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Eating patterns are associated with cognitive function in the elderly at risk of metabolic syndrome from rural areas

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Abstract. – **OBJECTIVE:** The Mediterranean diet (MedDiet) represents a promising approach in the prevention of cognitive decline, but the evidence for such beneficial effect, especially among elderly populations in non-Mediterranean regions, is at present inconsistent. This study investigated the relationship between adherence to MedDiet and cognitive function (CF), along with selected sociodemographic (SD) and clinical indices, in Polish elderly people > 60 years of age, with high risk of metabolic syndrome (MS), living in rural area.

SUBJECTS AND METHODS: Complete SD and lifestyle information was collected. The dietary outcome was recorded as a MedDiet score with the frequencies of consumption of the main food groups in the a MedDiet pyramid. Parameters identifying MS and body weight status were determined, and 11 psychological test results were examined in four domains: visual memory, executive function, attention, and global cognition.

RESULTS: The lower MedDiet score was more often connected with living without children and with CF impairment. The MedDiet score was linked with global cognition; frequency of consumption of vegetable, fish, olive and rapeseed oil with visual memory, attention, executive function respectively. The consumption of full-fat dairy products and red meat and meat products was negatively related to executive and global CF. Also, insufficient physical activity, low educational status, female gender, living without children, and the existence of MS were factors of risk of CF impairment.

CONCLUSIONS: Greater adherence to MedDiet and frequency of consumption of some foods were associated with better scores in several CF tests in elderly individuals with high risk of MS living in a rural community. However, lifestyle, clinical, and SD factors should also be considered.

Key Words:
Older adults, Mediterranean diet, Cognitive function, Rural area.

Introduction

It is well-recognized worldwide that the population is ageing, and that this trend will have significant economic and social impacts. The number of people over the age of 60 is projected to reach 1 billion by 2020, and almost 2 billion by 2050, representing 22% of the world's population[1]. Approximately 13% of the total population in Poland is aged 60 and older, and it is expected that, in 2030, the fraction of older adults will increase to 30%[2]. It is well known that aging is associated with the decline of cognitive functions (CF) (particularly memory, spatial orientation, and executive function abilities)[3]. The magnitude of this decline varies from person to person and depends on demographic factors, lifestyle, and in particular, health-related factors[3]. Among the lifestyle-related factors that have been recently proposed as a first line of defense against the development and progression of cognitive impairment, focusing on nutrition constitutes is an interesting approach[4]. For example, both subclinical deficiencies in essential nutrients (antioxidants such as vitamins C and E and β-carotene, as well as vitamin B_{12}, vitamin B_6, and folate) and nutrition-related disorders, such as hypercholesterolemia, hypertriacylglycerolemia, hypertension, and diabetes mellitus, may be among the nutrition-related risk factors that can be present for a long time before cognitive impairment becomes evident[5]. Clinical and epidemiologic data indicate that oxidative stress and the generation of free radicals are factors in the process of atherogenesis and in the pathological changes associated with Alzheimer's disease. This suggests an intriguing link between the etiopathogenetic mechanisms of both Alzheimer's-type and vascular dementia[6]. Furthermore, a high intake of n-6 polyunsaturated fatty acids, such as linoleic acid, can increase ox-

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idative stress, and has been found to be positively associated with cognitive deficit, whereas a high level of consumption of fish – an important source of n-3 polyunsaturated fatty acids – is inversely associated with cognitive deterioration[7]. Moreover, it has been suggested that the decline in cognitive function associated with aging may even be reversible with the use of improved vitamin supply, especially in the case of vitamin B_{12}, vitamin B_6, and folate[8]. However Huijbregts et al[9] have hypothesized that it is a healthy and well-balanced diet, rather than the intake of isolated nutrients or foods, that leads to the maintenance of good cognitive function. Taking all this together, it seems that a "healthy-eating pattern" might have some protective effects against cognitive decline in older individuals. In Europe, the crucial example of favorable food habits is the Mediterranean diet (MedDiet), which is characterized by a limited intake of red meat, animal fat, and processed foods, and by high consumption of fish and a variety of plant-based foods (fruit, vegetables, breads, and other whole-grain cereals, pulses, nuts, and seeds), wine, and olive oil (as the main source of lipids). According to Curtis and O'Keefe[10], the traditional MedDiet is an ideal eating pattern, and is considered the "gold standard" for the prevention of cardiovascular disease. In Central European countries, the healthy-eating pattern could be introduced on similar principles, but taking advantage of locally produced food, such as rapeseed oil, which is a source of both n-3 polyunsaturated and monosaturated fatty acids.

The Western dietary pattern stands opposed to the MedDiet pattern, based as it is on red meat and meat products, animal fat, and high-sugar, low-fiber foods. This includes the eating habits common in the developed countries of Western Europe and the USA[11]. Such unhealthy patterns of consumption closely resemble a hard-working farmer's diet, and are nowadays supplemented with high-processed food, being highly inadequate to changing occupations, environment, and lifestyle.

The MedDiet represents a promising approach in the prevention of cognitive decline and the risk of dementia, due to its impact, direct or indirect, on the aging of the brain through its nutritional constituents, which may enhance neuronal plasticity, counteract inflammation and oxidative stress, and improve vascular variables[12]. However, according to Wyka et al[13] elderly individuals living in rural areas tend to make more mistakes in nutrition and lifestyle, and their adherence to the healthy-eating pattern is rather poor. This may be associated with several factors: the lack of health-care programs promoting a healthy lifestyle among the rural population; the individuals' relationship with traditional diet; low income; living far away from supermarkets. On the other hand, Kesse-Guyot et al[12] have suggested that the evidence for an association between adherence to the MedDiet (especially among populations in non-Mediterranean regions) and cognitive function among elderly individuals is at present inconsistent. It seems to be crucial to take the interactions of numerous social and health-related factors into account in the analysis of the impact of diet on cognitive deficits in later life. Therefore, the aim of this study is to assess the relationship between adherence to a healthy-eating pattern (close to MedDiet) and selected demographic and clinical factors, as well cognitive function in group of elderly individuals (over 60 years of age) from a community with a high risk of metabolic syndrome (MS) living in rural areas of Wielkopolska in Poland.

Subjects and Methods

Subjects

The study was carried out with a total of 87 participants, aged 60 y and over, patients of a general practitioner in Sokolniki. All subjects were residents of 5 rural districts (Sokolniki, Bieganowo, Szamarzewo, Gorazdowo, and Gałezewice) in Wrzesnia County, Wielkopolska Voivodeship, Poland. Elderly individuals were excluded if multivitamin, mineral, or fish oil supplementation had been used in the six months prior to the study. Participants were required to give their fully informed written consent before taking part in the study. The protocol was reviewed and accepted by the Poznań Medical Ethics Committee for the ethical treatment of subjects participating in biomedical research (No. 187/10).

Measurement of Sociodemographic and Lifestyle Factors

The participants were invited to answer some questions regarding their demographic (gender, age) and socioeconomic situations: family status (FS) and educational status (ES), as well as lifestyle outcomes including leisure time physical activity (PA), and cigarette smoking habits. Based on the data obtained in this way, the two following categories were established for each variable: educational status equal/higher or lower than secondary school; gender: female or male; self-assessment of PA: active during leisure time (PA every day or 2-3 times per week) or inactive during leisure time (PA once a week or a sedentary lifestyle); self-declared smoking habits: smoker or nonsmoker; living with children (or with partner and children), living alone without children, or living without children but with partner.

Anthropometric measurements

Body weight was measured in light clothing without shoes to the nearest 0.1 kg, using electronic scales (model WPT 200.0 from RadWag, Poland). Height was measured in the standing position, without shoes, to the nearest 0.01 m (using model WPT 200.0 from RadWag, Poland). The waist circumference (WC) was measured to the nearest 0.1 cm at the level of the iliac crest with the subject at minimal respiration[14]. Body-weight status was described by body mass index (BMI), expressed as the weight in kilograms divided by the square of the height in meters (kg/m^2).

Metabolic Variables

Venous blood samples were obtained between 8:00 and 9:00 a.m. after 12-h fast and after 15-min supine rest and then collected in the EDTA tubes, centrifuged at 4°C and 1500 × g for 10 min to separate plasma. Frozen plasma was shipped to a central laboratory (Diagnostyka Laboratory, Poznan, Poland) for future biochemical analysis. High density lipoprotein cholesterol (HDL-Ch), and triacylglycerol (TG) concentrations in the plasma, were measured using an Olympus AU560 analyzer[15,16], blood glucose (BG) – using the hexokinase method[17]. Resting seated blood pressure was measured 3 times, and an average value was calculated, according to guidelines of the European Society of Hypertension[18].

Diagnosis of MS

MS was diagnosed if at least three of the following characteristics were found: WC ≥ 94 cm for men or ≥ 80 cm for women; systolic blood pressure higher than 130 mm Hg or diastolic blood pressure higher than 85 mm Hg or treatment of previously diagnosed hypertension; HDL-C less than < 1.0344 mmol/l (40 mg/dl) for men or < 1.293 mmol/l (50 mg/dl) for women or specific treatment for this lipid abnormality; TG levels ≥ 1.6935 mmol/l (150 mg/dl) or specific treatment for this lipid abnormality; and BG level ≥ 5.55 mmol/l (100 mg/dl) or previously diagnosed type 2 diabetes[19].

Dietary assessment and MedDiet score

Participants were visited at home by a specially trained dietician who administered a food frequency questionnaire (FFQ), derived from diet history and validated previously in elderly subjects in the SENECA study[20]. The food items were grouped according to the Eurocode system[21] into 13 groups: milk and milk products; Eggs and egg products; Meat and meat products; Fish, mollusks, reptiles, crustaceans and their products; Oils, fats and their products; Grains and grain products; Pulses, seeds, kernels, nuts, and their products; Vegetables and vegetable products; Fruits and fruit products; Sugar, sugar products, chocolate products and confectionery; Beverages (nonmilk); Miscellaneous, soups, sauces, snacks, and products; and Products for special nutritional use. Respondents participating in the study were obliged to indicate which products they consumed and at what frequency over the course of the last month, by indicating one of the following possible answers: A (4-5 times per day), B (2-3 times per day), C (once a day), D (4-6 times per week), E (2-3 times per week), F (once a week), G (2-3 times per month), H (once a month), J (rarely or never). For each product or dish, the individuals freely determined their usual portion size using an album of photographs of food products and dishes[22].

The frequency of consumption was quantified approximately in terms of the number of times per month the food was consumed. Thus, daily consumption was multiplied by 30, and weekly consumption by 4; a value of 0 was assigned to food items rarely or never consumed. Consumption of alcoholic beverages was measured in ml (100 ml being considered to contain 12 g of ethanol). The MedDiet score was calculated according to Panagiotakos et al[23], and included the following 11 food groups from the MedDiet pyramid: unrefined cereals (whole bread, pasta, rice, other grains, biscuits, etc.), fruit, vegetables, legumes, potatoes, fish, red meat and meat products, poultry, full-fat dairy products (such as cheese, yoghurt, and milk), and olive (or rapeseed) oils, as well as alcohol beverages. Then, the frequency of consumption of these foods was assessed, assigning individual ratings (from 0 to 5 or reverse) to each of the 11 food groups that were part of the MedDiet. For items which, according to the MedDiet, are recommended to be eaten on a daily basis or with more than 4 servings per week (unrefined cereals, fruits, vegetables, legumes, olive or rapeseed oils, fish, and potatoes), we assigned a score of 0 when no consumption was reported, a score of 1 for consumption of 1-4 servings/month, a score of 2 for 5-8 servings/month, a score of 3 for 9-12 servings/month, a score of 4 for 13-18 servings/month, and a score of 5 for more than 18 servings/month. On the other hand, for the foods presumed to be a minor part of this diet (red meat and meat products, poultry, and full-fat dairy products), we assigned the scores using the reverse scale: i.e., 5 when no consumption was reported to 0 for almost daily consumption. In particular, for alcohol, we assigned a score of 5 for the consumption of less than 300 ml of alcohol/day, a score of 0 for the consumption of more than 700 ml/day, and scores of 4, 3, 2, and 1 for, respectively, the consumption of 300, 400-500, 600 and 700 or 0 ml/day (100 ml being considered to have 12 g ethanol concentration). Thus, the total dietary score could range from 0 to 55. Higher values of the dietary score indicate greater adherence to the MedDiet, whereas lower values indicate adherence to a more westernized dietary pattern. The median value (27) of the MedDiet score was used to distinguish two categories of the index, and in consequence, two groups of subjects were considered: the first contained those with scores of less than 27, while second included those with scores equal to or greater than the median of 27.

Cognitive Function Assessment

Trained psychologists administered an extensive cognitive test battery to each participant, including:

1. *The Mini-Mental State Examination (MMSE*), which is a sum-score evaluating various dimensions of cognition (including tests of attention, memory, language, and visual-spatial skills), used as an index of global cognitive performance. Scores range from 0 to 30. A score of greater than or equal to 25 points (out of 30) indicates normal cognition. Below this, scores indicate severe (≤ 9 points), moderate (10-20 points), or mild (21-24 points) cognitive impairment[24]. In our study, 21% of participants had mild cognitive impairment (with MMSE ≤ 24 points). More severe impairment (MMSE ≤ 20 points) was found in 6% of examined persons.
2. *Trail Making Test (TMT) Part A and B* consist of two paper-and-pencil challenges, TMT-A, and TMT-B. TMT-A test consists of connecting, in ascending sequential order, 25 numbered circular targets arranged randomly in a paper space without lifting the pencil. TMT-B involves linking 23 circular targets, which are divided into a set of numbers (1-13) and a set of letters (A-L). In TMT-B, the set of numbers and the set of letters must be alternately linked in ascending order: from A-1 to L-13, without lifting the pencil from the paper. The performance of each part of the test is based on the time in seconds needed to complete each part, and on penalizing errors by adding additional time to the final score[25].
3. *Stroop test, part A*, where the subject was asked to read, as quickly as possible, ten rows with the name of five colors printed in black ink on a white card; *part B*, where a second card containing ten rows of five names of colors printed in unmatched colors was presented, and the subject was asked to name, as quickly as possible, the ink color of the print. The time (in seconds) to finish the reading and the number of incorrect ink colors given are the scores resulting from the Stroop test[26].
4. *Seven subtests from the CANTAB (Cambridge Neuropsychological Test Automated Battery)* battery of tests were chosen: (1) *The Pattern Recognition Memory (PRM) test:* in the first phase, the participant is presented with a series of 12 colored visual patterns for three seconds. The examinee is asked to memorize these patterns. In the second phase, 12 paired patterns, new and old, are presented, in which the participant is required to choose between a pattern they have already seen and a novel pattern. This test is scored using two indices: mean correct latency and number correct. (2) The *Spatial Recognition Memory (SRM) test*: in the first phase, the participant is presented with a white square which appears at five different locations on the screen. The participant is asked to remember the locations of the square. In the second phase, the participant sees a series of five pairs of squares, one of which is in a place previously seen in the presentation phase. The participant must choose the square which was presented previously. This test has two indices for scoring: mean correct latency and number correct. (3) The *Spatial Span (SSP) test*; after presenting a sequence of boxes that opening to reveal differ-

ent colors, the subject was asked to recall the order of the colors that appeared by pointing to the correct boxes in sequence. (4) *The Stockings of Cambridge (SOC) test,* where participants are shown a split screen with a set of three 'stockings' displayed at the top of the screen and again in the bottom half of the screen. The top half of the screen shows the location of colored balls within the stocking array in the "goal" state. The bottom half of the screen contains the same number of colored balls in a "start" state. Participants are instructed to make the bottom half of the screen "look like" the top half of the screen, in as few moves as possible, by moving colored balls from one stocking to another. Time taken to make the first move of the sequence ("initial thinking time"), time taken to make remaining moves in the sequence ('subsequent thinking time') and the number of occasions upon which the subject completes the problem in the minimum number of moves ('minimum move solutions') were measured. However, in our study we have taken into account only the letter results. (5) *The Spatial Working Memory (SWM) test*: Here, the subject is required to attempt to locate all the blue squares hidden inside a subset of boxes on the left side of the screen and to transfer them to the right side of the screen without reopening any box that has previously been selected. Two scores are calculated: SWM (be) Between errors, defined as the times the subject revisits a box in which a token has previously been found. This is calculated for trials of four or more tokens only; SWM (t) Strategy: it was suggested that an efficient strategy for completing this task is to follow a predetermined sequence by beginning with a specific box and then, once a blue token has been found, to return to that box to start the new search sequence. An estimate of the use of this strategy is obtained by counting the number of times the subject begins a new search with the same box. A high score represents poor use of this strategy and a low score equates to effective use. (6) *The Rapid Visual Information Processing (RVP) test*, in which subjects are requested to detect target sequences of digits from 2 to 9 appearing in the center of the computer screen in a pseudorandom order within the box at a rate of 100 digits per minute, and to register responses using the press pad. The key outcome variables are RVP A' (a number in the range 0-1 that represents the ability to detect targets, with 1 representing perfect detection) and the mean response latency. (7) *Paired Associates Learning (PAL) test*: here, some boxes are displayed on the screen and opened in a randomized order. One or more of them contains a pattern. The patterns are then displayed one by one in the middle of the screen. The participant is instructed to touch the box in which the pattern was originally seen. There are different stages in which the number of patterns is increased to eight. An error occurs when the participant selects a box that did not contain the target stimulus[27].

These 11 tests yielded 16 separate grading scales. The tests were grouped into four domains: (1) *visual memory* [The Paired Associates Learning (PAL) test, the Pattern Recognition Memory (PRM) test, and the Spatial Recognition Memory (SRM) test]; (2) *executive function* (TMT-B, the Spatial Span (SSP) test, the Spatial Working Memory (SWM) test, the Stockings of Cambridge (SOC) test, and the Stroop test part A); (3) *attention* (TMT-A, the Rapid Visual Information Processing (RVP) test); and (4) the MSEE test for *global cognition*.

Statistical Analysis

The data were processed using Statistica software, version 9.0 for Windows (StatSoft, Inc., Tulsa, Oklahoma, OK, USA). Continuous variables are represented as mean values ± standard deviation, while categorical variables are presented as absolute values with frequencies. The sociodemographic, lifestyle, and clinical characteristics of the subjects by categories of MedDiet adherence were compared using student's *t*-test for continuous variables and the chi^2 test for categorical variables. The frequency of consumption of several food groups according to the MedDiet score was compared using analysis of variance. Mixed model ANOVA was used to reflect the differences between food consumption in two categories of the MedDiet score, after adjusting for gender, age category, smoking status, educational level, existence of MS, physical activity (PA) and FS.

We fitted multiple linear regression models (generalized ANCOVA/MANCOVA linear models) to assess independent associations of sociodemographic, clinical, and dietary variables with cognitive function tests. In the first model, with the cognitive test results (scores or time scores) as dependent variables, we introduced the MedDiet score and the frequencies consumption of various food groups (cereals, vegetables, fruits, legumes, full-fat dairy products, poultry, olive or rapeseed oil, red meat and meat products, and alcohol) as independent variables. In the second model, we correlated the MedDiet score and the frequency of consumption of food groups, which were significantly associated with cognitive test results in the first model, and then adjusted for age, gender, ES, FS, current smoking, leisure time PA, and existence of MS as potential confounders. In Table III, only the results showing $p < .05$ after regression analyses of the second model are presented. The level of statistical significance is set at $p < .05$.

Results

In Table I, the characteristics of the study participants and their adherence to the Mediterranean diet are presented. MedDiet scores range from 14 to 37: 53% of participants had a score in the range from 14 to 26: 47% from 27 to 37; 27 was the median value. No significant differences in means or the distribution of frequencies were found for age, gender, BMI, leisure-time PA, ES, smoking status, or the existence of MS between subjects who more or less adhered to the MedDiet. The proportion of subjects with mild cognitive impairment was significantly lower ($p < .001$) in the group with higher MedDiet scores (5.0%) than in the group that adhered less well to the MedDiet (23.0%). Also, the proportion of subjects who lived without their children was significantly ($p < .05$) higher in the group of elderly individuals who indicated low adherence to the MedDiet (25.0%) than in the group of those who adhered better to the MedDiet (10%).

Table II presents the differences in the frequencies of food consumption and alcohol intake by categories of MedDiet score, adjusted and unadjusted to random variables (gender, age category, smoking status, ES, existence of MS, PA, and FS). The participants with higher adherence to the MedDiet (score ≥ 27) had a significantly ($p < .05$) higher intake of vegetables (87.0 ± 11.2 servings/month) than those with lower adherence to the MedDiet (56.4 ± 6.5 servings/month). However, this effect was statistically more significant in the adjusted model (Table II). Among the participants with lower adherence to the MedDiet, a significantly ($p < .05$) higher intake of red meat and meat products (53.9 ± 5.00 servings/month) and full-fat dairy products (68.3 ± 6.12 servings/month) was observed. However, after adjustment for random variables, there were no significant differences in the frequencies of consumption of these foods between the two compared groups.

Various clinical, demographic, and dietary variables were associated with the different neurophysiological tests through multiple linear regression analyses. The fully adjusted associations between nutritional outcomes and cognitive test results with significant correlation of random variables are shown in Table III. The frequencies of consumption of certain foods independently contributed to cognitive function, when adjusted for clinical and demographic variables. The specific associations (standardized regression beta coefficients) were found between olive or rapeseed oil consumption and executive function in the Stroop test A (–0.21; $p < .05$) and the SSP test (0.8; $p < .05$); fish intake was associated with attention measured by the TMT A test (–0.21; $p < .05$); and vegetable consumption was associated with visual memory in the PRM test (0.30; $p < .01$). Furthermore, higher MedDiet scores were associated with better global cognition (0.36; $p < .001$), as evaluated by MSEE test. In contrast, more frequent consumption of some foods was independently related to poorer cognitive function. It was observed that higher consumption of red meat and meat products was associated with poorer executive function in the SOC test (problems solved in minimal number of moves) (–0.33; $p < .01$) and global cognition in the MMSE test (–0.25; $p < .01$); also, consumption of full-fat dairy products was associated with poorer executive function measured by the SWM test (Strategy) (0.25; $p < .05$). Also, some clinical, lifestyle and sociodemographic variables were related to certain aspects of cognitive function. It was shown that insufficient PA is associated with lower global cognition in the MMSE test (–0.29; $p < .01$), lower visual memory in the PRM test (–0.22; $p < .05$) and lower executive function in SWM test (0.21; $p < .05$); low educational status was associated with poorer attention in the TMT A test (0.20; $p < .05$); female gender with both poorer attention in the TMT A test (0.20; $p < .05$) and executive function in the SOC (problems solved in minimal number of moves) test (–0.22; $p < .05$); living alone without children and the presence of MS with lower executive function in

Table I. Lifestyle, health, anthropometric, and sociodemographic variables by categories of MedDiet score among older individuals living in rural areas in Poland.

Characteristics	All (n = 87)	MedDiet score		
		Group 1 < median (27.0) value (n = 46)	Group 2 ≥ median (27.0) value (n = 41)	*p*-value[b]
Age (years; means ± SD)	70.0 ± 6.5	69.0 ± 7.0	72.0 ± 6.0	NS
Sex (males, %)	31.0 (35.0)	15.0 (17.0)	16.0 (18.0)	NS
Body mass index (kg/m^2 means ± SD)	30.0 ± 5.1	30.0 ± 5.5	29.3 ± 4.7	NS
Leisure time PA (n, %)	19.0 (21.5)	10.0 (11.5)	9.0 (10.0)	NS
Current smokers (n, %)	11.0 (13.0)	5.0 (6.0)	6.0 (7.0)	NS
Existence of MS (n, %)	52.0 (59.5)	30.0 (34.5)	22.0 (25.0)	NS
At least mild cognitive impairment (n, %)[c]	24.0 (28.0)	20.0 (23.0)	4.0 (5.0)	< .001
Educational status (n, %)[a]	11.0 (13.0)	5.0 (6.0)	6.0 (7.0)	NS
Living without children (n, %)	31.0 (35.0)	22.0 (25.0)	9.0 (10.0)	< .05

[a]Higher than primary school; [b]Differences in continuous variables were compared using Student's *t*-test. Categorical variables were tested using the χ^2 test; [c]Evaluated using the MMSE test.

the Stroop test part A (0.24; $p < .05$ and 0.21; $p < .05$, respectively); and older age with poorer executive function in SSP test (–0.32; $p < .05$).

Discussion

In our study, the prevalence of mild cognitive impairment, as assessed by MMES, was 21% among the examined elderly members of rural communities at high risk of MS. More severe cognitive impairment was found in 6% of the participants. Pajak et al[28] have observed that, among 943 elderly individuals living in a rural province of Poland (Tarnobrzeg Voivodeship), almost half had mild cognitive impairment, and more severe impairment was found in 15%. Thus, the studied population is not representative of Polish people in terms of cognitive deficits. However, it should be noticed that only 5% of subjects with mild cognitive impairment were placed in the group that scored higher on the healthy-eating pattern (MedDiet), while the group that adhered less well to the MedDiet con-

Table II. Frequency of consumption of several food groups, by categories of MedDiet diet score, among older individuals living in rural areas in Poland.

Variables	Group 1 (n = 46)	Group 2 (n = 41)	*p*-value[c] (unadjusted)	*p*-value[d] (adjusted)
Food category, mean (SEM), servings/month				
Unrefined cereals (serv./month)[a]	18.7 ± 5.06	31.5 ± 4.50	NS	NS
Fruit (serv./month)	64.3 ± 8.2	85.0 ± 10.4	NS	NS
Vegetables (serv./month)	56.4 ± 6.5	87.0 ± 11.2	< .05	< .01
Legumes (serv./month)	3.37 ± 0.44	4.82 ± 0.87	NS	NS
Potatoes (serv./month)	20.6 ± 3.15	25.7 ± 2.87	NS	NS
Fish (serv./month)	4.2 ± 0.40	6.5 ± 1.00	NS	NS
Red meat and meat products (serv./month)	53.9 ± 5.00	40.3 ± 4.36	< .05	NS
Poultry (serv./month)	12.8 ± 1.68	9.4 ± 0.82	NS	NS
Full-fat dairy products (serv./month)[b]	68.3 ± 6.12	51.0 ± 5.20	< .05	NS
Olive and rapeseed oil (serv./month)	15.6 ± 2.74	20.9 ± 2.70	NS	NS
Alcohol beverage (mL/d)	0.52 ± 0.26	0.37 ± 0.18	NS	NS

[a]Includes consumption of whole bread, pasta, rice, other grains, biscuits, etc.; [b]Includes consumption of cheese, yoghurt, and milk; [c]Derived from ANOVA. Reflect the differences in food consumption between categories of MedDiet score; [d]Derived from mixed model ANOVA. Reflect the differences in food consumption between categories of MedDiet score, after adjustment for gender, age category, smoking status, educational level, existence of MS, PA and FS.

Table III. Independent associations of cognitive test scores with food intake using multiple linear regression.

Use of the test	Neuropsychological test	Independent variables	Regression coefficient (95% confidence interval)	β*	*p*-value
Global cognition	MMSE	MedDiet score	0.25 (0.12 0.37)	0.36	0.001
		Red meat and meat products	-0.02 (-0.04 -0.007)	-0.25	0.01
		Physical inactivity	-1.07 (-1.7 -0.44)	-0.29	0.01
Attention	TMT A	Fish	-1.97 (-4.4 -0.10)	-0.21	0.05
		Gender (Women)	10.7 (-0.5 21.8)	0.20	0.05
		Lower than secondary school	14.9 (-1.8 31.6)	0.20	0.05
Visual memory	PRM	Vegetables	0.09 (0.02 0.14)	0.30	0.01
		Physical inactivity	-4.26 (-8.5 -0.05)	-0.22	0.05
Executive function	Stroop test part A	Olive or rapeseed oil	-0.33 (-0.70 0.03)	-0.21	0.05
		Living without children	7.3 (0.32 14.4)	0.24	0.05
		Existence of MS	6.3 (-0.23 12.8)	0.21	0.05
	SOC Problems solved in min. moves	Red meat and meat products	-0.02 (-0.03 -0.007)	-0.33	0.01
		Gender (Women)	-0.45 (-0.89 -0.004)	-0.22	0.05
	SWM (Strategy)	Full-fat dairy products	0.02 (0.003 0.03)	0.25	0.05
		Physical inactivity	0.69 (0.02 1.36)	0.21	0.05
	SSP	Olive and rapeseed oil	0.06 (0.01 0.1)	0.28	0.05
		Older age	-0.03 (-0.05 -0.002)	-0.32	0.05

The independent variables listed are those showing $p < 0.05$ after regression analyses; MMSE: Mini Mental State Examination; PRM: Pattern Recognition Memory; SSP: Spatial Span; SWM: Spatial Working Memory; SOC: Stockings of Cambridge; TMT A: Trail Making Test A; β, Standardized regression coefficient; The variables allowed into the models were gender, age, education level, smoking status, family status, leisure time PA, existence of MS.

tained 23.0% of subjects characterized by mild cognitive impairment. A similar association has been shown between nutritional pattern and mental health in several previous studies, especially among the elderly from the Mediterranean region[29,30]; there are also a small number of reports replicating and confirming these findings in non-Mediterranean populations. In our study, higher adherence to the MedDiet was associated first of all with a higher frequency of vegetable consumption, and also with a lower frequency of consumption of red meat and meat products and full-fat dairy products. However, after adjustment for various confounders (gender, age category, smoking status, ES, existence of MS, PA, and FS) only differences in the frequency of vegetable consumption among those more or less adhering to the MedDiet were observed.

The main finding of our study is that, even after adjustment for some sociodemographic, lifestyle, and clinical variables, higher adherence to the MedDiet and the independent intake of olive or rapeseed oil, vegetable, and fish, were all associated with better global cognitive function, attention, visual memory, and executive functions. On the other hand, higher consumption frequencies of red meat and full-fat dairy products were associated with worsened cognitive functioning in older adults. The magnitude of these associations was variable, and they were present in some, though not all, tests for evaluating the detailed components of cognitive performance.

A common characteristic of the foods directly related to better cognitive performance in our study is their richness in monounsaturated fatty acids and n-3 fatty acids, as well as in polyphenols, vitamins and minerals, and highly bioactive molecules with beneficial effects on brain function. However, it should be noted that the model of this work does not permit us to determine whether the healthier diet is the cause of the improved cognitive functioning or that, inversely, subjects with better mental status are more likely to choose foods more favoring health. Nevertheless, in the research conducted by Féart et al[31] on 1410 nondemented French participants aged 65 or older, over 5 years of follow-up higher MedDiet scores were associated with slower cognitive decline, as measured by MMSE. Furthermore, the authors of that study indicate that the beneficial effects of the MedDiet exist during the long prodromal phase of dementia, rather than in the very last years preceding dementia[31].

Previously, several observational studies have also suggested that fish oil (containing both eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), as well as plant sources (e.g. rapeseed oil, containing alpha linolenic acid (ALA) of long-chain polyunsaturated fatty acids (LCPs n-3) act protectively against dementia and age-related cognitive impairment[32,33]. The brain is particularly rich in fatty acids, and adequate LCP n-3 status may help maintain membrane integrity and neuronal function. Moreover DHA may modify the expression of genes that regulate a variety of biological functions potentially important for cognitive health, including neurogenesis and neuronal function[34]. In addition, LCPs n-3 possess anti-inflammatory properties that may also be associated with improvement in cognitive function. For example, in a middle-aged group of healthy subjects, circulating levels of interleukin 6 (IL-6) were inversely related to performance on a cluster of cognitive tests evaluating auditory recognition memory, attention, working memory, and executive function[35]. Thus, fish and olive and rapeseed oil consumption should be strongly promoted among the elderly, as it may prevent brain ageing processes and reduce cognitive decline. Other explanations for the beneficial influence of the Mediterranean dietary pattern on cognition observed in our study are related to olive oil and to vegetable consumption. Recently, however, a weak association of total olive oil intake with reduced risk of cognitive impairment was reported in a large French cohort[36]. Valls-Pedret et al[36] noticed that a relationship between cognitive function and the intake of olive oil exist, but only in the context of virgin olive oil consumption. In both North and Central Europe, an important dietary source of monounsaturated (MUFA) and n-3 LCPs is rapeseed (canola) oil. It should be noted that, in Poland, the increased availability of some vegetable oils for human consumption, including olive oil, was connected with the economic and market transformation of the early 1990s[37]. Yet low erucic acid rapeseed oil was commonly used in households from the 1980s. Palomäki et al[38] have observed that short-term modification of the diet with cold-pressed turnip rapeseed oil replacing butter decreased the concentration of circulating LDL cholesterol and oxidized LDL, suggesting that it may be beneficial for treating hyperlipidemia and for diminishing oxidative stress (especially in patients with MS), thereby delaying the progression of atherosclerosis. Moreover cross-sectional analyses in an Italian cohort showed that MUFA intake was significantly associated with better global cognitive function and selective attention[39]. The nutritional components of fruits and vegetables with biological properties – such as natural antioxidants like vitamin E and A and flavonoids –, have also been hypothesized to have a protective effect against dementia and cognitive impairment[40]. These biocomponents may reduce neuronal damage and death from oxidative reactions, by inhibiting the generation of reactive oxygen species, lipid peroxidation, apoptosis, protein oxidation, damage to cell membranes and/or DNA, and beta-amyloid toxicity or deposition[40,41].

Other variables associated with cognitive function in our study – such as insufficient PA, low educational status, female gender, living alone without children, and the existence of MS – showed relationships mostly in the expected direction. Large observational epidemiologic studies also suggest the apparent benefits of PA on cognitive function[42-44], and all of them have reported that greater PA is related to less cognitive decline. Wueve et al noted that long-term regular PA, including walking, is associated with significantly better cognitive function and less cognitive decline in older women[45]. Also, the findings from our study clearly indicate that even strong adherence to the MedDiet could be less effective in maintaining the appropriate global cognitive functioning (as well as particular aspects of mental health) if the physical activity level is insufficient.

It is known that educational attainments set the stage for a broad spectrum of other socioeconomic factors that can influence health in general, and mental health in particular. We found that low educational status was associated with both poorer attention and poorer executive function in older adults. A similar investigation evaluated individuals older than 80 years with low educational levels from different Brazilian regions as to aspects of cognitive functioning[46]. The findings showed worse performance in working memory, attention, and verbal fluency as compared with more educated populations[46]. Our findings, as well as the results mentioned above, corroborate the previous reports that show a protective factor of schooling throughout time in certain cognitive functions.

We observed that the impairment of attention and the executive function were associated with female gender, and the latter one with older age. Several studies have reported cognitive deficits, such as worsened memory, an inability to concentrate, and deficits in abstract reasoning, attention, and set-shifting flexibility in middle-aged women. It has been suggested that women's cognitive decline with age may be due to several factors, including hormonal changes, the normal processes of aging, age-related changes in dopaminergic neurotransmission, and interindividual variations in brain function and cognitive abilities associated with genetic factors[47].

In previous studies, it has been shown that living with a partner or a child is a protective factor for some specific cognitive abilities, especially memory and orientation[48]. In our work, subjects who stated that they lived without children also had poorer executive function. It was also observed that subjects who stated that they lived together with children had higher scoring on the MedDiet. It seems that living with family members is a factor that protects health status for the elderly, not only because of the availability of social support, and higher economic resources, but also in terms of the regulation of lifestyle behaviors towards healthier eating pattern.

The existence of MS was associated with executive dysfunction in the rural elderly examined by Johnson et al., especially among those living without children[49]. Moreover, McEvoy et al[50] have also confirmed that MS is a risk factor for accelerated cognitive decline, but only in women. It should be stated that the prevalence of MS in our study was high (59.5%), but comparable to results obtained from the Polish Norwegian Study (PONS), where the prevalence of MS among older adults aged 60-64 years was identified as 47.1%[51].

Therefore, prevention, early detection, and treatment of the cardiovascular risk factors of MS may aid in the maintenance of cognitive function, independence, and quality of life in old age. Although it is known that the MedDiet is considered an important protective factor against some diseases related to MS[52], we did not find any significant differences in MedDiet adherence by body weight status or the existence of MS. Perhaps the small, statistically insignificant difference in the distribution of elderly people with MS between the groups of low and high adherence to MedDiet was due to the remaining strong attachment of older adults living in rural areas to traditional farmer's diet based on dishes fried in animal fat, red meat, and full-fat dairy products (e.g. cream). It seems that MS could be an independent factor that influences cognitive health negatively, especially in terms of executive function.

However, our study has some limitations. The sample we studied was relatively small, which limits its generalizability. The neuropsychological test battery used does not include all cognitive functions. Our cohort was at particularly high risk of MS, and so the results may not be generalizable to the average European elderly population. Additionally, based on the model of our study, we are not able to state with certainty that the healthy dietary pattern is causally related to better cognition function, rather than the inverse.

Conclusions

The promotion of a healthy-eating pattern modeled on the MedDiet in general, and the consumption of vegetables, fish, and olive or rapeseed oil with limitations in the intake of red meat, meat products, full-fat dairy product in particular, may provide a dietary strategy aimed at producing a cognitive health benefit. The pattern would seem to be easily adaptable to the elderly from non-Mediterranean rural communities, and is also relevant for individuals at high risk of MS or already suffering from MS. We determined that nutritional variables are significantly related to all examined aspects of cognitive performance: attention, visual memory, executive function, and global cognition. The nutritional variables remain significant after the incorporation of sociodemographic, lifestyle, and clinical factors into the statistical model. Among these factors, physical inactivity, and then female gender, education level lower than secondary school, living without children, the existence of MS, and older age had crucial importance for different aspects of cognitive impairment. Thus, more effort is needed to inform older individuals about the mental health benefits of the MedDiet and to take special care of those who are physically inactive, in spite of advice to the contrary, or who are less educated, have MS, live without children, or who are women.

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Conflict of interest

The Authors declare that they have no conflict of interests.

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