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ORIGINAL ARTICLE

DIETARY NUTRIENT DENSITY AND FRAILTY SYNDROME IN ELDERLY

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ABSTRACT

Background. Diet quality is an important determinant of healthy aging. The Elderly Nutrient Rich Food (E-NRF7.3) score, based on European dietary recommendations, assesses nutrient density in the diets of older adults. The aim of the study was to investigate the relationship between the nutrient density of the diet and the occurrence of frailty syndrome (FS) among the elderly.

Material and Methods. The study included 140 adults aged ≥ 60 years. Dietary nutrient density was assessed using the E-NRF7.3 algorithm based on three-day dietary records. Frailty syndrome was evaluated according to Fried's five criteria. Frail and pre-frail individuals were combined into one group ("FS+preFS"), while participants without FS symptoms formed the "noFS" group.

Results. At least one FS symptom was identified in 45% of participants. In univariate analysis, the "FS+preFS" group was significantly older, less physically active, reported poorer health, and had higher rates of smoking, dietary supplement use, and hypertension. They were less likely to spend time outdoors and be exposed to sunlight. Robust participants had higher intakes of water, polyunsaturated fatty acids, sodium, calcium, iodine, thiamine, and riboflavin, and slightly higher intakes of plant protein, dietary fiber, iron, and zinc. Regression analysis, adjusted for sex revealed such associations for dietary fiber, calcium, sodium, and trend for potassium; adjusted for sex and age revealed only for dietary fiber and calcium. The mean E-NRF7.3 score was 13.9 in the "noFS" group and 14.9 in the "FS+preFS" group ($p = 0.592$ univariate analysis; $p = 0.803$ regression analysis).

Conclusions. Despite the higher intake of some nutrients considered recommended, such as dietary fiber and calcium, by people without symptoms of frailty, we did not demonstrate that a higher E-NRF7.3 score is associated with the number of frailty symptoms.

Keywords: *frailty syndrome, nutrient density, elderly, going outside, lifestyle*

INTRODUCTION

Almost every country in the world is experiencing growth in population ageing. The global number of elderly people, aged 65 and above, is projected to 2.2 billion in 2080, compared to 703 million in 2019 and 1.1 billion in 2023 [1]. Unfortunately, age-related diseases, especially those that make independent life difficult, including the frailty syndrome (FS), often require regular help from a family member or even require provide a constants health care [2]. Therefore, healthy aging activities should focus on prevention and health promotion, including improving the quality of the diet [3]. Dietary habits are associated with a risk of chronic diseases and can potentially be a major contributor to mortality [4].

Frailty syndrome is weakening of the physical and/or mental condition, with increase the risk of institutionalization and mortality, but also is decreasing life quality [5]. This syndrome is more prevalent in older women, than men. Moreover, physical inactivity is an independent factor associated with FS, common to both men and women, but the differences between gender are multifaceted [6]. Additionally, it is disturbing that the presence of FS can reduce the survival rate in women, but not in men [7].

The aging process and the occurrence of FS are also closely related to diet. Protein and energy deficiency in the diet may increase the risk of developing or worsening symptoms of FS, although the results are not conclusive. However, low energy intake can cause deficiencies in essential nutrients, muscle mass and strength wasting, and further-advancing frailty syndrome [8]. With age, energy needs decrease, while the need for important nutrients increases or remains unchanged [9]. Beneficial nutrients in the context of

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FS include, among others, vitamin D [10] or folate [11]. Therefore, properly balancing the diet is a big challenge, as it should have a high nutrient density. Nutrient density refers to the amount of beneficial nutrients in a food or diet relative to its calorie content. High nutrient density concerns to a diet that is rich in vitamins, minerals, and other essential nutrients, while being relatively low in calories. One of the most well-known methods for calculating nutrient density is the Nutrient Rich Foods (NRF9.3) index, developed for the adult population and based on Dietary Guidelines for Americans [12]. Recently, a new indicator dedicated to older people, the Elderly Nutrient Rich Food (E-NRF7.3) score, was created, using European dietary recommendations. The main difference is that the E-NRF7.3 algorithm takes into account the nutrients that are deficient in European seniors – vitamin D and folates [9].

The aim of this study was to analyze the relationship between the occurrence of frailty syndrome and the nutrient density of the diet of older people.

MATERIAL AND METHODS

Participants

The study was conducted in two research centers in Poland, Rzeszow University and Warsaw University of Life Sciences, between 2021 and 2024, in the winter-spring periods, among 151 independently living individuals. The inclusion criteria for participation included: age ≥ 60 years old, able to walk and missing advanced dementia. All respondents were volunteers and signed informed consent to participate in the study. Two meetings were held with each respondent.

The protocol of the study was approved on September 30, 2019, by the Ethical Committee of the Warsaw University of Life Sciences (Resolution No. 50p/2019). This study was carried out in accordance with the Declaration of Helsinki of 2024 (https://www.wma.net/policies-post/wma-declaration-of-helsinki/).

General data

Sociodemographic, health and lifestyle factors were collected using questionnaire by trained research assistants, during the first visit with respondents. The questionnaire included 39 questions contained in the following sections: 1. socio-demographic characteristics, like sex, age or marital status, 2. health condition, among other self-reported health, occurrence of chronic diseases, 3. lifestyle status, including sunlight exposure last summer, alcohol intake or dietary supplements use. Body Mass Index (BMI) was calculated as weight (in kg) divided by the square of height (in m).

Frailty assessment

A Cardiovascular Health Study Scale (CHS) was applied to assess the frailty syndrome [5]. The five frailty components were operationalized as follows: 1) unintentional weight loss was indicated by a self-reported decrease of > 4.5 kg or 5% of body mass in the past year; 2) muscle weakness was determined by averaging three consecutive maximum grip strength trials of the dominant hand using a handheld dynamometer, with cut-offs adjusted for sex and BMI; 3) exhaustion was evaluated through two self-reported questions addressing energy levels over the last fortnight; 4) walking speed was assessed across 4.5 meters, accounting for sex and height; 5) physical inactivity was captured via a 1-year recall questionnaire, where participating in less than 2 hours of sports or exercise per week indicated low activity. Only 140 respondents agreed to conduct an analysis of the occurrence of FS. Due to the small number of frail participants, we combined frail and pre-frail elderly into one group, "FS+preFS". Participants without any symptoms of FS are in "noFS" group.

Nutrient density assessment

Daily intake, including dietary supplements use, was assessed by the three-day record method – one weekend day and two weekdays. On the first visit to the research center, the respondents were instructed on how to complete the food record questionnaire. Each participant completed a questionnaire at home. During second visit, the research assistant verified correctness of completing the questionnaire. An analysis of data from the food record questionnaires was carried out based on "Food Composition Tables" [13]. Food consumption data include salt. The E-NRF7.3 algorithm, presented in Table 1, was used to calculate the nutrient density. It includes nutrients that are particularly important for the health of older people: protein, dietary fiber, folate, vitamin D, calcium, magnesium, and potassium, as well as nutrients that should be limited: saturated fat, sodium, total mono-disaccharides. The higher the E-NRF7.3 score, the higher the nutrient density per 100 kcal [9].

Statistical analysis

Pearson's *Chi*-square test was used to determine the association between the prevalence of FS and the categorical variables and the Kruskal-Wallis test was used for continuous data (age, BMI, nutrients intake, frailty elements). The mean and standard deviation (SD) were shown for continuous data and the percentage for categorical variables. Analyses relationship between FS and variables were performed for 140 people who completed all questionnaires. Association between frailty status (noFS vs. FS+preFS) and nutrients intake were examined using multivariable logistic

Table 1. Algorithms used to calculate the E-NRF7.3 index

Model	Algorithm	Comment
$NR7_{100kcal}$	$\Sigma_i = 1\text{-}7$ $(Nutrient_i/RDV_i) \times 100$	$Nutrient_i$ = content of nutrient "i" in 100-kcal edible portion; RDV_i = recommended daily values for nutrient "i"
$LIM3_{100kcal}$	$\Sigma_i = 1\text{-}3$ $(Nutrient_i/MDV_i) \times 100$	$Nutrient_i$ = content of limiting nutrient "i" in 100-kcal edible portion; MDV_i = maximum daily values for nutrient "i"
$E\text{-}NRF7.3_{100kcal}$	NR7-LIM3	Difference between sums

NR7 – nutrient-rich score consisting of 7 beneficial nutrients: protein, dietary fibre, folate, vitamin D, calcium, magnesium, and potassium; LIM3 – limited nutrient score consisting of three nutrients to limit: saturated fat, sodium, total mono-disaccharides; E-NRF – elderly nutrient-rich foods score

regression with data presented as odds ratios (ORs) and 95% confidence intervals (CIs). Nutrients used for the E-NRF score, per 100 kcal, were included in the regression analysis. The regression models included the nutrients simultaneously to demonstrate the importance of the diet as a whole. The model was adjusted for sex (Model 1), as well as sex and age (Model 2). The regression model of E-NRF7.3 was analyzed separately and it did not include the nutrients, but was also adjusted for sex (Model 1), as well as sex and age (Model 2). The results with p-values ≤ 0.05 were considered statistically significant and as trend $0.1 > p > 0.05$. Data was analyzed using Statistica software version 13.3 (TIBCO Software Inc., Palo Alto, CA, USA).

RESULTS

Prevalence of frailty syndrome among respondents is presented in Table 2. Only 11.5% of people, including 8.7% of men and 14.1% of women, had FS (at least 3 symptoms). With 1-2 symptoms (pre-frail) were 33.8% of elderly, including 29.0% of men and 38.0% of women, and respectively 54.7% of respondents, incl. 62.3% of men and 47.9% of women, had no FS (no symptoms). Women tend to have a higher incidence of FS ($p = 0.086$). There was no statistical significance in the occurrence of individual components of FS, as well as the number of criteria of FS met, depending on sex.

Respondents with at least 1 frailty criteria were statistically significantly older ($p = 0.003$), as well as having slightly less education ($p = 0.057$) and tend to live alone ($p = 0.083$) (Table 3).

People in the "FS+preFS" group were more likely to smoke, have lower physical activity level, poorer health, use dietary supplements, and have higher rates of hypertension, as well as being less likely to go outside during the last summer and less likely to be exposed to the sunlight, than those who were in "noFS" group ($p < 0.05$ for each comparison; Table 3).

The analysis of energy, water, micro and macronutrient intake is presented in Table 4. Individuals without frailty symptoms had significantly higher average intake of water (2542 g per day in noFS group vs. 2134 g in FS+preFS group), PUFA (12.2 g vs. 10.1 g), sodium (3467 mg vs. 2768 mg), calcium (805 mg vs. 662 mg), iodine (136 µg vs. 116 µg), thiamine (1.48 mg vs. 1.12 mg) and riboflavin (1.96 mg vs. 1.75 mg) ($p \leq 0.05$ for each comparison). Robust older adults also tended to

Table 2. Prevalence of frailty syndrome in study population

Factor	Total n = 140	Men n = 69	Women n = 71	p-value
Unintentional weight loss – Yes (%)	13.7	14.5	12.7	0.753[1)]
Low handgrip strength – Yes (%)	29.5	26.1	32.4	0.412[1)]
Exhaustion – Yes (%)	17.3	15.9	18.3	0.710[1)]
Slow walking speed – Yes (%)	12.2	10.1	14.1	0.475[1)]
Low physical activity – Yes (%)	15.1	13.0	16.9	0.522[1)]
Average number of FS components	0.81	0.72	0.89	0.205[2)]
Frailty status				0.086[1)]
Frail ≥ 3 criteria (%)	11.5	8.7	14.1	
Pre-frail 1-2 criteria (%)	33.8	29.0	38.0	
Not frail 0 criteria (%)	54.7	62.3	47.9	

tests used to determine significance between sexes: [1)] Pearson Chi^2 test, [2)] Kruskal-Wallis test

Table 3. General characteristics of participants according to frail status

Factor	Total n = 140	noFS n = 77 (55.0%)	FS+preFS n = 63 (45.0%)	p-value
Sex, women (%)	50.7	44.7	58.7	0.100[1)]
Age (years) mean ± SD	74.6 ± 5.28	73.2 ± 3.81	76.4 ± 6.25	0.003[2)]
Educational level (%) Primary Secondary Higher	 12.9 30.0 57.1	 7.9 27.6 64.5	 19.1 33.3 47.6	0.057[1)]
Living alone (%)	45.0	38.2	52.4	0.083[1)]
Occupation – Yes (%)	9.3	8.5	18.7	0.387[1)]
Residential area (%) City ≥ 100,000 inh. City < 100,000 inh. Village	 84.3 6.4 9.3	 88.2 3.9 7.9	 79.4 9.5 11.1	0.308[1)]
Self-rated physical activity (%) High Average Low	 16.4 47.9 35.7	 23.7 55.3 21.0	 7.9 38.1 54.0	< 0.001[1)]
Frequency of going outside last summer (%) < 1 time a week 1-4 times a week ≥ 5 times a week	 0.0 12.9 87.1	 0.0 2.6 97.4	 0.0 25.4 74.6	< 0.001[1)]
Exposed to sunlight last summer (%) Never Sometimes Often	 0.7 20.7 78.6	 0.0 10.4 89.6	 1.6 33.3 65.1	0.002[1)]
Use sun cream during last summer months (%) Always Often Never	 5.5 34.7 59.8	 5.6 33.3 61.1	 5.4 36.4 58.2	0.938[1)]
Frequency of going outside in the last month (%) < 1 time a week 1-4 times a week ≥ 5 times a week	 0.0 15.7 84.3	 0.0 3.9 96.1	 0.0 30.2 69.8	< 0.001[1)]
Smoking (%) Never Current smoking Smoking in the past	 46.4 11.9 41.7	 47.4 5.2 47.4	 39.7 20.6 39.7	0.023[1)]
Alcohol drinking – Yes (%)	78.8	86.8	77.8	0.159[1)]
Dietary supplement use – Yes (%)	74.3	68.8	84.1	0.014[1)]
BMI (kg/m^2) mean ± SD	26.5 ± 4.7	26.8 ± 3.9	26.2 ± 5.6	0.252[2)]
Self-rated health status (%) Good Average Poor	 50.3 37.7 12.0	 64.5 32.9 2.6	 38.1 46.0 15.9	0.001[1)]
Diabetes – Yes (%)	7.9	7.9	7.9	0.993[1)]
Hypertension – Yes (%)	61.6	48.7	71.4	0.007[1)]
Osteoporosis – Yes (%)	21.4	17.1	27.0	0.159[1)]
Osteoarthritis – Yes (%)	23.2	19.7	31.7	0.104[1)]

tests used to determine significance between frailty groups: [1)] Pearson *Chi*^{2} test, [2)] Kruskal-Wallis test; noFS – people without symptoms of frailty syndrome, FS+preFS – people at least 1 criteria of frailty syndrome

Table 4. Nutrients intake according to frail status

Factor	Total N = 140	noFS n = 77 (55.0%)	FS+preFS N = 63 (45.0%)	p-value[1)]
Total energy (kcal)	1855.5 ± 577.0	1914.1 ± 631.4	1783.9 ± 498.3	0.287
Water (g)	2358.2 ± 689.3	2541.8 ±719.8	2133.7 ± 580.5	0.002
Total protein (g)	77.6 ± 23.2	79.7 ± 23.1	74.9 ± 23.4	0.217
Animal protein (g)	50.8 ± 17.7	51.6 ± 17.4	49.7 ± 18.2	0.372
Plant protein (g)	26.3 ± 9.1	27.5 ± 10.0	24.8 ± 7.8	0.097
Fat (g)	69.3 ± 25.7	72.6 ± 26.4	65.4 ± 24.4	0.157
SFA (g)	25.6 ± 10.6	26.5 ± 10.9	24.4 ± 10.1	0.272
MUFA (g)	26.7 ± 11.1	27.8 ± 11.1	25.3 ± 10.9	0.123
PUFA (g)	11.2 ± 5.6	12.2 ± 6.1	10.1 ± 4.8	0.039
Cholesterol (mg)	321.6 ± 135.1	318.8 ± 124.6	324.9 ± 147.9	0.943
Omega-3 : omega-6 ratio	1 : 4.8 ± 1 : 2.6	1 : 4.5 ± 1 : 2.6	1 : 5.1 ± 1 : 2.7	0.174
Carbohydrate (g)	240.6 ± 86.0	247.3 ± 96.9	232.4 ± 70.3	0.400
Dietary fiber (g)	22.5 ± 8.8	23.9 ± 9.7	20.8 ± 7.3	0.056
Mono-disaccharides (g)	41.2 ± 29.4	43.8 ± 34.7	38.1 ± 21.1	0.880
Sodium (mg)	3153.2 ± 1313.6	3468.5 ± 1423.3	2767.9 ± 1054.1	0.004
Potassium (mg)	3390.8 ± 1062.1	3516.3 ± 1143.9	3237.4 ± 939.0	0.117
Magnesium (mg)	370.4 ± 159.2	380.6 ± 146.6	357.8 ± 173.7	0.118
Calcium (mg)	740.4 ± 321.2	804.7 ± 353.5	661.7 ± 258.2	0.023
Phosphorus (mg)	1313.6 ± 431.5	1362.4 ± 432.6	1254.0 ± 425.9	0.119
Iron (mg)	12.8 ± 5.1	13.3 ± 5.2	12.1 ± 5.1	0.091
Zinc (mg)	11.0 ± 4.4	11.3 ± 3.7	10.5 ± 5.1	0.096
Iodine (µg)	126.7 ± 60.8	135.6 ± 60.2	115.8 ± 60.2	0.050
Vitamin A (µg)	1554.4 ± 1575.4	1586.9 ± 1567.3	1514.7 ± 1597.0	0.471
Vitamin E (mg)	13.9 ± 31.1	16.5 ± 41.6	10.8 ± 5.2	0.280
Vitamin D (µg)	6.62 ± 9.07	6.61 ± 8.26	6.63 ± 10.0	0.681
Thiamin (mg)	1.32 ± 1.02	1.48 ± 1.31	1.12 ± 0.40	0.016
Riboflavin (mg)	1.86 ± 0.72	1.96 ± 0.72	1.75 ± 0.72	0.044
Niacin (mg)	18.2 ± 7.60	18.2 ± 6.76	18.2 ± 8.6	0.524
Pyridoxine (mg)	3.02 ± 4.97	3.05 ± 3.66	2.98 ± 6.25	0.779
Cobalamin (µg)	5.11 ± 3.75	5.19 ± 3.41	5.01 ± 4.16	0.400
Folate (µg)	332.2 ± 133.8	340.1 ± 137.6	322.5 ± 129.4	0.443
Vitamin C (mg)	167.8 ± 181.1	162.5 ± 173.3	174.3 ± 191.3	0.874
E-NRF7.3	14.3 ± 8.4	13.9 ± 8.3	14.9 ± 8.6	0.592

test used to determine significance between frailty groups: [1)] Kruskal-Wallis test; noFS – people without symptoms of frailty syndrome, FS+preFS – people at least 1 criteria of frailty syndrome; SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids

intake more plant protein (27.5 g vs. 24.8 g), dietary fiber (23.9 g vs. 20.8 g), iron (13.3 mg vs. 12.1 mg) and zinc (11.3 mg vs. 10.5 mg) ($0.1 < p \leq 0.05$ for each comparison).

In multivariate regression analysis (Table 5), a significant difference was found between the two analyzed groups of frailty and the intake of dietary fiber, calcium and sodium (in the model adjusted for sex), and also dietary fiber and calcium (in the model adjusted for sex and age). Additionally, we found a borderline trend for potassium intake, but only in the model adjusted for sex ($p = 0.054$). The odds of being robust (in the noFS group) increased by more than 12-fold (adjusted for sex) or almost 8-fold (adjusted for sex and age) with each 1 g/100 kcal increase in dietary fiber intake. For calcium, the odds increased by 3.5% and 4.0%, respectively, for each 1 mg/100 kcal increase. In the model adjusted for sex only, an increase in sodium intake by 1 mg/100 kcal increases the chance of being in the noFS group by 0.9%. However, an increase in potassium intake by 1 mg/100 kcal reduces the chance of being in this group by 1.3%. But in the

Table 5. Logistic regression results depicting the relationship between nutrients (per 100 kcal) and no-frail status

Nutrient	Model 1			Model 2		
	p-value	OR	95% CI	p-value	OR	95% CI
Total protein (g)	0.589	1.164	0.670-2.024	0.561	1.191	0.660-2.147
Dietary fiber (g)	0.006	12.049	2.075-69.964	0.024	7.885	1.305-47.655
Folate (μg)	0.534	0.984	0.934-1.036	0.245	0.969	0.919-1.022
Vitamin D (μg)	0.710	0.854	0.370-1.967	0.643	0.816	0.345-1.930
Calcium (mg)	0.039	1.035	1.002-1.069	0.023	1.040	1.005-1.075
Magnesium (mg)	0.160	0.953	0.890-1.019	0.080	0.941	0.879-1.007
Potassium (mg)	0.054	0.987	0.974-1.001	0.273	0.992	0.979-1.006
Sodium (mg)	0.019	1.009	1.002-1.017	0.157	1.006	0.998-1.015
SFA (g)	0.523	1.445	0.467-4.476	0.427	1.624	0.491-5.375
Mono-disaccharides (g)	0.811	1.030	0.811-1.307	0.852	0.977	0.767-1.245
E-NRF7.3	0.803	0.855	0.250-2.926	0.663	0.752	0.208-2.719

SFA – saturated fatty acids

model adjusted for sex and age, there was also a trend towards a 5.9% lower chance of being robust with each 1 mg/100 kcal increase in magnesium intake ($p = 0.080$). No statistically significant difference was found between the two frailty syndrome groups and the E-NRF7.3 value for either model.

DISCUSSION

Frailty syndrome affects a significant proportion of older adults in Poland, with the incidence ranging from approximately 15% among independently living individuals` seniors to even 60% among the oldest-old (nonagenarians and centenarians), often institutionalized [14, 15]. While the difference in FS prevalence between men and women in our study was not statistically significant, many studies confirm higher rates in women, often attributed to biological and social factors [14, 16]. Additionally, lower education is consistently associated with higher frailty risk [14, 16, 17]. Age remains the strongest, most consistent predictor of frailty [14, 15, 17]. Whereas age is a non-modifiable risk factor, much can be done to address the social component of frailty here represented by education. Some studies suggest that education may positively impact health literacy, self-care, and access to resources, which can reduce the risk of frailty [2].

Further risk factors for frailty include low income, living alone, widowhood, low physical activity, and reduced social support [16-18]. However, the relationship is complex: while cross-sectional studies show an association, longitudinal study suggests living alone does not always predict future frailty unless compounded by social isolation or poor support [19]. Moreover, hospitalized elderly and those with chronic diseases (e.g., diabetes, COPD, Parkinson's) show even higher rates, sometimes above 90% [18, 20].

The relationship between the occurrence of FS and diet has already been the subject of many studies, although they focused on the consumption of particular nutrients [8, 11, 21] or on the consumption of particular groups of products [22]. The relationship between FS and the nutrient density of the diet is still poorly researched. In our study, there was no statistically significant difference in the nutrient density of the diets of people with and without symptoms of FS. Available research shows that increasing the intake of essential nutrients for seniors, such as protein and some vitamins, rather than increasing energy intake, is most beneficial for seniors [23], reducing the risk of developing FS [24]. In the Rotterdam Study, individuals aged $\geq$ 55 years with higher NRF9.3 values, especially women, had a lower risk of death from all causes [25]. The lack of difference in our study may be due, among other things, to the method of participant recruitment. Elderly adults attending senior clubs and at Third Age Universities can be more interested in a healthy lifestyle, including diet. Another reason may be the similar dietary habits of most seniors, i.e. similar intake levels of most of the nutrients included in the e-NRF7.3 formula, including a profound vitamin D deficiency. Our low result reflects the problem of vitamin D deficiency in Polish society [14, 26]. Moreover, low intake is a problem not only in Poland but also in other countries [11, 21]. We found no relationship between vitamin D intake and the number of symptoms of FS (zero vs. at least 1 frailty criteria). The relationship between FS and vitamin D intake is inconclusive [10, 11]. However, a meta-analysis of 26 studies showed a significant correlation between the level of 25(OD)D in the blood and FS [10]. It should also be emphasized that the level of vitamin D in the

blood decreases with age in older people, even despite supplementation [14]. The causes include health- and lifestyle-related factors, such as renal dysfunction, avoidance of sun exposure, reduced physical activity, increased body fat, and smoking [27]. Regular supplementation therefore appears all more important, and the dose of the supplement should be determined individually.

B-vitamins intake can be correlated with prevalence of FS [28]. The age-related decline in DNA methylation increases the demand for methyl group donors, such as folates [29]. In a Danish intervention study, higher intake of B-vitamins in people with frailty had a positive effect on nutritional status parameters, including homocysteine levels [30], which may be correlated with the prevalence of frailty [31]. In our study, in univariate analysis, only the intake of thiamine and riboflavin was significantly higher in the group of people without symptoms of FS. Folate intake in the study group was higher than the average intake in Poland, which is approximately 260 μg/day, but it was still lower than the recommendation [26]. Folate deficiency in the diet of older people may, among others, increase the risk of cognitive impairment and Alzheimer's disease, which is positively correlated with FS [32].

It is widely believed that excess sodium is a leading risk factor for death among older adults [4]. The National Institute on Aging recommends limiting sodium intake for people over 51 years of age to a maximum of 2300 mg/day, i.e. 1 teaspoon of salt, from all sources [33], while the World Health Organization recommends that all adults should not exceed 2000 mg of sodium per day [34]. In our study, people without symptoms of FS consumed significantly more sodium (3468.5 mg/day) than people with at least 1 symptom (2767.9 mg/day). Similar results were obtained in other studies [35, 36]. It is increasingly being pointed out that it is not sodium, but refined sugars, especially added fructose, that more likely increases blood pressure, which is one of the main nutritional risk factors for cardiovascular diseases, especially dangerous in the elderly [37]. Moreover, according to the results of the large PURE study, a moderately elevated sodium intake, within the 3-5 g/day range, may reduce mortality and the risk of cardiovascular events compared to levels below or above this range. Additionally, increasing potassium intake and reducing the sodium-to-potassium ratio have a protective effect [38]. In the case of FS, the protective effect of sodium may be due to its participation in protein digestion. Unfortunately, a decrease in gastric acid output in the elderly, due to gastric diseases, is very common [39]. Higher sodium intake by robust elderly, regardless of sex, may be another reason for the lack of association between E-NRF7.3 and the FS symptoms, because the algorithm assumes a restriction of intake of sodium. We have not confirmed the assumption from the E-NRF7.3 formula that sodium should be limited in the diet. Individuals without symptoms of FS had a higher intake (about 3.5 g/day) than those with symptoms (about 2.8 g/day). When sex is taken into account, in our opinion, this is the key reason for the lack of association between E-NRF7.3 score and FS result in our study. However, it should be noted that when both sex and age were considered, the effect of sodium disappeared, therefore, it is unlikely that sodium contributed to the lack of statistical significance for the E-NRF7.3 score.

Calcium intake differed significantly in both univariate and regression analyses. In addition to protein [8], calcium (as well as magnesium) is a key factor influencing muscle function. Low calcium intake is associated with lower muscle mass, which can lead to sarcopenia and, consequently, frailty syndrome [40].

Dietary fiber intake by our respondents was a significant factor modulating the number of FS symptoms (no symptoms vs. at least one symptom), similarly to the Naito study [28]. However, not all studies show such a correlation [36]. In general, dietary fiber reduces inflammation and modifies the intestinal microflora, which was found in both healthy elderly and frail individuals [41].

We found that the frequency of going outside, both in the last month and in the last summer, strongly differentiated the two study groups not regarding FS symptoms ($p < 0.000$). On the one hand, this may be related to greater endogenous vitamin D synthesis, and on the other hand, to greater physical and social activity. Many studies have shown that socialization of seniors, even those with FS, has a very positive impact on their health, both physical and mental [42]. Our seniors were recruited in senior clubs and at Third Age University, so in very social places. This may explain the low percentage of people with at least 3 criteria of FS. This proves that going outside, spending time with other people, socialization are significant risk factors for the occurrence of FS.

A strength of our study is the use of E-NRF7.3, a formula that takes into account the specific nutritional requirements of older people in Europe. The second advantage is the relatively equal number of women and men. Men are less willing to participate in scientific research, and among people of retirement age in Polish there are almost twice less of them as women [43]. One of the weaknesses of our study is the small number of participants. However, we wanted to test the E-NRF7.3 formula before planning a large study. Furthermore, recruitment is limited to senior clubs and the University of the Third Age. Therefore, it is worthwhile to conduct research comparing

these factors between socially active and inactive individuals. The next limitation of our study is its cross-sectional nature, which makes it impossible to assess the causal relationship between nutrient density of the diet and development and/or severity of FS. Therefore, further studies using E-NRF7.3 as a predictor of FS are needed.

CONCLUSIONS

Although in univariate analysis we did not demonstrate a relationship between dietary nutrient density, as measured by the E-NRF7.3 formula, and the incidence of FS symptoms, but we did demonstrate that higher intakes of water, PUFA, dietary fiber, sodium, calcium, iodine, thiamine, and riboflavin were associated with a lower risk of at least one FS symptom. Regression analysis, adjusted for sex, revealed such associations for dietary fiber, calcium, sodium, and trend for potassium. In general, despite the higher intake of some nutrients considered recommended, such as dietary fiber and calcium, by people without symptoms of frailty, we did not demonstrate that a higher nutritional density of the diet (E-NRF7.3 score) is associated with the number of frailty symptoms.

Among non-dietary factors, at least one FS symptom was more common among individuals who were older, had a lower level of education, lived alone, had lower physical activity, spent less time outdoors and were less exposed to sunlight, smoked cigarettes, used dietary supplements more frequently, had poorer self-rated health, and had hypertension.

Conflict of interest

The authors have no conflicts of interest to declare.

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