) were calculated from the 3-day food diaries.

Statistical significance for group differences was evaluated using independent t test for evenly distributed continuous variables and Mann–Whitney U test for unevenly distributed variables. In addition, we used analysis of covariance (ANCOVA) to investigate independent associations with

ALM/ m^2 . Adjustments were made for age, BMI, protein intake, g, insulin levels and tea drinking. Analyses were performed using the SPSS statistical program, version 24 (SPSS IBM, Armonk, NY, USA).

Selection of covariates

Covariates were selected based on the results of our analysis and prior research. Insulin was selected as a covariate because muscle is a major organ for glucose metabolism [4], tea because it was inversely associated with higher ALM in test, and protein intake for its importance to muscle. Age is associated with loss of skeletal muscle mass and BMI with higher muscle mass.

Results

130 men participated in the clinic visit, 126 returned food diaries and 102 underwent the DXA scan. Age, MNA, SPPB or insulin and glucose levels did not differ significantly between the two ALM/ m^2 groups. Higher ALM/ m^2 was associated with higher BMI ($p < 0.001$), total protein intake ($p = 0.033$), consumption of protein of animal origin ($p = 0.043$) and meat protein ($p = 0.033$). Protein distribution between daily meals differed at lunch only; those in the higher ALM/ m^2 group ate 26 g protein at lunch, compared to 20 g in those with low ALM/ m^2 ($p = 0.047$, Table 1). Of foods consumed, total fruits and vegetables intakes differed significantly between the ALM/ m^2 groups; those with higher ALM/ m^2 consumed more fruits and vegetables: 341 g/d compared to 243 g/d ($p = 0.022$, Table 2). Meat intake was higher in those who had higher ALM/ m^2 ($p = 0.006$), whereas tea intake was negatively associated with ALM/ m^2 ($p = 0.027$).

General linear model confirmed the bivariate findings with respect to protein intake and BMI to ALM/ m^2 . Protein intake remained significant to ALM/ m^2 after adjusting for age, and additionally with insulin levels, BMI, and tea intake (Table 3).

Discussion

In this study, total protein intake, protein source and distribution as well as meat, fruit and vegetable intakes were associated with higher ALM/ m^2 in oldest old community-dwelling men, whereas tea drinking was inversely associated with

Table 1 Baseline characteristics, protein distribution between daily meals and protein source by level of appendicular lean mass (ALM)/m²

| Baseline characteristics | ALM groups | | <i>p</i> value ^a |
|---|--|--|-----------------------------|
| | ALM < 7 kg/m ² <i>n</i> = 45 | ALM ≥ 7 kg/m ² <i>n</i> = 57 | |
| Age, years | 87 (3) | 87 (3) | 0.670 |
| BMI, kg/m ² | 24.7 (2) | 26.6 (3) | < 0.001 |
| MNA points (range 0–14) (SD) | 13 (1) | 13 (1) | 0.249 |
| SPPB points (range 1–12) (SD) | 9 (3) | 10 (2) | 0.215 |
| Insulin, mmol/L | 8.8 (5.1) | 7.3 (3.3) | 0.112 |
| Glucose, mmol/L | 6.2 (1.0) | 6.2 (0.8) | 0.905 |
| Protein distribution between daily meals, (g) | | | |
| Breakfast, g (SD) | 16 (8) | 16 (7) | 0.927 |
| Morning snack, g (SD) | 2 (3) | 4 (8) | 0.071 |
| Lunch, g (SD) | 20 (12) | 26 (15) | 0.047 |
| Dinner, g (SD) | 20 (20) | 19 (16) | 0.692 |
| Afternoon snack, g (SD) | 5 (8) | 5 (7) | 0.615 |
| Evening snack, g (SD) | 6 (8) | 8 (7) | 0.141 |
| Total Protein, g (SD) | 69 (24) | 79 (21) | 0.033 |
| Protein % of total energy | 19.4% (3.3) | 17.8% (3.3) | 0.016 |
| Protein source, g | | | |
| Animal protein total, g (SD) | 48 (21) | 56 (18) | 0.043 |
| Meat protein, g (SD) | 19 (12) | 24 (13) | 0.033 |
| Milk protein, g (SD) | 16 (10) | 18 (10) | 0.374 |
| Egg protein, g (SD) | 2 (3) | 2 (3) | 0.943 |
| Fish protein, g (SD) | 11 (12) | 12 (11) | 0.717 |
| Plant protein, g (SD) | 21 (7) | 22 (7) | 0.373 |
| Total protein, g (SD) | 69 (24) | 79 (21) | 0.033 |

BMI body mass index, *MNA* Mini Nutritional Assessment, *SPPB* short physical performance battery, *SD* standard deviation, *ALM* appendicular lean mass

^aDifference between higher and lower ALM was tested with independent *t* test in even distributed variables and Mann–Whitney *U* test for unevenly distributed variables

ALM/m². Only participants in the higher ALM/m² group reached the amount of protein in a single meal considered to be sufficient for effective protein synthesis.

Proteins of animal origin are high in essential amino acids important for the muscle. Especially the amino acid leucine that is abundant in foods of animal origin has been shown to be important for muscle development and strength [13]. Therefore, it was not surprising that meat protein and meat consumption were associated with higher ALM/m² in our study. Earlier studies have suggested that even protein distribution in daily meals would be most beneficial for older people in relation to muscle health [14]. However, meals with high protein bolus have also been found to be beneficial [15]. In our study protein distribution was relatively even in both ALM groups, as breakfast, lunch,

and dinner were the meals with the highest protein intake, whereas the daily snacks contained relatively low amounts of protein. It has been suggested that ingestion of approximately 25–30 g of protein per meal maximally stimulates muscle protein synthesis in older people [13]. Only the participants classified under the higher ALM group reached this amount in a single meal at lunch, which was the only meal that differed significantly between the ALM groups in our study. The lower ALM group did not reach this threshold in any of their daily meals. These findings underline the importance of educating older people about timing and distribution of their protein intake.

Those with higher ALM ate more fruits and vegetables, which are an essential part of several healthy dietary patterns, including Mediterranean, Nordic, and DASH diets.

Table 2 Food, energy and nutrient intake by level of appendicular lean mass (ALM)/m²

| Food intake/day | ALM groups | | <i>p</i> values ^a |
|-------------------------------------|--|--|------------------------------|
| | ALM/m ² < 7 kg <i>n</i> = 45 | ALM/m ² ≥ 7 kg <i>n</i> = 57 | |
| Fruits and berries, g (SD) | 112 (119) | 170 (183) | 0.056 |
| Vegetables, g (SD) | 138 (104) | 176 (153) | 0.163 |
| Total fruits and vegetables, g (SD) | 243 (163) | 341 (265) | 0.022 |
| Whole grain products, g (SD) | 98 (60) | 102 (65) | 0.738 |
| Other grain products, g (SD) | 233 (130) | 242 (148) | 0.749 |
| Legumes, g (SD) | 9 (24) | 6 (18) | 0.448 |
| Nuts, g (SD) | 1 (3) | 8 (20) | 0.060 |
| Fish, g (SD) | 56 (56) | 66 (61) | 0.364 |
| Milk products, g (SD) | 280 (222) | 347 (220) | 0.138 |
| Meat, g (SD) | 89 (48) | 120 (60) | 0.006 |
| Egg, g (SD) | 17 (30) | 15 (26) | 0.761 |
| Alcohol, g (SD) | 7 (10) | 4 (7) | 0.136 |
| Tea, g (SD) | 87 (141) | 160 (177) | 0.027 |
| Coffee, g (SD) | 218 (159) | 294 (216) | 0.051 |
| Energy and nutrient intakes | | | |
| Energy, kcal (SD) | 1550 (391) | 1634 (358) | 0.262 |
| Protein, g (SD) g/kg BW/d | 69 (24) 0.95 (0.3) | 80 (21) 0.99 (0.24) | 0.033 0.584 |
| Carbohydrates, g (SD) | 164 (44) | 170 (43) | 0.505 |
| Fat, g (SD) | 63 (21) | 67 (22) | 0.314 |
| Vitamin D, µg (SD) | 9 (8) | 10 (7) | 0.310 |
| Vitamin E, mg (SD) | 10 (4) | 11 (6) | 0.181 |
| Iron, mg, (SD) | 10 (3) | 11 (3) | 0.174 |

BMI body mass index, *SD* standard deviation, *ALM* appendicular lean mass

^aDifference was between higher and lower ALM was tested with independent *t* test

Fruits and vegetables contain high amounts of vitamins, minerals, antioxidants, and other bioactive compounds and in addition, alkaline salts may also be important in preserving muscle [7, 8, 15]. Tea drinking was associated with lower ALM/m², but as we did further testing, we found that tea drinking was associated with lower BMI which would explain the result.

The strengths of this study include its robust findings—despite the relatively small study sample—and the fact that there are few other studies on oldest-old (> 85 years of age) people. Limitations involve generalization: the survivors of HBS differ in many ways from the general population by being men from upper socioeconomic class; and the cross-sectional design of the

study, which prevents drawing conclusions about causal relationships.

Conclusions and implications

Our study extends previous findings on the importance of protein intake and the threshold in a single meal in the maintenance of muscle mass of the oldest-old. Moreover, fruit and vegetable intakes, emphasized in healthy dietary patterns, were also important for muscle mass. Therefore, the importance of protein intake and distribution, as well as healthy dietary patterns should be highlighted also for the oldest-old.

Table 3 ANCOVA models of factors associated with appendicular lean mass (ALM)/m²

| | <i>B</i> | 95% confidence interval | | <i>p</i> value |
|--------------------------------|--------------|-------------------------|-------------|----------------|
| | | Lower bound | Upper bound | |
| Model 1 | | | | |
| Intercept | 9.724 | 5.641 | 13.807 | <0.001 |
| Age | − 0.038 | − 0.085 | 0.009 | 0.111 |
| Protein, g | 0.009 | 0.003 | 0.015 | 0.003 |
| Adjusted <i>R</i> ² | 0.087 | | | |
| Model 2 | | | | |
| Intercept | 5.205 | 1.161 | 9.249 | 0.012 |
| Age | − 0.018 | − 0.060 | 0.025 | 0.406 |
| Protein, g | 0.005 | − 0.026 | 0.825 | 0.067 |
| BMI | 0.119 | 0.073 | 0.165 | <0.001 |
| Adjusted <i>R</i> ² | 0.273 | | | |
| Model 3 | | | | |
| Intercept | 5.368 | 1.379 | 9.357 | 0.009 |
| Age | − 0.018 | − 0.060 | 0.024 | 0.392 |
| Protein g | 0.005 | 0.000 | 0.011 | 0.063 |
| BMI | 0.124 | 0.078 | 0.169 | <0.001 |
| Insulin | − 0.033 | − 0.061 | − 0.005 | 0.020 |
| Adjusted <i>R</i> ² | 0.300 | | | |
| Model 4 | | | | |
| Intercept | 5.368 | 1.437 | 9.299 | 0.008 |
| Age | − 0.017 | − 0.058 | 0.024 | 0.420 |
| BMI | 0.120 | 0.099 | 0.185 | <0.001 |
| Protein, g | 0.418 | 0.076 | 0.165 | 0.048 |
| Insulin | − 0.030 | − 0.056 | 0.003 | 0.032 |
| Tea, g/d | − 0.001 | − 0.001 | <0.000 | 0.052 |
| Adjusted <i>R</i> ² | 0.320 | | | |

Bold values indicate the amount of observed variation that can be explained by the model's inputs

B unstandardized beta, *BMI* body mass index, *BW* body weight, *kg* kilograms, *g* grams, *d* day

Acknowledgements Open access funding provided by University of Helsinki including Helsinki University Central Hospital.

Author contributions SKJ designed and performed the data-analysis, AU carried out the clinic visits. All authors contributed to writing of the manuscript and approved the final version.

Funding This work was supported by Foundation of Nutrition Research, VTR-funding of the Helsinki University Hospital (EVO), Helsinki University Hospital Internal Medicine and Rehabilitation and Academy of Finland, grant number 311492, NordForsk, and Helsinki Institute of Life Science. The sponsors did not have any role in the study design, analysis or interpretation of data, or in writing the report or the decision to submit this article. The authors were independent researchers not associated with the funders.

Data availability The data can be enquired from Professor Timo Strandberg, timo.strandberg@oulu.fi.

Compliance with ethical standards

Conflict of interest SKJ: reports no conflict of interest. AU: reports no conflict of interest. MK: was supported by NordForsk, the Academy of Finland (311492), and Helsinki Institute of Life Science. TES: reports having various educational and consultative cooperation with several companies, including Nutricia, Abbott, Amgen, Merck, Pfizer, Novartis, and Novo-Nordisk; a minor amount of stock in Orion Pharma; and is a board member and former president of executive board of European Union Geriatric Medicine Society which has cooperation also with the nutrition industry.

Ethical approval The study protocol was approved by the Ethics Committee of the Helsinki University Hospital, Department of Medicine. The study is registered with ClinicalTrials.gov identifier: NCT02526082.

Informed consent All participants signed an informed consent.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

1. Tieland M, Trouwborst I, Clark BC (2018) Skeletal muscle performance and ageing. *J Cachexia Sarcopenia Muscle* 9:3–19. <https://doi.org/10.1002/jcsm.12238>
2. Roshanravan B, Patel KV, Fried LF, Robinson-Cohen C, de Boer IH, Harris T et al (2017) Association of muscle endurance, fatigability, and strength with functional limitation and mortality in the health aging and body composition study. *J Gerontol A Biol Sci Med Sci* 72:284–291
3. Johnson ML, Robinson MM, Nair KS (2013) Skeletal muscle aging and the mitochondrion. *Trends Endocrinol Metab* 24:247–256
4. Scott D, de Courten B, Ebeling PR (2016) Sarcopenia: a potential cause and consequence of type 2 diabetes in Australia's ageing population? *Med J Aust* 205(7):329–333
5. Houston DK, Nicklas BJ, Ding J, Harris TB, Tyllavsky FA, Newman AB et al (2008) Dietary protein intake is associated with lean mass change in older, community-dwelling adults: the Health, Aging, and Body Composition (Health ABC) Study. *Am J Clin Nutr* 87:150–155
6. Tieland M, Dirks ML, van der Zwaluw N et al (2012) Protein supplementation increases muscle mass gain during prolonged resistance-type exercise training in frail elderly people: a randomized, double-blind, placebo-controlled trial. *J Am Med Dir Assoc* 13:713–719

7. Tyrovolas S, Haro J-M, Mariolis A, Piscopo S, Valacchi G, Bountziouka V, Anastasiou F, Zeimbekis A, Tyrovolas D, Foscolou A (2016) Skeletal muscle mass and body fat in relation to successful ageing of older adults: the multinational MEDIS study. *Arch Gerontol Geriatr* 66:95–101
8. Kelaiditi E, Jennings A, Steves C, Skinner J, Cassidy A, MacGregor A, Welch A (2016) Measurements of skeletal muscle mass and power are positively related to a Mediterranean dietary pattern in women. *Osteoporos Int* 27(11):3251–3260
9. Strandberg TE, Salomaa V, Strandberg AY et al (1074h) Cohort profile: the Helsinki Businessmen Study (HBS). *Int J Epidemiol* 45:1074–1074h
10. Vellas B, Guigoz Y, Garry PJ et al (1999) The Mini Nutritional Assessment (MNA) and its use in grading the nutritional state of elderly patients. *Nutrition* 15(2):116–122
11. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG et al (1994) A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol* 49:M85–94
12. Gould H, Brennan SL, Kotowicz MA et al (2014) Total and appendicular lean mass reference ranges for Australian men and women: the Geelong osteoporosis study. *Calcif Tissue Int* 94:363–372
13. Nowson C, O’Connell S (2015) Protein requirements and recommendations for older people: a review. *Nutrients* 7:6874–6899. <https://doi.org/10.3390/nu7085311>
14. Bouillande CE, Hamon-Vilcot B et al (2013) Impact of protein pulse feeding on lean mass in malnourished and at-risk hospitalized elderly patients: a randomized controlled trial. *Clin Nutr* 32:186–189
15. Dawson-Hughes B, Harris SS, Ceglia L (2008) Alkaline diets favour lean tissue mass in older adults. *Am J Clin Nutr* 87:662–665

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.