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ORIGINAL CONTRIBUTION

Association of the Baltic Sea and Mediterranean diets with indices of sarcopenia in elderly women, OSPTRE-FPS study

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Abstract
Purpose To examine whether higher adherence to Baltic Sea diet (BSD) and Mediterranean diet (MED) have beneficial association with sarcopenia indices in elderly women.
Methods In total 554 women, aged 65–72 years belonging to OSTPRE-FPS study answered a questionnaire on lifestyle factors and 3-day food record at baseline in 2002. Food consumptions and nutrient intakes were calculated. Nine components were selected to calculate BSD score. MED score was calculated using eight components. Body composition was measured by dual-energy X-ray absorptiometry. Physical function measures included walking speed 10 m, chair rises, one leg stance, knee extension, handgrip strength and squat at baseline and at year 3. Sarcopenia and short physical performance battery (SPPB) score were defined based on the European working group on sarcopenia criteria. Lower body muscle quality (LBMQ) was calculated as walking speed 10 m/leg muscle mass.
Results Women in the higher quartiles of BSD and MED scores lost less relative skeletal muscle index and total body lean mass (LM) over 3-year follow-up ($P_{trend} \leq 0.034$). At the baseline, women in the higher BSD score quartiles had greater LM, faster walking speed 10 m, greater LBMQ, higher SPPB score ($P_{trend} \leq 0.034$), and higher proportion of squat test completion. Similarly, women in the higher quartiles of MED sore had significantly faster walking speed 10 m, greater LBMQ ($P_{trend} \leq 0.041$) and higher proportion of squat test completion.
Conclusions Better diet quality as measured by higher adherence to BSD and MED might reduce the risk of sarcopenia in elderly women.

Keywords Baltic Sea diet · Mediterranean diet · Sarcopenia · Muscle mass · Physical function

Introduction

Sarcopenia, the degenerative and involuntary loss of skeletal lean mass (LM) and physical function (PF), has been determined as a major cause of mobility disability, and loss of independence. Sarcopenia is estimated to affect one-quarter of the elderly [1–3]. The pathogenesis of sarcopenia is multifactorial and is attributed to undernutrition, oxidative stress, inflammation, endocrine changes and physical inactivity [4]. Studies that assessed the role of nutrition in sarcopenia have focused on specific components of foods, often single nutrients. Although these studies have consistently provided knowledge for benefits of nutritional factors such as vitamin D, vitamin E, carotenoids, energy, protein, and whole grains in ageing sarcopenia [5, 6], this approach has limitations [7]. The role of a single factor is often small and difficult to capture in observational studies; also, people eat foods, not nutrients. Thus, dietary score analysis is

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a sensible approach to understand the role of the whole diet on sarcopenia.

A dietary score represents a summary value of consumed foods or nutrients and characterizes a measure of adherence to a predefined (healthy) diet [8, 9], in which higher scores indicate diet quality and a higher intake of beneficial foods (such as whole grains, vegetables, fruits, and fish). In the past years, Mediterranean (MED) and Baltic Sea diets (BSD) have been related to positive health outcomes and received growing attention in European and particularly in Nordic settings (Denmark, Finland, Iceland, Norway and Sweden) [8, 10]. The MED is a model of a healthy diet that represents the dietary pattern in population from the Mediterranean area which has also been frequently applied in other populations [8]. However, due to the differences in food culture, applying MED directly to the Nordic population could be challenging [10]. BSD was therefore initially developed in order to present the healthier choices for the diet consumed in the Nordic countries [10, 11]. Many foods produced in the Nordic countries, for example, apples and berries, rye, rapeseed oil, salmon and dairy products, are considered to have health-enhancing features [12]. The detailed definitions of MED and BSD scores are varied due to different study settings and dietary assessment methods. The difference between MED and BSD scores regarding their components is that MED is characterized by high consumption of olive oil, and lower consumption of dairy products, whereas BSD focuses on the dietary fat quality and low-fat milk intake. Higher adherence to MED has consistently been associated with lower cognitive functional decline, less dementia and better PF in the elderly [8, 13, 14]. It was shown that higher adherence to MED was associated with better lower body performance [15]. Higher adherence to the MED was associated also with lower odds of sarcopenia among elderly men and women [14]. However, to our knowledge the association of MED with sarcopenia in Nordic countries has not been studied. BSD is likely to be inversely associated with abdominal obesity [11], and it was associated with better overall physical performance in elderly Finnish women [16].

Studies examining the effect of diet quality on indices of sarcopenia in the elderly are scarce. We hypothesized that higher adherence to BSD and MED provide a wide range of foods and nutrients that can benefit LM and PF. We evaluated and compared the associations of BSD and MED scores with LM, and PF measures in Finnish elderly women in both cross-sectional and prospective settings.

Methods

Study population

Data of the present study were collected from the Osteoporosis Risk Factor and Prevention-Fracture Prevention Study (OSTPRE-FPS), which was a 3-year intervention to investigate the effect of calcium and vitamin D supplementation on incidence of falls and fractures among postmenopausal elderly women. Inclusion criteria was minimum age 65 years. The subjects were selected from the population-based OSTPRE-cohort [17]. In total 3432 women age 65–72 years volunteered to participate in the study, and 750 women (with no significant differences at the baseline) were randomly invited into this subsample for participating in detailed examinations including measurement of body composition, clinical, physical and laboratory tests [18]. Of these, 554 returned valid food record. All the 554 participants enrolled in this study had valid body composition and PF measurements for both at the baseline and at the 3-year follow-up. The subjects were randomized to intervention group ($n=272$) receiving daily cholecalciferol 800 IU and calcium 1000 mg for 3 years and control group receiving neither supplementation nor placebo ($n=282$). All clinical measurements were performed in Kuopio Musculoskeletal Research Unit of the Clinical research center of the University of Kuopio. All participants provided written permission for participation. The study was approved in October 2001 by the ethical committee of Kuopio University Hospital. The study was registered in Clinical trials.gov by the identification NCT00592917.

Dietary intakes

Dietary intake was assessed by using a 3-day food record at the baseline. A questionnaire and the instructions were sent to participants beforehand, and they were returned on the visiting day. Questionnaire included 3 consecutive days, with 2 days during the week and one day in the weekend (Saturday or Sunday). In case of uncertainties in the food record, a nutritionist called the participant for additional information [19]. Assessment of underreporting has previously been described and none of the participants was excluded due to low energy intake [18]. Consumption of foods and the intake of nutrients were calculated using Nutrica program (version 2.5, Finnish social insurance institute, Turku, Finland).

Baltic Sea diet score

We used published definitions of BSD that have been applied in Nordic settings with slight modifications due to different dietary assessment methods in earlier studies [10].

The final BSD score consisted of nine components, including five foods or food groups, four nutrient intakes, and alcohol intake (g/d). Due to the limitation of the Nutrica software used to calculate the food components, we were not able to extract the specific Nordic food items such as apples and pears from other fruits or red meat from other meat products. Foods and nutrients were categorized into quartiles. The positive component received score 0 for lowest quartile and 3 for the highest quartile, the order for negative components were in the reverse order. Frequency of consumption of alcohol portions (1 portion = 12 g) was asked in a separate questionnaire. (1) Alcohol intake was scored as 1 if the intake was ≤12 g/d, otherwise 0. Total score ranged from 0 to 25, higher score indicating higher adherence to BSD. The BSD score positive components were (2) Total fruits (mostly apples and pears) and berries (3) vegetables (root vegetables, legumes, nuts, mushrooms and vegetable products—potatoes excluded), (4) fiber from total cereal products, (5) total fish intake, (6) low-fat milk (skim milk and milk with fat content less than 2%), (7) ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acid (SFA) indicating quality of fat intake. The negative components of BSD score were (8) processed meat products (sausage) and (9) total fat intake expressed as a percentage of total energy intake (*E*%). The score construction is presented in Table 1. BSD score ranged from 0 to 25, higher points indicating higher adherence to BSD.

Mediterranean diet score

MED score is the most widely used diet score [8]. A predefined MED score was selected based on the existing literature and particularly those studies that have applied the MED score in Nordic cohorts [8, 20, 21], as well as on the suggested positive association of MED score with PF [13]. For each positive component of MED score, a value of 1 was given if a persons' intake was equal or above the median, and otherwise 0 was given. Those who met all the MED score components received a score of 8, reflecting maximum adherence. The score comprised of six positive components, including (1) high intake of root vegetables, legumes and nuts, mushrooms and vegetable products (potato excluded), (2) high intake of fruit, (3) high intake of cereals and potatoes, (4) high intake of fish, (5) high PUFA + monounsaturated fatty acid (MUFA): SFA ratio (as surrogate of quality of dietary fat), and (6) moderate alcohol intake (5–25 g/d). Two negative components were included (7) total meat including sausage and eggs, and (8) total milk and dairy products. Construction of MED score is described in Table 1.

Table 1 Construction of the Baltic Sea diet and Mediterranean diet scores

Components	Scoring
Baltic Sea diet score components	
Total fruits (mostly apples and pears), and berries (g/d)	Q1 = 0, Q2 = 1, Q3 = 2, Q4 = 3
Vegetables: root vegetables, legumes and nuts, mushrooms and vegetable products (potato excluded) (g/d)	Q1 = 0, Q2 = 1, Q3 = 2, Q4 = 3
Fiber from total cereal products (g/d)	Q1 = 0, Q2 = 1, Q3 = 2, Q4 = 3
Fish (g/d)	Q1 = 0, Q2 = 1, Q3 = 2, Q4 = 3
Milk, low fat < 2%	Q1 = 0, Q2 = 1, Q3 = 2, Q4 = 3
Processed meat products, sausage (g/d)	Q1 = 3, Q2 = 2, Q3 = 1, Q4 = 0
Ratio of PUFA:SFA	Q1 = 0, Q2 = 1, Q3 = 2, Q4 = 3
Total fat intake energy %	Q1 = 3, Q2 = 2, Q3 = 1, Q4 = 0
Alcohol (g/d)[a]	≤12 g/d = 1 and otherwise = 0
Mediterranean diet score components	
Vegetables: root vegetables, legumes and nuts, mushrooms and vegetable products (g/d)	≥Median intake = 1, <median intake = 0
Total fruits (g/d)	≥Median intake = 1, <median intake = 0
Total cereals and potatoes (g/d)	≥Median intake = 1, <median intake = 0
Fish, (g/d)	≥Median intake = 1, <median intake = 0
Ratio of PUFA + MUFA: SFA	≥Median intake = 1, <median intake = 0
Total meat including sausage, and eggs (g/d)	≥Median intake = 0, <median intake = 1
Total milk and dairy products (g/d)	≥Median intake = 0, <median intake = 1
Alcohol (g/d)	5–25 g/d = 1 and <5 and >25 g/d = 0

Q quartile, *PUFA* polyunsaturated fatty acid, *MUFA* monounsaturated fatty acids, *SFA* saturated fatty acids

[a]One portion of alcohol was calculated as 12 g

Health examination and measurements

All the information related to lifestyle, income per month, chronic diseases, falls and medications was gathered by using a self-administered questionnaire at the baseline [22]. Height and weight of participants were measured in light indoor clothing without shoes, and BMI was calculated kg/m^2. Total exercise time/week was based on self-reported amounts and types of exercise/week. To measure body composition whole body dual-energy X-ray absorptiometry (DXA) scans were performed by specially trained nurses [23]. Relative skeletal muscle index (RSMI) was calculated as the sum of the nonfat, nonbone skeletal muscle in arms and legs divided by the square of height (m^2) which is an indicator of LM in the diagnosis of sarcopenia [3].

Physical function measurements

PF measures were assessed by trained nurses at the baseline and at year 3, consisting of handgrip strength (kPa), number of chair rises in 30 s, ability to squat, knee extension (kPa), maximal walking speed 10 m (m/s), and one leg stance performance for 30 s. Handgrip strength was measured in a controlled sitting position with a pneumatic handheld dynamometer (Martin Vigorimeter, Germany) by calculating the mean of three successive measurements from the dominant hand [18]. The chair rise test was conducted if participant could stand at least once without using arms from a straight-backed, non-padded, armless chair. Maximal walking speed was calculated by the time of walking the 10 m. The follow-up variable of knee extension was excluded from analysis due to unexpected increase in measured extension force and/or possible data entry errors. Absolute changes in PF measures were calculated by subtracting the baseline measures from those measured at year 3. PF assessment methodology have been described and applied earlier in this data set [18, 22].

Short physical performance battery (SPPB) score was calculated based on European working group on sarcopenia (EWGSOP) definition [24]. Three individual measures of physical performance including walking speed 10 m (m/s), chair rises in 30 s and one leg stance performance were included [25]. Individuals unable to complete the task received a score of 0, PF tests were further categorized in quartiles and each quartile was scored on scale of 1–4 points. The total SPPB score ranging from 0 to 12; higher scores indicate better performance. Previous studies indicated that an SPPB cut point of less than 10 identifies individuals at increased risk of mobility disability [26]. However, due to the different study setting and that only 8 percent of women had SPPB score over 10, we defined the development of "mobility disability" as an SPPB score belonging to the lowest quartile. The lower body muscle quality (LBMQ) was calculated using walking speed 10 m per leg LM, explained by association between lower leg LM and poorer low extremity performance and walking speed in older men and women [27, 28].

Diagnosis of sarcopenia

We have previously defined sarcopenia based on EWGSOP criteria in this data set [18, 22]. In brief, women were subdivided into quartiles for their RSMI, handgrip strength and walking speed values (the women who were not able to perform the tests allocated into the group of the lowest quartile). A woman was classified as sarcopenic if she belonged to the lowest quartile of RSMI and the lowest quartile of either handgrip strength or walking speed or both. A non-sarcopenic woman did not belong to the lowest quartile of any measurement, whereas pre-sarcopenic women were in the lowest quartile of RSMI but not in the lowest quartile of any other outcome measure. Non-classified women belonged to the lowest quartile of either handgrip strength or walking speed or both, but not to that of RSMI. To achieve balanced numbers of participants in the stratified analysis, women were classified as sarcopenic if they belonged to pre-sarcopenia, sarcopenia and severe sarcopenia (lowest quartile of RSMI) and non-sarcopenic group was compiled from non-sarcopenic and non-classified groups (normal RSMI).

Statistical analysis

We reported MED and BSD scores in quartiles to enable comparability of their results. We analyzed BSD and MED score also as continuous variables. The agreement between the MED and BSD score was not significant (κ value = 0.020 and $P = 0.148$). We compared the participant characteristics according to BSD and MED score quartiles using Chi square analysis or ANOVA, as appropriate. Independent sample t test was used to compare the baseline characteristic between sarcopenic and non-sarcopenic groups as well as intervention and control groups.

For the cross-sectional analysis, the baseline values of LM, RSMI and PF measures were tested in total population. In the follow-up analysis, we tested the interaction terms between BSD and MED with vitamin D and calcium intervention. There was no significant interaction by intervention; therefore, data were pooled for total population (intervention and control group) adjusted for the intervention. However, to account for the possible effect of vitamin D and calcium intervention, we tested further the associations only in the control group. In the prospective analysis, we used the absolute changes of PF measures, and the proportional change of LM and RSMI to correct for effect of body size since bigger individuals have greater LM.

ANCOVA was used to test the mean differences among the groups and to measure the effect size reported as partial eta squared (η^2) for continuous outcome variables [29]. Multiple linear regression models were used to calculate mean difference and SE introducing LM, RSMI and PF at the baseline and changes in them as dependent variables with BSD or MED score as independent variable. Logistic regression was used to determine the association of BSD and MED with categorical outcomes (sarcopenia, mobility disability, and squat test). P_{trend} was based on a linear trend across BSD and MED score quartiles by using the median value in each category as a continuous variable in the linear regression model as exposure.

We used two models with hierarchical adjustments. Model 1 was adjusted for age and energy intake. Model 2 was adjusted for variables in model 1 and smoking, total physical activity, hormone therapy, osteoporosis, rheumatoid arthritis, coronary heart disease, income per month, and fat mass percentage. Depression, diabetes, and fall were not included in the models because their associations with the diet scores and outcome measures in the bivariate correlation analysis were $P > 0.10$. Longitudinal analyses were adjusted for the muscle mass and PF baseline measures to account for differential subsequent changes depending on the initial measures. All statistical analysis were executed using SPSS software version 21 for Windows (IBM Corp., Armonk, NY). Result was considered significant if a P value was <0.05.

Results

Characteristics of the study population at baseline

The BSD score ranged from 1 to 25 in our population, and the mean was 13 points. Energy intake was highest in the highest quartile of BSD score. In the model adjusted for age and energy intake the consumption of positive BSD score components (fruits, berries, vegetables, fiber from cereals, fish, milk with fact content <2%, and PUFA to SFA ratio) were substantially higher, and intakes of negative BSD score components (sausage and total fat energy %) were lower in higher score quartiles. At the baseline, women in higher BSDS quartiles were more likely to be nonsmokers and engage more in physical activity (Table 2). Further, the mean for MED score was 4.7 and ranged from 0 to 8. Energy intake was significantly higher in the higher quartile of MED score (Table 3). Consumptions of fruits, vegetables, potato, legumes and nuts were significantly higher in higher MED score quartiles.

In Supplemental Table 1, the baseline characteristics between sarcopenic and non-sarcopenic women are described. Sarcopenic women ($n = 127$) had significantly lower mean weight (−11.4 kg), BMI (−3.5 kg/m^2), FM (−5 kg) and LM (−4.5 kg) as compared to non-sarcopenic group ($n = 398$). Sarcopenic women had also higher protein intake (g/kg BW), higher PUFA to SAFA ratio and higher MUFA + PUFA to SAFA ratio. At the 3 year of follow-up 386 women were non-sarcopenic and 139 were sarcopenic, whereas in the control group 216 women were classified as non-sarcopenic and 66 as sarcopenic. There were no significant differences in the baseline characteristics between intervention and control groups (data not shown).

Association of BSD score and sarcopenia indices at the baseline and over 3-year follow-up

At the baseline, in model 2 women in the higher quartiles of BSD score had significantly greater LM ($\eta^2 = 0.070$, $P_{trend} = 0.044$), faster walking speed 10 m ($\eta^2 = 0.034$, $P_{trend} = 0.006$), and longer one leg stance performance ($\eta^2 = 0.044$, $P_{trend} = 0.050$) than lower quartiles. Those women had higher SPPB score ($\eta^2 = 0.016$, $P_{trend} = 0.034$) and better LBMQ ($\eta^2 = 0.017$, $P_{trend} = 0.017$) (Table 4; Supplemental Table 2). BSD score was non-significantly associated also with lower mobility disability (OR 1.64, $P_{trend} = 0.051$) (Supplemental Table 2).

In prospective analysis, women in the highest quartile of BSD score lost less RSMI ($P_{trend} = 0.022$) and total body LM ($P_{trend} = 0.015$) as compared to those in lower quartiles (Fig. 1). Further, in the analyses using BSD score as continuous variable, a positive cross-sectional association with total body LM, walking speed, LBMQ and SPPB was observed, whereas BSD score as a continuous variable was positively associated with proportional changes of RSMI and total body LM over the 3-year follow-up (Supplemental Table 3).

The interaction of BSD with interventional vitamin D and calcium supplementation was not significant ($P \geq 0.180$). In the separate prospective analysis in the control group, women in the lowest quartile of BSD score lost more RSMI ($P_{trend} = 0.018$), and total body LM ($P_{trend} = 0.004$) compared to those in higher quartiles. Women in the highest BSD score quartile, showed the highest SPPB improvement ($P_{trend} = 0.041$), had a 55% higher squat test completion (OR 0.45; 95% CI: 0.11–0.98) and 67% lower risk of sarcopenia (OR 0.33; 95% CI: 0.13, 0.79) as compared to the lowest quartile, over 3 year of follow-up (Supplemental Table 4). Similar results were observed using the BSD score as continuous variable (data not shown).

Table 2 Selected baseline characteristics and dietary factors of the participants by Baltic sea diet score quartiles

	Baltic sea diet score quartiles				*P*
	Q1 (≤9)	Q2 (10–13)	Q3 (14–15)	Q4 (≥16)	
	n 146	*n* 125	*n* 129	*n* 107	
Age (years)	67.9 (1.8)	67.9 (1.8)	68.0 (1.8)	67.4 (1.8)	0.587
BMI (kg/m^2)	27.3 (4.5)	27.7 (4.0)	27.2 (4.3)	26.9 (3.8)	0.520
Current smoker *n* (%)	12 (7.4)	5 (4.1)	4 (3.1)	2 (1.9)	0.015
Current hormone therapy use *n* (%)	32 (21.9)	28 (22.4)	28 (21.7)	29 (27.1)	0.509
Osteoporosis *n* (%)	15 (11.0)	9 (7.0)	17 (15.0)	7 (5.0)	0.055
Rheumatoid arthritis *n* (%)	10 (8.2)	5 (3.8)	8 (6.8)	7 (5.3)	0.448
Depression *n* (%)	6 (4.5)	7 (5.0)	4 (2.9)	2 (1.5)	0.385
Falls in last 12 months *n* (%)	24 (17.5)	27 (22.4)	30 (28.3)	18 (17.7)	0.210
Coronary heart disease *n* (%)	30 (20.7)	24 (19.2)	22 (17.1)	14 (13.1)	0.445
Physical activity (h/month)	42.6 (4.4)	45.1 (3.9)	55.0 (5.2)	58.7 (4.7)	0.009
Income (euros/month)	816 (281)	886 (325)	884 (297)	880 (294)	0.502
Body composition					
Fat mass (kg)	28.8 (9.1)	29.1 (8.1)	29.4 (4.5)	27.9 (8.5)	0.584
Lean mass (kg)	39.8 (4.3)	39.2 (4.0)	40.3 (4.4)	40.8 (3.9)	0.012
Dietary factors					
Mediterranean diet score	3.6 (1.2)	4.0 (1.3)	4.2 (1.3)	4.7 (1.1)	0.001
Fruits (g/d)	73.5 (86.2)	116.3 (110.5)	136.0 (116.5)	169.1 (131.5)	<0.001
Berries (g/d)	33.6 (37.7)	42.8 (41.59)	52.71 (51.3)	68.0 (52.1)	<0.001
Vegetables (g/d)	103.3 (64.0)	128.6 (69.9)	156.0 (79.0)	190.8 (84.4)	<0.001
Potato (g/d)	76.5 (48.6)	80.1 (47.9)	76.4 (47.2)	91.7 (49.7)	0.053
Fiber from cereals (g/d)	13.5 (5.1)	14.2 (5.1)	15.5 (5.7)	16.8 (4.8)	<0.001
Legumes and nuts (g/d)	2.6 (5.9)	4.6 (9.19)	4.1 (11.1)	6.5 (19.5)	0.115
Milk and dairy products (g/d)	732.3 (425.1)	870.1 (530.6)	857.6 (424.6)	1031.8 (418.3)	0.384
Milk with fat content <2%	533.2 (532.1)	696.0 (609.4)	893.9 (677.4)	1189.9 (650.8)	0.001
Total meat intake (g/d)	84.7 (46.6)	71.6 (41.5)	73.9 (54.2)	65.9 (39.9)	0.011
Sausage (g/d)	30.9 (29.7)	17.6 (25.3)	12.0 (23.3)	5.0 (13.7)	<0.001
Egg (g/d)	20.1 (17.7)	17.5 (13.7)	17.6 (15.8)	14.8 (12.4)	0.047
Fish (g/d)	21.0 (27.8)	38.9 (37.3)	46.8 (42.5)	67.1 (54.2)	<0.001
Energy intake (kJ/d)	6414 (1635)	6447 (1547)	6367 (1450)	6952 (1514)	0.014
Alcohol (g/d)	11.8 (21.3)	10.8 (17.4)	10.0 (16.3)	7.2 (11.5)	0.076
Protein (g/d)	61.0 (16.8)	64.2 (6.0)	69.5 (16.7)	77.0 (18.0)	<0.001
Protein (g/kg BW/d)	0.87 (0.29)	0.91 (0.25)	0.96 (0.25)	1.10 (0.30)	<0.001
Carbohydrate (g/d)	182.8 (49.1)	186.2 (45.4)	189.9 (46.3)	211.1 (49.2)	<0.001
Fat (g/d)	59.5 (19.1)	55.0 (18.4)	49.8 (19.7)	50.0 (16.1)	<0.001
PUFA to SFA ratio	0.33 (0.11)	0.41 (0.17)	0.47 (0.14)	0.57 (0.19)	<0.001
PUFA + MUFA to SFA ratio	1.06 (0.26)	1.22 (4.20)	1.31 (0.32)	1.51 (0.41)	<0.001
Vitamin D (μg/d)	4.9 (2.6)	7.0 (4.0)	8.2 (4.5)	9.8 (6.2)	<0.001
Vitamin E (mg/d)	7.0 (2.8)	7.0 (4.0)	9.5 (5.2)	10.1 (3.7)	<0.001
Vitamin C (mg/d)	73.6 (41.6)	87.6 (2.9)	108.6 (61.4)	127.3 (72.4)	<0.001
Total carotene (μg/d)	1802 (1666)	1992 (1379)	2459 (1775)	3565 (2471)	<0.001

Data are presented as mean (SD) or *n* (%). ANOVA and Chi square tests were used to evaluate the differences in participant characteristics and dietary factors among Baltic Sea diet score quartiles. Adjusted for age and energy intake

Q quartile, *BMI* Body Mass Index, *PUFA* polyunsaturated fatty acid, *MUFA* monounsaturated fatty acids, *SFA* saturated fatty acids

Table 3 Selected baseline characteristics and dietary factors of the participants by Mediterranean diet score quartiles

	Mediterranean diet score quartiles				*P*
	Q1 (≤3)	Q2 (4)	Q3 (5–6)	Q4 (≥7)	
	n 160	*n* 147	*n* 117	*n* 79	
Age (years)	67.7 (1.8)	67.8 (1.8)	67.8 (1.8)	67.9 (1.9)	0.915
BMI (kg/m^2)	27.4 (4.0)	28.0 (4.4)	27.1 (4.1)	26.8 (4.3)	0.163
Current smoker *n* (%)	9 (5.5)	7 (5.3)	5 (4.0)	1 (1.4)	0.247
Hormone therapy use *n* (%)	31 (18.6)	33 (24.6)	29 (23.4)	20 (25.6)	0.868
Osteoporosis *n* (%)	10 (6.3)	9 (6.1)	7 (4.3)	15 (10.1)	0.438
Rheumatoid arthritis *n* (%)	10 (6.3)	6 (3.8)	8 (5.6)	12 (7.7)	0.433
Depression *n* (%)	9 (5.7)	1 (0.7)	2 (1.7)	10 (6.3)	0.131
Falls in last 12 months *n* (%)	35 (22.4)	22 (24.4)	29 (18.7)	31 (20.5)	0.744
Coronary heart disease % (*n*)	29 (17.5)	21 (15.8)	20 (16.1)	15 (19.2)	0.918
Physical activity (h/month)	46.1 (39.9)	46.5 (39.3)	48.5 (47.6)	55.2 (44.2)	0.144
Income (euros/month)	830 (310)	861 (251)	892 (301)	891 (367)	0.272
Body composition					
Fat mass (kg)	28.9 (8.5)	29.9 (8.7)	28.5 (7.9)	27.5 (9.3)	0.219
Lean mass (kg)	39.9 (4.0)	40.3 (4.39)	40.3 (4.5)	40.1 (4.2)	0.830
Dietary factors					
Baltic Sea diet score	11.6 (3.6)	12.6 (4.0)	13.9 (3.7)	15.0 (3.8)	<0.001
Fruits (g/d)	71.9 (80.9)	113.3 (114.0)	145.5 (114.3)	184.4 (123.0)	0.001
Berries (g/d)	45.7 (45.3)	45.9 (51.1)	52.7 (49.0)	51.2 (47.8)	0.557
Vegetables (g/d)	114.0 (68.09)	143.8 (85.2)	164.8 (78.8)	178.8 (79.8)	0.001
Potato (g/d)	70.7 (42.8)	82.4 (43.6)	87.2 (51.5)	94.8 (57.3)	0.001
Fiber from cereals (g/d)	15.3 (5.3)	14.6 (5.3)	14.7 (5.6)	15.8 (4.6)	0.363
Legumes and nuts (g/d)	2.7 (5.2)	4.0 (9.9)	4.6 (5.6)	9.5 (25.1)	0.001
Milk and dairy products (g/d)	1054.1 (499.0)	846.7 (384.1)	733.9 (434.2)	595.3 (386.0)	0.001
Milk with fat content <2%	825.2 (718.1)	760.6 (595.1)	858.1 (725.3)	799.8 (645.6)	0.073
Total meat intake (g/d)	77.3 (50.5)	78.9 (47.2)	70.5 (41.1)	69.8 (47.0)	0.331
Sausage (g/d)	15.9 (22.6)	18.6 (48.7)	14.9 (21.9)	14.8 (28.2)	0.579
Egg (g/d)	18.7 (15.1)	18.0 (14.9)	16.9 (21.9)	16.6 (13.6)	0.672
Fish (g/d)	46.2 (42.2)	43.8 (43.9)	42.1 (28.7)	28.8 (41.3)	0.024
Energy intake (kJ/d)	6272 (1587)	6512 (1507)	6713 (1542)	7127 (1567)	0.001
Alcohol (g/d)	11.7 (21.3)	10.7 (17.0)	8.6 (13.0)	7.6 (8.6)	0.237
Protein (g/d)	65.6 (17.5)	69.1 (18.8)	68.8 (16.7)	72.8 (19.0)	0.034
Protein (g/kg body weight/d)	0.93 (0.30)	0.95 (0.29)	0.97 (0.27)	1.05 (0.31)	0.034
Carbohydrate (g/d)	181.2 (47.0)	191.2 (45.2)	199.2 (49.2)	218.8 (47.6)	0.001
Fat (g/d)	52.8 (19.5)	53.3 (17.5)	55.5 (18.5)	56.6 (18.2)	0.380
PUFA to SFA ratio	0.39 (0.17)	0.45 (0.17)	0.48 (0.17)	0.51 (0.16)	0.001
PUFA + MUFA to SFA ratio	1.15 (0.39)	1.29 (0.36)	1.36 (0.47)	1.41 (0.33)	0.001
Vitamin D (μg/d)	7.76 (4.49)	7.83 (5.12)	7.82 (5.37)	7.12 (4.63)	0.726
Vitamin E (mg/d)	7.7 (3.1)	8.3 (3.2)	9.2 (4.2)	10.5 (5.0)	0.001
Vitamin C (mg/d)	87.0 (58.4)	92.9 (55.4)	112.0 (70.0)	120.9 (54.7)	0.001
Total carotene (μg/d)	1934 (1721)	2624 (157)	2685 (1819)	2948 (1963)	0.001

Data are presented as mean (SD) or proportions or *n* (%). ANOVA and Chi square tests were used to evaluate the differences in participant characteristics and dietary factors among Mediterranean diet score quartiles. Adjusted for age and energy intake

Q quartile, *BMI* Body Mass Index, *PUFA* polyunsaturated fatty acid, *MUFA* monounsaturated fatty acids, *SFA* saturated fatty acids

Table 4 Baseline muscle mass and physical function measures across the Baltic Sea and Mediterranean diet scores quartiles

	Baltic sea diet score quartiles				P_{trend}	
	Q1 (≤9) *n* 146	Q2 (10–13) *n* 125	Q3 (14–15) *n* 129	Q4 (≥16) *n* 107	Model 1	Model 2
RSMI (kg/m^2)	6.65 (0.64)	6.76 (0.66)	6.81 (0.66)	6.60 (0.65)	0.725	0.707
Total body LM (kg)	39.68 (4.43)	39.65 (3.90)	40.62 (4.42)	41.20 (3.91)	0.064	0.044
Walking speed (m/s)	1.59 (0.33)	1.68 (0.28)	1.72 (0.31)	1.81 (0.31)	0.007	0.006
Chair rises	7.71 (3.14)	7.59 (3.0)	7.70 (2.87)	7.98 (2.45)	0.214	0.831
One leg stance for 30 s	17.48 (10.16)	18.53 (10.85)	19.32 (11.27)	20.11 (9.76)	0.047	0.050
SPPB	5.77 (2.01)	6.21 (1.80)	6.36 (1.91)	6.47 (1.64)	0.022	0.034
LBMQ	0.12 (0.03)	0.13 (0.02)	0.13 (0.02)	0.14 (0.02)	0.041	0.017
Grip strength (kPa)	26.05 (5.21)	25.47 (4.71)	25.58 (4.42)	26.43 (4.56)	0.617	0.255
Knee extension (kg)	298.17 (96.51)	297.33 (72.43)	311.46 (93.36)	303.14 (78.51)	0.652	0.771
Mobility disability *n* (%) [a]	62 (45.6)	46 (37.4)	39 (33.1)	31 (31.0)	0.061	0.051
Ability to squat *n* (%) [a]	133 (92.4)	121 (97.6)	123 (95.3)	104 (97.2)	0.143	0.322
Sarcopenia *n* (%) [a]	31 (21.4)	36 (28.8)	27 (25.2)	24 (18.6)	0.148	0.317
	Mediterranean diet score quartiles				P_{trend}	
	Q1 (≤3) *n* 160	Q2 (4) *n* 147	Q3 (5–6) *n* 117	Q4 (≥7) *n* 79	Model 1	Model 2
RSMI (kg/m^2)	6.77 (0.70)	6.70 (0.54)	6.69 (0.66)	6.76 (0.68)	0.837	0.924
Total body LM (kg)	39.80 (3.93)	40.0 (4.0)	40.2 (4.7)	40.3 (4.2)	0.624	0.720
Walking speed (m/s)	1.59 (0.27)	1.66 (0.28)	1.68 (0.31)	1.78 (0.38)	0.013	0.041
Chair rises	7.68 (2.85)	7.73 (2.96)	7.74 (2.61)	8.42 (2.36)	0.279	0.846
One leg stance for 30 s	18.81 (10.5)	18.59 (11.03)	19.93 (9.07)	19.91 (9.70)	0.418	0.655
SPPB	6.07 (0.16)	6.22 (0.17)	6.34 (0.19)	6.38 (0.23)	0.195	0.450
LBMQ	0.12 (0.02)	0.13 (0.02)	0.13 (0.01)	0.14 (0.02)	0.053	0.017
Grip strength (kPa)	24.80 (0.43)	25.58 (0.44)	26.23 (0.49)	26.24 (0.61)	0.081	0.144
Knee extension (kg)	4.21 (1.23)	4.16 (1.11)	4.29 (1.02)	4.61 (1.48)	0.250	0.179
Mobility disability *n* (%) [a]	58 (36.9)	44 (35.5)	50 (40.2)	22 (30.1)	0.443	0.490
Ability to squat *n* (%) [a]	155 (93.4)	127 (96.9)	118 (96.7)	76 (97.4)	0.319	0.225
Sarcopenia *n* (%) [a]	43 (25.9)	31 (22.6)	30 (25.0)	14 (17.9)	0.868	0.960

ANCOVA was used to measure the mean and SD for continuous outcome variables

RSMI relative skeletal muscle index, *LM* lean mass, *LBMQ* lower body muscle quality, *SPPB* short physical performance battery. P_{trend} was based on a linear trend across Baltic Sea and Mediterranean diet score quartiles by using the median value in each category as a continuous variable in the linear regression model as exposure. Model 1 was adjusted for age and energy intake. Model 2 was adjusted for variables in model 1 plus smoking, total physical activity, hormone therapy, osteoporosis, rheumatoid arthritis, coronary heart disease, income per month and fat mass percentage

[a]Chi-square was used to calculate n (%) for categorical outcomes

Association of MED score and sarcopenia indices at the baseline and over 3-year follow-up

Women in the higher quartiles of MED score had significantly faster walking speed 10 m (η^2 = 0.040, P_{trend} = 0.041), greater LBMQ (η^2 = 0.020, P_{trend} = 0.017) at the baseline (Table 4; Supplemental Table 2). In prospective analysis, women in the lowest quartile of MED score lost more RSMI (P_{trend} = 0.001) and total body LM (P_{trend} = 0.008) as compared to those in higher quartiles (Fig. 2). When using MED score as a continuous variable, a significant positive association was observed with walking speed and knee extension at the baseline and with proportional changes of RSMI and total body LM over the 3-year follow-up (Supplemental Table 3).

The interaction of MED score with vitamin D and calcium supplementation was not significant ($P \geq 0.730$). In the separate analysis using only the control group, women in the lowest quartile of MED score had higher loss of RSMI (P_{trend} = 0.007) and total body LM (P_{trend} = 0.001) compared to those in higher quartiles over the 3-year follow-up (Supplemental Table 4). We observed the similar results using the MED score as continuous variable (data not shown).

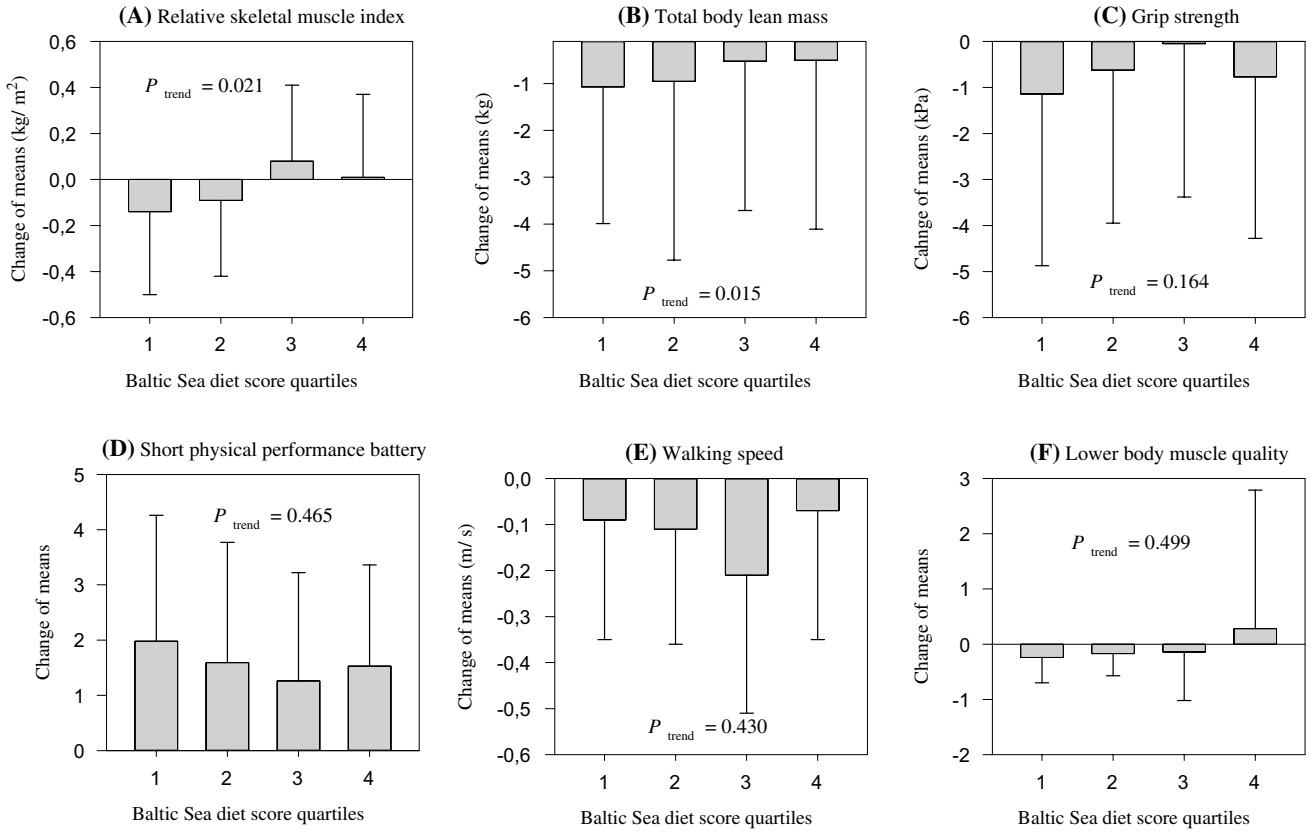

Fig. 1 Changes of muscle mass and physical function measures across Baltic Sea dietary score quartiles. Values are means with their standard errors represented by vertical bars. P_{trend} was based on a linear trend across Baltic Sea diet score quartiles by using the median value in each category as a continuous variable in the linear regression model as exposure. Model was adjusted for age, energy intake, smoking, total physical activity, hormone therapy, osteoporosis, rheumatoid arthritis, coronary heart disease, income per month, fat mass percentage, baseline variables, and intervention group. Median score value in quartiles are Q1 (8), Q2 (12), Q3 (14), Q4 (18)

Association of BSD and MED score components with sarcopenia indices

We assessed further the associations of the BSD and MED score components with total body LM and PF at the baseline and over the 3-year follow-up with same adjustment as in model 2 (age, energy intake, smoking, total physical activity, hormone therapy, osteoporosis, rheumatoid arthritis, income per month, and fat mass percentage). Results showed no significant associations except that higher total fruit and vegetable (excluding potato) consumptions were positively associated (mean difference ≥ 0.08 and $P \leq 0.049$) with walking speed 10 m, while higher alcohol consumption was negatively associated with walking speed 10 m at the baseline (mean difference $= -0.30$ and $P = 0.034$) (data not shown).

Discussion

This cross-sectional and prospective study addressed the associations of BSD and MED with sarcopenia indices in elderly women. Findings of our study indicated that women with the lower adherence to BSD and MED lost more RSMI and total body LM as compared to those with higher adherence over the 3-year follow-up. The cross-sectional results showed that better adherence to BSD was associated with greater total body LM, faster walking speed 10 m, longer one leg stance performance, higher SPPB score, and greater LBMQ at the baseline. Those with higher adherence to BSD tended to have lower risk of mobility disability. Further, women with higher adherence to MED had faster walking speed 10 m and greater LBMQ at the baseline. One explanation to the attenuation observed in the prospective analysis could be the small changes in PF

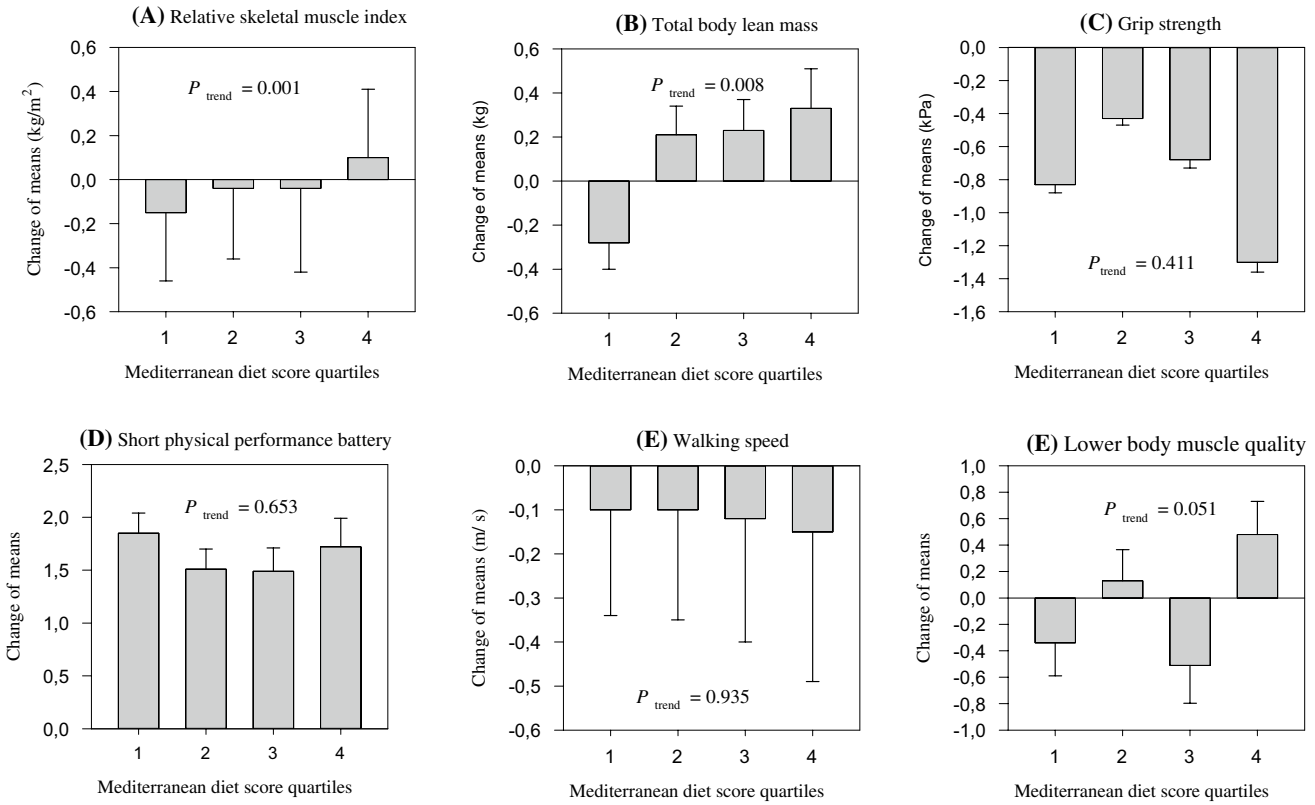

Fig. 2 Changes of muscle mass and physical function measures across Mediterranean diet score quartiles. Values are means with their standard errors represented by vertical bars. P_{trend} was based on a linear trend across Mediterranean diet score quartiles by using the median value in each category as a continuous variable in the linear regression model as exposure. Model was adjusted for age, energy intake, smoking, total physical activity, hormone therapy, osteoporosis, rheumatoid arthritis, coronary heart disease, income per month, fat mass percentage, baseline variables, and intervention group. Median score value in quartiles are Q1 (3), Q2 (4), Q3 (5), Q4 (6)

measures over of the 3-year follow-up. The associations of the components of BSD and MED with muscle mass and PF measures were not significant; except for the association of fruits and vegetables with walking speed 10 m. Therefore, consistent with previous studies, the overall quality of diet might have more importance than only one food item [11, 30], and it might not be sufficient to measure only one food item.

Vitamin D supplementation can potentially affect muscle mass and PF in the elderly [31–33]. Given that about half of the subject in this study received calcium and vitamin D supplementation over the 3-year follow-up, we performed stratified analysis to evaluate the association of BSD and MED with sarcopenia indices only in the control group. Among women in the control group, lower adherence to BSD was associated with greater loss of RSMI and total body LM. Those women in higher BSD scores had better SPPB, better results in squat test and lower risk of sarcopenia over the 3-year follow-up. Lower adherence to MED was associated also with greater loss of RSMI and total body LM. Further analysis in the present data showed no significant effect of vitamin D and calcium supplementation on muscle mass and PF measures (M.I, A.E and J.S, unpublished results), which was also explained elsewhere [18, 34]. Therefore, the possibility of vitamin D and calcium supplementation modification on the muscle mass and PF measures is not likely in this study. However, previous findings regarding the effect of vitamin D supplementation on sarcopenia are inconclusive [35, 36]. A recent meta-analysis suggested that vitamin D has no significant effect on muscle mass [35]. However, in a cross-sectional study that included 2258 men and 3005 women aged ≥50 years, sarcopenia (defined as appendicular skeletal muscle mass/body weight (BW) <2 standard deviations below gender-specific means for young adults) was inversely associated with serum vitamin D levels in women, but not in men [37]. In another cohort study vitamin D status was associated with functional limitations cross-sectionally and longitudinally in individuals aged 55–65 years and those 65 years and older [38].

Our results are consistent with the existing, although limited, literature that supports an association between diet quality and PF in the elderly. In the recent prospective study among ageing women and men, a higher adherence

to BSD was associated with better physical performance 10 years later, including the 6-min walk, arm curl and chair stand tests, reflecting better aerobic endurance and upper- and lower-body strength [16]. Results of the InCHIANTI study [15], indicated that higher adherence to MED was associated with better lower body performance. Participants with higher adherence experienced less decline in SPPB score, at the 3, 6 and 9 year follow-up, compared to those with lower adherence. Higher adherence to MED at baseline was also associated with a lower risk of low physical activity and low walking speed but not with feelings of exhaustion and poor muscle strength. In the study by Shahar et al. [13] among 2225 well-functioning men and women aged ≥ 70 years, over 8 years of follow-up, both usual and rapid 20 m walking speed declined in the three MED adherence groups; however, the group with the highest adherence to the MED performed better at all time points.

Multiple mechanisms can explain the effects of BSD and MED on LM and PF in the elderly. Oxidative stress is a major mechanism implicated in the pathogenesis of sarcopenia, and aging muscle shows increased oxidative damage to DNA, protein, and lipids [39, 40]. High intake of fruits and vegetables in MED and BSD could provide antioxidants such as vitamin C, vitamin E and carotenoids. Carotenoids and antioxidants quench free radicals, reduce damage from reactive oxygen species, and appear to modulate redox-sensitive transcription factors (such as NF-κB, IL-6 and other proinflammatory cytokines) [6, 41, 42]. Recent epidemiological studies in community-dwelling older adults show that low serum/plasma carotenoids and vitamin E are independently associated with low skeletal muscle strength and the development of walking disability [43–45]. Results from two independent studies including Finnish participants aged 25–74 years ($n = 4579$), and the Helsinki Birth Cohort Study ($n = 1911$) showed that among individuals with higher adherence to BSD score hs-CRP concentration was lower compared to those with lower adherence [46]. There were significantly higher intakes of carotenoids, vitamin E and vitamin C in the highest quartiles of BSD and MED score (Tables 2, 3). In contrast, intakes of fat and processed meat are related to increased oxidation and inflammation [47]. Those in the lowest BSD score quartile had significantly higher fat and sausage intakes. However, fat, total meat and sausage intakes were not significantly different by MED score quartiles. This can be explained by that total fat intake was not included in MED score construction. In addition, dietary fat quality might have more importance than the total fat intake. Both MED and BSD are characterized by high PUFA and MUFA intake to SFA ratio [8, 11]. Intake of n-3 PUFA (EPA, DHA and ALA) which are known for their anti-inflammatory properties were related to leg strength and chair-rise capacity [48], and similarly consumption of fatty fish (as enriched source of PUFAs) to grip strength [49]. In addition, n-3 PUFAs have potential to stimulate the muscle protein synthesis and subsequently muscle mass production [50]. In the InCHIANTI study, serum levels of n-3 PUFA were related to physical performance [51]. This suggests that the anti-inflammatory actions of n-3 PUFA may play a role in the prevention of sarcopenia.

Compared to younger adults, older adults have lower rates of protein synthesis and propensity to eat less, leading to lower protein intake [52]. We have previously shown that dietary protein intake was positively associated with LM, appendicular LM and trunk LM [34]. Moreover, in this data those women with protein intake higher than 0.8 g/kg BW/day had less decline in handgrip strength/ BW, one leg stance and walking 6 m over 3 years (significances were attenuated after controlling for FM) [18]. The overall dietary protein intake was higher in the highest BSD score quartile 1.10 g/kg BW than in the lowest (0.87 g/kg BW); as well as in the highest MED score quartile (1.05 g/kg BW) than in the lowest quartile (0.93 g/kg BW) (Tables 2, 3). Difference in protein intake can partially explain the mechanism by which women with lower adherence to BSD and MED had greater decline in total body LM and RSMI. The difference in protein intake between lowest and highest quartile of BSD score (16 g/d) was larger compared to MED score quartiles (7.2 g/d). However, women in the highest MED score quartile had increase in both total body LM and RSMI, whereas those in the highest BSD score quartile had a modest increase in RSMI and less decline in total body LM. This might be due to unrevealed stronger interaction of protein intake with other nutrients or foods in the highest quartiles of MED score compared to BSD score. Also, the baseline characteristics of women in the highest MED score quartiles might be different from those in the highest BSD score quartile which is not captured in our study.

In our study, associations of MED and BSD with muscle strength measures (handgrip strength and chair rises) were not significant. Thus, it might be that higher adherence to MED and BSD can be more related to preserving lower extremity muscle strength (walking speed and one leg stance) rather than upper extremity muscle strength [16]. Women with higher adherence to BSD tended to have lower mobility disability as compared to those with lower adherence. It has been shown that intake of dietary long-chain n-3 PUFAs was associated with decreased risk of developing rheumatoid arthritis as chronic inflammatory disease of joints that can affect the walking speed in the elderly [53], which may partially explain the MED and mobility disability association [54].

There were general similarities between the components of BSD and MED in our study as they are rich in fruits,

vegetables, and fiber. Findings of our study in a non-Mediterranean country (Finland) suggested that either BSD or MED (adapted to Nordic foods consumption) could be beneficial to prevent sarcopenia in Finnish elderly women. However, we observed stronger associations in the analysis using BSD as compared to MED. Thus, due to the diversity in construction of MED and difficulty of its application in Nordic countries alongside with food culture differences; BSD could facilitate recommending a healthy diet for elderly Nordic populations.

Current study has important strengths including the use of dual-energy X-ray absorptiometry to obtain total and regional body composition measures, use of extensive indices of sarcopenia, including LM, RSMI and PF measures as well as reporting both cross-sectional and prospective results. The PF measures and their changes have been applied and explained in this data set previously [18]. We have used categories based on distribution for BSD and MED rather than cut-off points based on recommendation.

There are some potential limitations that need to be considered while interpreting the results. First, food records were collected on consecutive days rather than non-consecutive days and only at the baseline, which may be insufficient to capture long-term dietary exposures. The imprecision of the dietary data may have reduced the ability to detect more robust associations between dietary scores and changes in PF. Second, lower adherence to BSD and MED might be linked to the inferior health of a participant and since we do not have information on the participants' earlier health status and eating patterns, reverse causality is possible. For instance, those with higher BSD score were more physically active than those with lower BSD score. Third, even though we were able to adjust for a wide range of potential confounders, the possibility of other residual confounding cannot be excluded. The study included relatively healthy elderly women from a rather homogenous Finnish population, so caution should be taken in generalization of the results to the entire elderly population. Fourth, we used income per month as a proxy of socioeconomic status. However, association of income and dietary scores were not significant. Finally, the observational nature of our study did not allow us to evaluate a causal association between dietary scores and changes in RSMI and LM.

This study has encouraging public health message that adherence to healthy BSD and MED could prevent sarcopenia with preserving LM. It is well documented that the loss of LM is associated with critical illnesses and sarcopenia. Further, although only at cross-sectional setting, a healthy diet was associated with better PF measures in elderly women. Previous studies have shown positive relation of BSD and MED with better physical performance, lower abdominal obesity, cognitive function and lower risk of metabolic syndrome [8, 10, 11, 16]. Thus, healthy MED or BSD seem to enhance overall health, physical performance as well as preventing sarcopenia in the elderly.

In conclusion, a higher adherence to BSD and MED might be beneficial in prevention of sarcopenia, since women with lower adherence to BSD and MED lost more RSMI and total body LM compared to others. However, associations of BSD and MED with PF measures were more pronounced in cross-sectional setting. This highlights the importance of a whole diet, not only single foods or nutrients. Further longitudinal studies are warranted to substantiate these recommendations.

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Author contributions H.K and M.T designed the original OSTPRE-FPS study. M.I, A.E, planned the present analysis together and collaborated on drafting the manuscript. M.I carried out the statistical analysis, and summarized the results in tables and figures. J.S, J.M, T.R, H.K, M.T critically revised the manuscript for important intellectual content. M.I, A.E had primary responsibility for the final content.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. Prado CMM, Wells JCK, Smith SR, Stephan BCM, Siervo M (2012) Sarcopenic obesity: a critical appraisal of the current evidence. Clin Nutr 31(5):583–601
2. Denison HJ, Cooper C, Sayer AA, Robinson SM (2015) Prevention and optimal management of sarcopenia: a review of combined exercise and nutrition interventions to improve muscle outcomes in older people. Clin Interv Aging 10:859–869
3. Cruz-Jentoft AJ, Landi F, Schneider SM, Zuniga C, Arai H, Boirie Y et al (2014) Prevalence of and interventions for sarcopenia in ageing adults: a systematic review. Report of the International Sarcopenia Initiative (EWGSOP and IWGS). Age Ageing 43(6):748–759
4. Cesari M, Landi F, Vellas B, Bernabei R, Marzetti E (2014) Sarcopenia and physical frailty: two sides of the same coin. Front Aging Neurosci 6:192
5. Mathers JC (2015) Impact of nutrition on the ageing process. Br J Nutr 113(Suppl):S18–S22
6. Rondanelli M, Faliva M, Monteferrario F, Peroni G, Repaci E, Allieri F, et al (2015) Novel insights on nutrient management of sarcopenia in elderly. BioMed Res Int 2015:524948
7. Mursu J, Steffen LM, Meyer KA, Duprez D, Jacobs DR Jr (2013) Diet quality indexes and mortality in postmenopausal women: the Iowa Women's Health Study. AJCN 98(2):444–453
8. Sofi F, Macchi C, Abbate R, Gensini GF, Casini A (2014) Mediterranean diet and health status: an updated meta-analysis

and a proposal for a literature-based adherence score. PHN 17(12):2769–2782
9. Ruusunen A, Lehto SM, Tolmunen T, Voutilainen S, Tuomainen T (2013) Adherence to the baltic sea diet is associated with lower prevalence of elevated depressive symptoms. Eur Psychiatry 28(Supplement 1):1
10. Kanerva N, Kaartinen NE, Schwab U, Lahti-Koski M, Männistö S (2014) The Baltic Sea Diet Score: a tool for assessing healthy eating in Nordic countries. PHN 17(8):1697–1705
11. Kanerva N, Kaartinen NE, Schwab U, Lahti-Koski M, Männistö S (2013) Adherence to the Baltic Sea diet consumed in the Nordic countries is associated with lower abdominal obesity. BJN 109(03):520–528
12. Bere E, Brug J (2009) Towards health-promoting and environmentally friendly regional diets–a Nordic example. PHN 12(01):91–96
13. Shahar DR, Houston DK, Hue TF, Lee J, Sahyoun NR, Tylavsky FA, et al (2012) Adherence to mediterranean diet and decline in walking speed over 8 years in community-dwelling older adults. JAGS 60(10):1881–1888
14. Hashemi R, Motlagh AD, Heshmat R, Esmaillzadeh A, Payab M, Yousefinia M et al (2015) Diet and its relationship to sarcopenia in community dwelling Iranian elderly: a cross sectional study. Nutrition 31(1):97–104
15. Milaneschi Y, Bandinelli S, Corsi AM, Lauretani F, Paolisso G, Dominguez LJ et al (2011) Mediterranean diet and mobility decline in older persons. Exp Gerontol 46(4):303–308
16. Perälä MM, von Bonsdorff M, Mannisto S, Salonen MK, Simonen M, Kanerva N, et al (2016) A healthy Nordic diet and physical performance in old age: findings from the longitudinal Helsinki Birth Cohort Study. BJN 115(5):878–886
17. Kärkkäinen M, Tuppurainen M, Salovaara K, Sandini L, Rikkonen T, Sirola J et al (2010) Effect of calcium and vitamin D supplementation on bone mineral density in women aged 65–71 years: a 3-year randomized population-based trial (OSTPRE-FPS). Osteoporos Int 21(12):2047–2055
18. Isanejad M, Mursu J, Sirola J, Kröger H, Rikkonen T, Tuppurainen M, et al (2016) Dietary protein intake is associated with better physical function and muscle strength among elderly women. BJN 115(7):1281–1291
19. Erkkilä AT, Jarvinen R, Karvonen H, Keronen L, Tuppurainen MT (2012) Validation of a semi-quantitative FFQ using food records as a reference in older women in the Kuopio Fracture Prevention Study (OSTPRE-FPS). PHN 15(4):635–639
20. Tognon G, Rothenberg E, Eiben G, Sundh V, Winkvist A, Lissner L (2011) Does the Mediterranean diet predict longevity in the elderly? A Swedish perspective. Age 33(3):439–450
21. Bamia C, Lagiou P, Buckland G, Grioni S, Agnoli C, Taylor AJ et al (2013) Mediterranean diet and colorectal cancer risk: results from a European cohort. Eur J Epidemiol 28(4):317–328
22. Sjöblöm S, Suuronen J, Rikkonen T, Honkanen R, Kröger H, Sirola J (2013) Relationship between postmenopausal osteoporosis and the components of clinical sarcopenia. Maturitas 75(2):175–180
23. Lohman M, Tallroth K, Kettunen JA, Marttinen MT (2009) Reproducibility of dual-energy X-ray absorptiometry total and regional body composition measurements using different scanning positions and definitions of regions. Metabolism 58(11):1663–1668
24. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F et al (2010) Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing 39(4):412–423
25. Kwon S, Perera S, Pahor M, Katula JA, King AC, Groessl EJ, et al (2009) What is a meaningful change in physical performance? Findings from a clinical trial in older adults (the LIFE-P study). JNHA 13(6):538–544
26. Vasunilashorn S, Coppin AK, Patel KV, Lauretani F, Ferrucci L, Bandinelli S et al (2009) Use of the Short Physical Performance Battery Score to predict loss of ability to walk 400 meters: analysis from the InCHIANTI study. J Gerontol A 64(2):223–229
27. Visser M, Kritchevsky SB, Goodpaster BH, Newman AB, Nevitt M, Stamm E, et al (2002) Leg muscle mass and composition in relation to lower extremity performance in men and women aged 70 to 79: the health, aging and body composition study. JAGS 50(5):897–904
28. Shin S, Valentine RJ, Evans EM, Sosnoff JJ (2012) Lower extremity muscle quality and gait variability in older adults. Age Ageing 41(5):595–599
29. Richardson JT (2011) Eta squared and partial eta squared as measures of effect size in educational research. Educ Res Rev 6(2):135–147
30. Mozaffarian D, Hao T, Rimm EB, Willett WC, Hu FB (2011) Changes in diet and lifestyle and long-term weight gain in women and men. N Engl J Med 364(25):2392–2404
31. Rizzoli R, Stevenson JC, Bauer JM, van Loon LJ, Walrand S, Kanis JA et al (2014) The role of dietary protein and vitamin D in maintaining musculoskeletal health in postmenopausal women: a consensus statement from the European Society for Clinical and Economic Aspects of Osteoporosis and Osteoarthritis (ESCEO). Maturitas 79(1):122–132
32. Salles J, Chanet A, Giraudet C, Patrac V, Pierre P, Jourdan M et al (2013) 1,25(OH)2-vitamin D3 enhances the stimulating effect of leucine and insulin on protein synthesis rate through Akt/PKB and mTOR mediated pathways in murine C2C12 skeletal myotubes. Mol Nutr Food Res 57(12):2137–2146
33. Mason C, Xiao L, Imayama I, Duggan CR, Foster-Schubert KE, Kong A et al (2013) Influence of diet, exercise, and serum vitamin d on sarcopenia in postmenopausal women. Med Sci Sports Exerc 45(4):607–614
34. Isanejad M, Mursu J, Sirola J, Kröger H, Rikkonen T, Tuppurainen M et al (2015) Association of protein intake with the change of lean mass among elderly women: the Osteoporosis Risk Factor and Prevention–Fracture Prevention Study (OSTPRE-FPS). J Nutr Sci 4:e41
35. Beaudart C, Buckinx F, Rabenda V, Gillain S, Cavalier E, Slomian J et al (2014) The effects of vitamin D on skeletal muscle strength, muscle mass, and muscle power: a systematic review and meta-analysis of randomized controlled trials. J Clin Endocrinol Metab 99(11):4336–4345
36. Mithal A, Bonjour JP, Boonen S, Burckhardt P, Degens H, El Hajj Fuleihan G et al (2013) Impact of nutrition on muscle mass, strength, and performance in older adults. Osteoporos Int 24(5):1555–1566
37. Park S, Ham J, Lee B (2014) A positive association of vitamin D deficiency and sarcopenia in 50 year old women, but not men. Clin Nutr 33(5):900–905
38. Sohl E, Van Schoor N, De Jongh R, Visser M, Deeg D, Lips P (2013) Vitamin D status is associated with functional limitations and functional decline in older individuals. JCEM 98(9):E1483–E1490
39. Robinson S, Cooper C, Aihie Sayer A (2012) Nutrition and sarcopenia: a review of the evidence and implications for preventive strategies. J Aging Res 2012:510801
40. Sims-Robinson C, Hur J, Hayes JM, Dauch JR, Keller PJ, Brooks SV, et al (2013) The role of oxidative stress in nervous system aging. PLoS ONE 8(7):e68011
41. Lauretani F, Semba RD, Bandinelli S, Dayhoff-Brannigan M, Lauretani F, Corsi AM et al (2008) Carotenoids as protection against disability in older persons. Rejuvenation Res 11(3):557–563

42. Alipanah N, Varadhan R, Sun K, Ferrucci L, Fried LP, Semba RD (2009) Low serum carotenoids are associated with a decline in walking speed in older women. JNHA 13(3):170–175
43. Semba RD, Lauretani F, Ferrucci L (2007) Carotenoids as protection against sarcopenia in older adults. Arch Biochem Biophys 458(2):141–145
44. Bartali B, Frongillo EA, Bandinelli S, Lauretani F, Semba RD, Fried LP et al (2006) Low nutrient intake is an essential component of frailty in older persons. J Gerontol A 61(6):589–593
45. Ble A, Cherubini A, Volpato S, Bartali B, Walston JD, Windham BG et al (2006) Lower plasma vitamin E levels are associated with the frailty syndrome: the InCHIANTI study. J Gerontol A 61(3):278–283
46. Kanerva N, Loo B, Eriksson JG, Leiviskä J, Kaartinen NE, Jula A et al (2014) Associations of the Baltic Sea diet with obesity-related markers of inflammation. Ann Med 46(2):90–96
47. Calder PC, Ahluwalia N, Brouns F, Buetler T, Clement K, Cunningham K, et al (2011) Dietary factors and low-grade inflammation in relation to overweight and obesity. BJN 106(S3):S1–S78
48. Rousseau JH, Kleppinger A, Kenny AM (2009) Self-reported dietary intake of omega-3 fatty acids and association with bone and lower extremity function. JAGS 57(10):1781–1788
49. Robinson SM, Jameson KA, Batelaan SF, Martin HJ, Syddall HE, Dennison EM, et al (2008) Diet and its relationship with grip strength in community-dwelling older men and women: the Hertfordshire Cohort Study. JAGS 56(1):84–90
50. Smith GI, Atherton P, Reeds DN, Mohammed BS, Rankin D, Rennie MJ et al (2011) Dietary omega-3 fatty acid supplementation increases the rate of muscle protein synthesis in older adults: a randomized controlled trial. Am J Clin Nutr 93(2):402–412
51. Abbatecola AM, Cherubini A, Guralnik JM, Lacueva CA, Ruggiero C, Maggio M et al (2009) Plasma polyunsaturated fatty acids and age-related physical performance decline. Rejuvenation Res 12(1):25–32
52. Nowson C, O'Connell S (2015) Protein requirements and recommendations for older people: a review. Nutrients 7(8):6874–6899
53. Calder PC (2015) Marine omega-3 fatty acids and inflammatory processes: effects, mechanisms and clinical relevance. Biochim Biophys Acta 1851(4):469–484
54. Talegawkar SA, Bandinelli S, Bandeen-Roche K, Chen P, Milaneschi Y, Tanaka T et al (2012) A higher adherence to a Mediterranean-style diet is inversely associated with the development of frailty in community-dwelling elderly men and women. J Nutr 142(12):2161–2166