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ORIGINAL ARTICLE

# Are cognitive functions in post-menopausal women related with the contents of macro- and micro-components in the diet?

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## Abstract

The objective of the study was an evaluation of the relationship between the level of cognitive functions and contents of micro- and macro-components in the diet of postmenopausal women. A group of 402 women was recruited to the study. The inclusion criteria were: minimum two years after the last menstruation, FSH concentration 30 U/ml and no dementia signs on the Montreal Cognitive Assessment (MoCA). A computerized battery of the Central Nervous System Vital Signs (CNS VS) test was used to diagnose cognitive functions. The dietary questionnaire was evaluated based on observation of a seven-day diet. The data obtained were introduced into the database and analyzed using computer software DIETICIAN. Statistical analysis was performed using statistical software STATISTICA.

**Results.** The results of the study concerning diet unequivocally indicate a very poor quality of diet in the group of postmenopausal women examined. The daily diet had a too high energetic value. The women consumed an excessive amount of total fat, including definitely too much monounsaturated fatty acids, and insufficient polyunsaturated fatty acids. The dietary intake of sodium and phosphorus was too high, whereas deficiencies were observed in the consumption of iron, copper, potassium, calcium, magnesium and zinc. No significant correlations were found in the analysis of cognitive functions according to the energetic value of daily diet and contents of macro- and micro-components. The results concerning verbal memory significantly depended on the daily intake of polyunsaturated fatty acids. Women who consumed polyunsaturated fatty acids below the daily normal or normal level obtained significantly higher results in verbal memory.

## Key words

cognitive functions, diet, postmenopausal women

## INTRODUCTION

Menopause is a physiological phenomenon in the life of every woman. Deficiency of estrogens characteristic of this period, frequently accompanied by an inadequate mode of nutrition, intensify the symptoms of the so-called menopausal syndrome, increase the incidence of metabolic diseases and risk of cancer, and are associated with the occurrence or acceleration of the development of cognitive functions [1]. Therefore, it seems that diet adequately balanced from the aspect of quantity and quality, which would protect against the above-mentioned pathologies, including cognitive functions disorders, is a very important component of health promoting behaviours [2].

Many studies have shown that in individuals with mild cognitive impairments, which are observed among post-menopausal women [1], there occurs an elevated risk of Alzheimer's disease (AD) [2, 3]. According to these researchers, apart from mental activity, diet may play a very important role in the prevention of dementia. Earlier studies showed that the Mediterranean diet rich in fish, fruits, unsaturated fatty acids, but low in dairy products, meat and saturated fatty acids, decreases the risk of the development of dementia. The Mediterranean diet also decreases the level of cholesterol and glucose in blood, improves the condition of blood vessels, most probably decreases the intensity of inflammatory processes, which favourably affects the state of the nervous system, and may prevent the impairment of memory [4]. Increasingly more studies concern polyunsaturated fatty acids (PUFA) typical of the Mediterranean diet, and their relationship with preventing natural age-related degeneration of the brain. The researchers emphasize that the contents of PUFA in the 'Western' diet is insufficient for fully supplying the brain with docosahexaenoic acid (DHA) – the main component of the cellular membrane of neurons. DHA deficiency in the brain is related with the deterioration of memory, emotional liability, and brain degeneration. The researchers confirmed that supplying the brain with an adequate amount of DHA would slow down age-related deterioration of cognitive functions, brain degeneration, and would decrease the development of senile dementia. This could all happen through the optimization of intracerebral repair mechanisms, improvement of synaptic transport (especially glutamatergic in the hippocampus), and have an effect on neurogenesis in the region of the hippocampus, which is responsible for memory and normal cognitive functions [5].

However, not only the quality, but also an adequate amount of food is very important. During the peri-menopausal period, an adequately balanced diet and supplying the organism

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with an adequate energetic value is especially important. The optimum energetic value of a daily portion should be individualized, because the supply which exceeds the demand by 100 kcal causes an increase in body weight by 5 kg annually, on average. Diet should contain necessary macro- and micro-components, because their deficiency is also harmful for health. During this period of life, one should correct own nutritional habits by: 1) elimination of dietary errors, 2) implementation of technological changes in the preparation of food, 3) reduction of the excess of carbohydrates and fats containing saturated fatty acids in the daily food portion [2].

The recognized dementia risk factors which may be modified by diet are individual components of the metabolic syndrome: abdominal obesity, hypertriglyceridaemia, low HDL value, arterial hypertension, and impaired glucose tolerance [6, 7]. In older diabetic patients, the risk of development of dementia and mild cognitive impairments is approximately twice as high as in individuals without diabetes [4]. Preliminary observations indicate that diabetes was most strongly related with the risk of vascular dementia; and the latest studies confirm that diabetes is also related with a high risk of Alzheimer's disease (AD). In his studies, Nilsson directly states that the more criteria of metabolic syndrome that are met, the higher the risk of development of cognitive disorders in older age (in individuals who at present have no features of dementia) [4]. Considering the growing epidemic of obesity, type 2 diabetes, arterial hypertension, etc, as well as the fact of the ageing of society, we are also threatened by an epidemic of various forms of dementia, including AD. In order to prevent this, Nilsson proposes the application of a so-called 'active diet' – which has a confirmed potential of reducing the risk of cardiovascular diseases and development of an inflammatory state. To this diet contribute: a) products containing antioxidants (anti-inflammatory effect, beneficial effect on arterial tension, lipid profile, improvement of cognitive functions [8]; b) oily fish rich in PUFA (anti-inflammatory effect, decrease in the level of triglycerides, improvement of memory [9]; c) wholemeal products rich in fibre – prebiotic effect, improvement of glycaemia control, decrease in exponents of inflammatory response; d) products with decreased glycaemic index – reduction of the risk of type 2 diabetes, metabolic syndrome, inflammatory response, improvement of cognitive functions [10]; e) products improving lipid profile – roasted almonds, soya beans [11].

Among risk factors, oxidative stress and lipid perioxidase may be associated with a high content of fat in the diet, and in this way, with the pathogenesis of AD [5].

Thus, confirmation of the presence of a correlation between levels of selected micro- and macro-components would allow the undertaking of proper prophylactic actions aimed at the elimination of their negative effect on cognitive functions disorders, as well as other symptoms related with menopause.

**Objective.** The objective of the study was an evaluation of the relationship between the level of cognitive functions and contents of micro- and macro-components in the diet of postmenopausal women.

## MATERIALS AND METHOD

**Study group.** The study was conducted in 2011 at the Institute of Rural Health in Lublin. The study group were women from south-eastern Poland. The criteria of inclusion in the study were as follows: age 50–65, good general health, education level at least completed elementary. The women were also qualified into the study group based on clinical symptoms (minimum 2 years from the last menstrual period) and based on the criterion of FSH level (FSH>30 mlU/ml). The criteria for exclusion from the study were as follows: active cancerous disease within the period of 5 years before recruitment; mental diseases in medical history, including depressions before menopause; addiction to drugs and alcohol; diagnosed nosologic unit with the symptoms of dementia. At the stage of qualification for the study, a brief MoCA test was conducted in order to include the patients who did not show the features of dementia [12]. The Montreal Cognitive Assessment (MoCA) scale for evaluation of cognitive functions was designed as a quick screening instrument for the evaluation of mild cognitive dysfunctions, with a Polish adaptation of the scale by Magierska et al. The maximum number of scores in this test is 30; and the result of 26 or more scores is considered as normal. All the women included in the study obtained more than 26 scores in the MoCA test.

**Neuropsychological assessment.** Cognitive functions were evaluated using the Polish version of the diagnostic instrument CNS-Vital Signs (CNS-VS) [13] with software by CNS Vital Signs (Chapel Hill, NC, USA). The instrument in the form of a battery of computer tests is standardized, and has been subjected to the full validation procedure, and has a Polish adaptation. The entire research procedure with the use of a computer was performed in Polish. The report concerning test results is published in English. CNS-VS covers the following tests: Verbal Memory Test (VBM) – examines motor functioning; Finger Tapping Test (FTT), Symbol Digit Modalities Test (SDMT), Stroop Test (ST), Shifting Attention Test (SAT) and Continuous Performance Test (CPT). CNS-VS assesses 9 cognitive functions: memory, verbal memory, visual memory, processing speed, executive functions, psychomotor speed, reaction time, complex attention, and cognitive flexibility. Based on 5 of these functions – memory, psychomotor speed, reaction time, complex attention, and cognitive flexibility – the Neurocognition Index (NCI) is calculated. The computer data from the CNS-VS test provides: raw results, standardized results, percentiles, and evaluations according to the 5-point scale for each of the 9 cognitive functions examined and the Neurocognitive Index. These evaluations are as follows: above average – more than 109 standardized scores, average – 90–109, below average – 80–89, low – 70–79, very low – less than 70.

**Diet.** The dietary questionnaire was evaluated based on observation of a 7-day diet. The women in the study described qualitatively and quantitatively the food products and meals consumed during the 7 days of the week. The data obtained were introduced into the database and analyzed using computer software DIETICIAN, developed at the Institute of Food and Nutrition in Warsaw. The computer software served to calculate the energetic value of daily diet and the contents of macro- and micro-components in the daily diet. The results of the study were compared with the results of studies of the Recommended Dietary Allowance (RDA) standards of nutrition for the selected Polish population [13].

**Statistical analysis.** Statistical analysis was performed using statistical software STATISTICA. The NCI and cognitive functions were analyzed (standard scores), as well as calorific value and contents of micro- and macro-components in the daily diet of the women examined (both in natural units and standard intervals). Minimum and maximum values, as well as the mean values and standard deviations, were provided for cognitive functions, and micro- or macro-components. Absolute and relative numbers were provided for standard intervals of micro- and macro-components.

In the analysis of correlations between cognitive functions and micro- and macro-components (in natural units), Pearson's linear correlation coefficient was used.

In the analysis of the NCI and cognitive functions according to the standard intervals for micro- and macro-components, the t test for the difference between 2 mean values in independent trials were used (while comparing cognitive functions in 2 standard intervals for micro- and macro-components), and F test for analysis of variance (when cognitive functions were compared at 3 intervals).

The level of significance was set at p=0.05.

Consent for the study was obtained from the Bioethical Committee at the Institute of Rural Health in Lublin.

## RESULTS

The study covered 402 women, aged 50–65; mean age 56.5±3.5, who weighed 45–98 kg, 69.3±11.4 kg, on average, with BMI from 15.9–42.8; 26.4±3.9kg/m$^2$, on average. As many as 245 of respondents (61%) had excessive weight, including 169 (42.0%) overweight, and (18.9%) obese, while 151 women (37.65%) had a normal body weight, and 6 (1.49%) were underweight.

In the daily diet of the women examined, the calorific value was analyzed, as well as macro- components such as proteins, fat, carbohydrates, saturated fatty acids, mono- and poly-unsaturated fatty acids, and cholesterol (Tab. 1).

The calorific value of the respondents' diet was from 1,300.50–3,162.64kcal/d; 1,959.73±426kcal, on average; 37.81% of women in the study had a normal calorie diet, whereas 45.02% – higher than normal.

The contents of proteins in the respondents' diet was from 49.39–119.62g; 73.55±14.87g, on average. In the majority of the women examined, the consumption of proteins was normal – 59.95%, higher than normal – 23.13%, and lower than normal – 16.92%.

The total consumption of fat in respondents' diet was 73.59±16.71g, on average; the consumption of saturated fatty acids was 27.83±6.33g on average; monounsaturated fatty acids – 29.03±7.21g, on average, whereas the mean consumption of polyunsaturated fatty acids was the lowest – 11.07±4.40g. The content of total fat in the diet was normal in 43.03% of women, and higher than normal in 56.97%. In 87.31% of women in the study, the content of monounsaturated fatty acids was higher than normal, while in 12.69% it was normal. In the case of polyunsaturated fatty acids, it was the opposite, the consumption below normal was noted in the diet of 62.94% of respondents, normal in 33.83%, and higher than normal in 3.23% of respondents.

In the group of women examined, the consumption of cholesterol was 285.60±92.73g, on average; 63.18% of respondents had normal cholesterol values in their diet, and 36.82% – higher than normal.

The respondents consumed from 143.08–486.49g carbohydrates; 269.20 ±72.84g, on average. The content of saccharose in their diet was 19.02–169.70 g, 63.92±29.41g, on average.

Dietary fibre in the diets analyzed was from 9.32–32.28g, 20.84±5.29g, on average.

Table 2 presents the content of micro-components in the daily diet of postmenopausal women.

In the diet of the women examined, the contents of the following were noted:

- sodium – 1,790.86±542.93mg; the intake was higher than normal in all the women;
- mean potassium content: 3,150±724.20mg, in 74.63% of the women examined it was below normal, and in 3.98% – normal, and in 21.39% – higher than normal.
- mean calcium content in the respondents' diet – 711.10±188,38mg, in 71% – below normal, in 26.12% – normal, and in 2.74% – higher than normal.
- mean phosphorus content in the group examined – 1,191.31±254.19mg.
- nearly all the women in the study consumed phosphorus in their diet beyond the normal level (99%).
- mean consumption of magnesium by the women in the study was 266.02±73.35mg, in approximately 7% of respondents it was on a normal level, the largest number of women consumed magnesium below normal (68.16%), and 24.88% – above normal.
- mean intake of iron – 10.42±3.41mg, in the majority of women iron consumption was below normal (87.31%).

**Table 1.** Macro-components in daily diet of women examined

| Macro-components | Min. | Max. | M | SD | Below normal | | Normal | | Higher than normal | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | n | % | n | % | n | % |
| Energy (kcal) | 1,300.50 | 3,162.64 | 1,959.73 | 426.37 | 69 | 17.16 | 152 | 37.81 | 181 | 45.02 |
| Proteins (g) | 49.39 | 119.62 | 73.55 | 14.87 | 68 | 16.92 | 241 | 59.95 | 93 | 23.13 |
| Fats (g) | 45.19 | 121.85 | 73.59 | 16.71 | 0 | 0.00 | 173 | 43.03 | 229 | 56.97 |
| Saturated fatty acids (g) | 16.93 | 45.60 | 27.83 | 6.33 | x | x | x | X | x | x |
| Monounsaturated fatty acids (g) | 16.54 | 50.32 | 29.03 | 7.21 | 0 | 0.00 | 51 | 12.69 | 351 | 87.31 |
| Polyunsaturated fatty acids (g) | 4.75 | 32.92 | 11.07 | 4.40 | 253 | 62.94 | 136 | 33.83 | 13 | 3.23 |
| Cholesterol (g) | 145.42 | 569.72 | 285.60 | 92.73 | 0 | 0.00 | 254 | 63.18 | 148 | 36.82 |
| Total carbohydrates (g) | 143.08 | 486.49 | 269.20 | 72.84 | x | x | x | X | x | x |
| Saccharose (g) | 19.02 | 169.70 | 63.92 | 29.41 | x | x | x | X | x | x |
| Lactosis (g) | 0.40 | 28.81 | 13.43 | 5.53 | x | x | x | X | x | x |
| Dietary fibre (g) | 9.32 | 32.28 | 20.84 | 5.29 | x | x | x | X | x | x |

**Table 2.** Micro-components in daily diet of the women examined

| Micro-components | Min | Max | M | SD | Below normal | | Normal | | Higher than normal | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | n | % | n | % | n | % |
| Sodium (mg) | 834.90 | 3,078.07 | 1,790.86 | 542.93 | 0 | 0.00 | 0 | 0.00 | 402 | 100.00 |
| Potassium (mg) | 1,565.33 | 5,420.33 | 3,150.82 | 724.20 | 300 | 74.63 | 16 | 3.98 | 86 | 21.39 |
| Calcium (mg) | 287.05 | 1,353.72 | 711.10 | 188.38 | 286 | 71.14 | 105 | 26.12 | 11 | 2.74 |
| Phosphorus (mg) | 775.50 | 1,885.78 | 1,191.31 | 254.19 | 0 | 0.00 | 4 | 1.00 | 398 | 99.00 |
| Magnesium (mg) | 130.89 | 485.95 | 266.02 | 73.35 | 274 | 68.16 | 28 | 6.97 | 100 | 24.88 |
| Iron (mg) | 5.55 | 25.05 | 10.42 | 3.41 | 351 | 87.31 | 33 | 8.21 | 18 | 4.48 |
| Zinc (mg) | 5.58 | 16.56 | 9.46 | 1.99 | 281 | 69.90 | 113 | 28.11 | 8 | 1.99 |
| Copper (mg) | 0.52 | 1.92 | 1.13 | 0.29 | 345 | 85.82 | 57 | 14.18 | 0 | 0.00 |
| Manganese (µg) | 1.64 | 10.24 | 3.85 | 1.40 | 109 | 27.11 | 151 | 37.56 | 142 | 35.32 |

– zinc – 9.46±1.99mg; in nearly 70% of the women the zinc intake was below normal, and in 28.11% – normal.
– mean daily copper intake – 1.13±0.29mg; in approximately 86% of respondents the copper intake was below normal level, and in 14.18% – normal.
– mean consumption of manganese – 3.85±1.4mg; in the diet of 37.56% of women it was normal, in 35.32% – higher than normal, and in 27.11% – below normal.

While analyzing the NCI of cognitive functions obtained by the women in the study (Fig. 1), it may be presumed that they obtained the poorest results in: cognitive flexibility, processing speed and executive functions (mean values obtained were below 80 scores – very low). They achieved the best results in the following domains: memory, verbal memory and visual memory (mean results over 90 scores – average). The women in the study achieved mean results in the following domains: psychomotor speed, complex attention and reaction time (mean values between 80–90 scores – low average).

There was a lack of linear correlation between the respondents' age, and their NCI and cognitive functions. Analysis of variance also did not show any significant differences between the results of cognitive functions according to 3 age groups ($p>0.05$). Also, no significant correlations were found between the respondents' BMI and results of NCI and cognitive functions ($p>0.05$).

No significant linear correlations were noted between cognitive functions and calorific value and content of macro-components (Tab. 3) and micro-components (Tab. 4) in the daily diet of the women examined.

In the analysis of cognitive functions according to the recommended standards of calorific value and macro-components in the daily diet of the women examined only one significant relationship was found (Tab. 5). The results concerning verbal memory significantly depended on the daily intake of polyunsaturated fatty acids (Fig. 2). Women who consumed polyunsaturated fatty acids below the daily normal or normal level obtained significantly higher results in verbal memory (respectively, mean values 92.0 and 91.1

**Table 3.** Results of analysis of variance between cognitive functions and calorific value and contents of macro-components in the diet of the women in the study

| Cognitive functions | Measure | Energy | Proteins | Total fat | Saturated fatty acids | Monoun-saturated fatty acids | Polyun-saturated fatty acids | Choles-terol | Total carbo-hydrates | Saccha-rose | Lactosis | Dietary fibre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NCI | R | 0.020 | 0.009 | -0.007 | 0.002 | -0.022 | -0.017 | 0.004 | 0.029 | 0.017 | 0.015 | 0.036 |
| | P | 0.687 | 0.860 | 0.886 | 0.968 | 0.662 | 0.730 | 0.937 | 0.563 | 0.735 | 0.769 | 0.473 |
| Memory | R | -0.034 | -0.017 | -0.023 | -0.013 | -0.036 | -0.025 | -0.037 | -0.035 | -0.030 | 0.015 | -0.036 |
| | P | 0.495 | 0.733 | 0.641 | 0.795 | 0.476 | 0.619 | 0.460 | 0.480 | 0.544 | 0.761 | 0.472 |
| Verbal memory | R | -0.074 | -0.069 | -0.081 | -0.052 | -0.085 | -0.084 | -0.051 | -0.058 | -0.032 | 0.007 | -0.045 |
| | P | 0.140 | 0.167 | 0.104 | 0.302 | 0.089 | 0.094 | 0.309 | 0.248 | 0.518 | 0.884 | 0.368 |
| Visual memory | R | 0.050 | 0.058 | 0.075 | 0.064 | 0.056 | 0.064 | -0.003 | 0.025 | 0.006 | 0.017 | -0.011 |
| | P | 0.318 | 0.244 | 0.131 | 0.202 | 0.263 | 0.198 | 0.955 | 0.614 | 0.902 | 0.739 | 0.834 |
| Processing speed | R | -0.037 | 0.004 | -0.013 | 0.010 | -0.035 | -0.011 | 0.015 | -0.051 | -0.082 | -0.038 | -0.027 |
| | P | 0.460 | 0.929 | 0.794 | 0.846 | 0.490 | 0.821 | 0.759 | 0.309 | 0.100 | 0.443 | 0.588 |
| Executive functions | R | 0.030 | 0.027 | -0.022 | -0.019 | -0.033 | -0.026 | 0.018 | 0.047 | 0.030 | 0.044 | 0.044 |
| | P | 0.548 | 0.581 | 0.662 | 0.701 | 0.504 | 0.610 | 0.721 | 0.349 | 0.556 | 0.374 | 0.375 |
| Psychomotor speed | R | -0.029 | -0.036 | -0.003 | 0.036 | -0.015 | -0.036 | 0.039 | -0.036 | -0.016 | -0.054 | 0.008 |
| | P | 0.552 | 0.473 | 0.951 | 0.468 | 0.771 | 0.475 | 0.439 | 0.475 | 0.748 | 0.281 | 0.873 |
| Reaction time | R | -0.042 | -0.038 | -0.038 | -0.041 | -0.036 | -0.025 | -0.034 | -0.035 | -0.062 | 0.000 | 0.028 |
| | P | 0.396 | 0.446 | 0.442 | 0.414 | 0.467 | 0.623 | 0.500 | 0.479 | 0.213 | 0.998 | 0.577 |
| Complex attention | R | 0.036 | 0.029 | -0.013 | -0.010 | -0.024 | -0.016 | 0.011 | 0.052 | 0.042 | 0.029 | 0.052 |
| | P | 0.476 | 0.565 | 0.799 | 0.838 | 0.637 | 0.749 | 0.824 | 0.302 | 0.402 | 0.561 | 0.299 |
| Cognitive flexibility | R | 0.039 | 0.037 | -0.006 | -0.006 | -0.020 | -0.013 | 0.024 | 0.050 | 0.035 | 0.038 | 0.046 |
| | P | 0.433 | 0.465 | 0.904 | 0.911 | 0.697 | 0.802 | 0.628 | 0.314 | 0.488 | 0.451 | 0.355 |

**Table 4.** Results of correlation analysis between cognitive functions and contents of micro-components in daily diet of the women examined

| Cognitive functions | Measure | Sodium | Potassium | Calcium | Phosphorus | Magnesium | Iron | Zinc | Copper | Manganese |
|---|---|---|---|---|---|---|---|---|---|---|
| NCI | r | 0.086 | -0.014 | 0.034 | 0.001 | 0.026 | 0.015 | 0.025 | -0.038 | 0.033 |
| | p | 0.085 | 0.785 | 0.492 | 0.987 | 0.603 | 0.768 | 0.615 | 0.443 | 0.507 |
| Memory | r | 0.016 | -0.036 | 0.021 | -0.027 | -0.032 | -0.018 | -0.025 | -0.056 | -0.015 |
| | p | 0.751 | 0.474 | 0.679 | 0.585 | 0.524 | 0.711 | 0.612 | 0.265 | 0.760 |
| Verbal memory | r | -0.037 | -0.042 | -0.008 | -0.055 | -0.046 | -0.031 | -0.051 | -0.057 | -0.029 |
| | p | 0.456 | 0.402 | 0.872 | 0.272 | 0.358 | 0.529 | 0.304 | 0.255 | 0.560 |
| Visual memory | r | 0.071 | -0.011 | 0.050 | 0.019 | -0.001 | 0.004 | 0.017 | -0.019 | -0.007 |
| | p | 0.158 | 0.833 | 0.315 | 0.699 | 0.989 | 0.943 | 0.732 | 0.691 | 0.892 |
| Processing speed | r | 0.035 | -0.047 | 0.016 | 0.012 | -0.025 | 0.026 | 0.017 | -0.067 | 0.009 |
| | p | 0.481 | 0.350 | 0.742 | 0.803 | 0.623 | 0.602 | 0.734 | 0.180 | 0.861 |
| Executive functions | r | 0.092 | -0.008 | 0.043 | 0.018 | 0.042 | 0.021 | 0.035 | -0.011 | 0.035 |
| | p | 0.065 | 0.879 | 0.386 | 0.712 | 0.401 | 0.672 | 0.489 | 0.820 | 0.484 |
| Psychomotor speed | r | -0.013 | -0.018 | 0.021 | -0.004 | 0.015 | 0.020 | 0.002 | -0.028 | 0.018 |
| | p | 0.797 | 0.723 | 0.679 | 0.935 | 0.760 | 0.689 | 0.968 | 0.577 | 0.724 |
| Reaction time | r | 0.052 | -0.041 | -0.003 | -0.035 | -0.023 | -0.008 | 0.010 | -0.066 | 0.010 |
| | p | 0.300 | 0.410 | 0.952 | 0.485 | 0.650 | 0.866 | 0.835 | 0.184 | 0.835 |
| Complex attention | r | 0.078 | 0.007 | 0.042 | 0.013 | 0.044 | 0.013 | 0.034 | -0.001 | 0.026 |
| | p | 0.119 | 0.888 | 0.407 | 0.801 | 0.379 | 0.799 | 0.501 | 0.989 | 0.599 |
| Cognitive flexibility | r | 0.095 | 0.000 | 0.046 | 0.022 | 0.046 | 0.022 | 0.039 | -0.012 | 0.036 |
| | p | 0.058 | 0.997 | 0.360 | 0.666 | 0.356 | 0.659 | 0.441 | 0.812 | 0.477 |

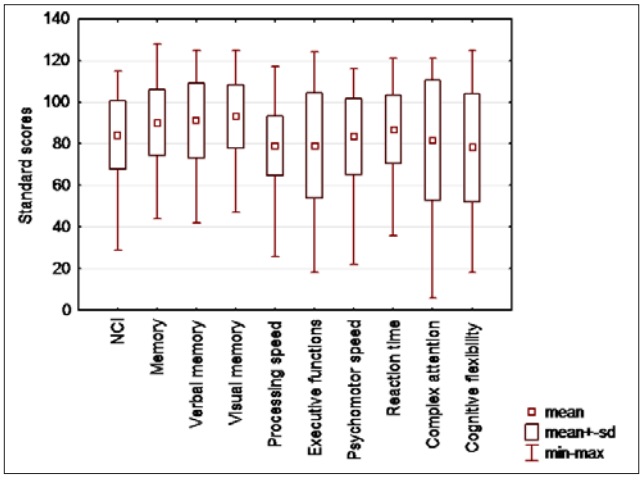


**Figure 1.** NCI and cognitive functions of the women in the study

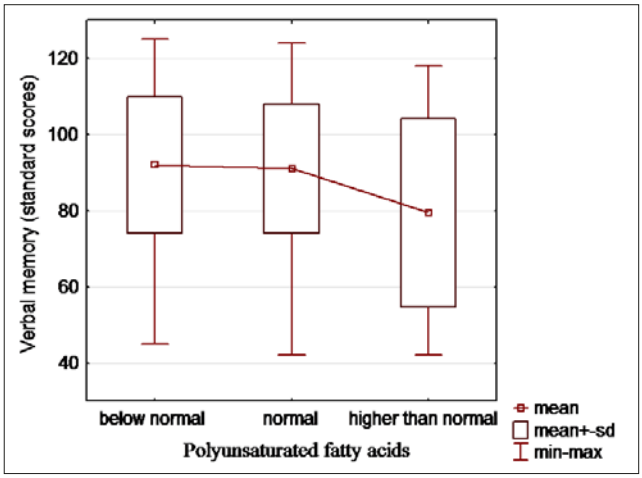


**Figure 2.** Verbal memory according to contents of polyunsaturated fatty acids in daily diet of the women examined

**Table 5.** Results of analysis of cognitive functions according to standards for the contents of energy and macro- components in daily diet of the women examined

| Cognitive functions | Energy | | Protein | | Total fat | | monounsaturated fatty acids | | Polyunsaturated fatty acids | | Cholesterol | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | p | F | p | t | p | t | p | F | p | t | p |
| NCI | 0.256 | 0.775 | 0.052 | 0.949 | 0.522 | 0.602 | 0.824 | 0.411 | 0.740 | 0.478 | 0.754 | 0.451 |
| Memory | 0.378 | 0.685 | 0.556 | 0.574 | 0.843 | 0.400 | 0.968 | 0.334 | 1.205 | 0.301 | 0.117 | 0.907 |
| Verbal memory | 0.894 | 0.410 | 0.668 | 0.513 | 1.298 | 0.195 | 1.663 | 0.097 | 3.053 | 0.048 | 0.299 | 0.765 |
| Visual memory | 1.080 | 0.341 | 0.272 | 0.762 | 0.468 | 0.640 | 0.718 | 0.473 | 2.264 | 0.105 | 0.744 | 0.458 |
| Processing speed | 0.120 | 0.887 | 0.964 | 0.382 | 0.831 | 0.406 | 0.313 | 0.754 | 0.031 | 0.969 | 0.495 | 0.621 |
| Executive functions | 0.314 | 0.731 | 0.000 | 1.000 | 0.514 | 0.607 | 0.836 | 0.404 | 0.727 | 0.484 | 0.797 | 0.426 |
| Psychomotor speed | 0.624 | 0.536 | 0.660 | 0.517 | 0.381 | 0.704 | 1.064 | 0.288 | 0.298 | 0.742 | 1.274 | 0.204 |
| Reaction time | 0.392 | 0.676 | 0.647 | 0.524 | 0.447 | 0.655 | 0.375 | 0.708 | 0.320 | 0.726 | 0.368 | 0.713 |
| Complex attention | 0.474 | 0.623 | 0.068 | 0.935 | 0.362 | 0.717 | 1.363 | 0.174 | 0.436 | 0.647 | 0.833 | 0.406 |
| Cognitive flexibility | 0.416 | 0.660 | 0.029 | 0.971 | 0.383 | 0.702 | 0.717 | 0.474 | 0.812 | 0.445 | 0.870 | 0.385 |

**Table 6.** Results of analysis of cognitive functions of the women in the study according to standards for the contents of micro-components in daily diet of the women examined

| Cognitive functions | Potassium | | Calcium | | Magnesium | | Iron | | Zinc | | Copper | | Manganese | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | p | F | p | F | p | F | p | F | p | T | p | F | p |
| NCI | 0.035 | 0.966 | 0.155 | 0.856 | 0.667 | 0.514 | 0.797 | 0.451 | 0.141 | 0.868 | 0.268 | 0.789 | 1.555 | 0.212 |
| Memory | 0.455 | 0.635 | 0.153 | 0.859 | 0.290 | 0.748 | 0.086 | 0.918 | 0.126 | 0.882 | 0.904 | 0.366 | 1.277 | 0.280 |
| Verbal memory | 0.575 | 0.563 | 1.131 | 0.324 | 0.047 | 0.954 | 1.546 | 0.214 | 0.351 | 0.704 | 1.073 | 0.284 | 0.884 | 0.414 |
| Visual memory | 0.337 | 0.714 | 0.515 | 0.598 | 1.107 | 0.332 | 2.076 | 0.127 | 0.481 | 0.618 | 0.103 | 0.918 | 0.479 | 0.620 |
| Processing speed | 0.297 | 0.743 | 0.503 | 0.605 | 0.098 | 0.906 | 2.036 | 0.132 | 0.299 | 0.742 | 0.019 | 0.985 | 0.567 | 0.567 |
| Executive functions | 0.009 | 0.991 | 0.130 | 0.878 | 0.646 | 0.525 | 0.541 | 0.583 | 0.081 | 0.922 | 0.068 | 0.945 | 0.930 | 0.395 |
| Psychomotor speed | 0.112 | 0.894 | 0.109 | 0.897 | 0.600 | 0.549 | 1.492 | 0.226 | 0.013 | 0.987 | 0.486 | 0.627 | 0.086 | 0.918 |
| Reaction time | 0.333 | 0.717 | 1.528 | 0.218 | 0.538 | 0.584 | 0.252 | 0.778 | 0.116 | 0.891 | 1.287 | 0.199 | 0.644 | 0.526 |
| Complex attention | 0.060 | 0.941 | 0.019 | 0.981 | 0.863 | 0.423 | 0.740 | 0.478 | 0.132 | 0.876 | 0.068 | 0.946 | 1.573 | 0.209 |
| Cognitive flexibility | 0.026 | 0.974 | 0.069 | 0.933 | 0.724 | 0.486 | 0.739 | 0.478 | 0.199 | 0.820 | 0.039 | 0.969 | 1.337 | 0.264 |

standard stores), compared to those with a daily intake of polyunsaturated fatty acids above the normal level (verbal memory 79.5, on average).

No differences in cognitive functions according to the normal levels were observed for any of the micro-components (Tab. 6). While analyzing cognitive functions according to the consumption of elements by recommended levels, sodium and potassium were not considered, because in all the women in the study the daily consumption of sodium was higher than normal, and in the case of phosphorus, in only 4 women the daily intake was normal, whereas in the reminder of the women – higher than normal.

## DISCUSSION

The results of the presented study concerning diet unequivocally indicate a very poor quality of diet in the group of postmenopausal women examined. The daily diet has a too high energetic value. The women in the study consumed excessive amount of total fat, including definitely too much monounsaturated fatty acids, and insufficient polyunsaturated fatty acids. Great abnormalities occur with respect to the consumption of micro-components. In nearly all the women, the dietary intake of sodium and phosphorus was too high, whereas in almost all the women deficiencies were observed in the consumption of iron and copper, and in a half of the respondents in the intake of potassium, calcium, magnesium and zinc. No significant correlations were found in the analysis of cognitive functions according to the energetic value of daily diet and contents of macro- and micro-components. However, differences in results were noted in the domain of verbal memory according to polyunsaturated fatty acids, and their excess – which is surprising – acted to the disadvantage of verbal memory in the group of women in the presented study.

Population studies report that the consumption of antioxidants or polyunsaturated fatty acids may be related with a decreased frequency of the occurrence of dementia. Despite the fact that in the presented study no relationship was found between cognitive functions and individual components of diet and its energetic value, considering the low quality of the diet observed and the occurrence of cognitive dysfunctions in all domains in a half of the women examined, the results concerning diet inadequately balanced from the quantitative and qualitative aspect seem to be significant.

Several studies have confirmed that older individuals consuming the Mediterranean diet are at a lower risk of the development of dementia and cognitive disorders. Scarmeas, together with a group of researchers from the Columbia University Medical Center, investigated nutritional habits (including observance of the Mediterranean diet) among individuals without memory impairment, and in patients with mild cognitive impairments. Four-and-a-half years after the onset of the project, in 275 from among 1,393 participants who had no problems with memory, there developed mild cognitive impairments. The researchers calculated that individuals who strictly observed the Mediterranean diet were at 28% lower risk of the development of these disorders, compared to those who did not observe these recommendations, whereas those who moderately observed the diet were at risk lower by 17%. In the second study group, in 106 from among 482 individuals with cognitive impairment, Alzheimer's disease developed 4 years and 3 months after the beginning of the study. The researchers presumed that the observance of the diet decreased the risk of transition of mild impairments into severe dementia by 45% – 48%, on average. Subsequent studies by these researchers confirmed the beneficial effect of diet on the prevention of the development of dementia [15].

In turn, Samieri [16] in her study did not confirm a beneficial effect of this diet on the improvement of cognitive functions. Also, Crichton reported the lack of effect of the Mediterranean diet on the improvement of cognitive disorders, although its beneficial effect on the improvement of psychological functions, general state of health, and decrease in the risk of depression was mentioned [17]. Similar to the Mediterranean diet, studies concerning the supplementation with PUFA with respect to cognitive functions were also unequivocal. Although several observation studies reported that individuals with high consumption of polyunsaturated fatty acids had a lower risk of occurrence of dementia and Alzhaimer's disease, in randomized clinical studies this effect was not confirmed [17]. Also, Sydenham reports the lack of benefits from the supplementation of PUFA in a group of older individuals without cognitive impairments [18].

In the presented study, the contribution of micro-components in the creation of an adequate diet cannot be omitted. In this tudy, apart from sodium and phosphorus, which were in excess in all women, in the majority of women the remaining micro-components were below

normal level. After menopause the absorption of calcium decreases, which is associated, among others, with estrogen deficiency. With ageing, it also decreases the production of endogenous metabolites of vitamin D. The absorption of calcium is affected by a balanced composition of diet, primarily an adequate supply of calcium and phosphorus (ratio 1:1). The presence of active metabolites of vitamin D, potassium, manganese, zinc, copper, vitamins C and K is also important [2]. The use of calcium and potassium in a diet may be hindered in the case of an excess of sodium. In Poland, the intake of sodium is more than twice higher than recommended [19] – in the presented study an excess of sodium was also found in all the women examined. Observation studies and studies on animals provide evidence for the beneficial effect of calcium and dairy products in counteracting obesity. Heiss, in his study, reported that the higher the intake of calcium, the lower the mass of fatty tissue in postmenopausal women [20]. According to Jacqmain, a higher consumption of products containing calcium results in an improvement of lipid profile and decreased risk of dementia changes associated with it [21].

The remaining nutrients in various mechanisms may play a role in the reduction of metabolic risk. Phosphorus and magnesium participate in the regulation of blood pressure. Magnesium modulates vascular function through its anti-oxidative and anti-inflammatory effect. In addition, magnesium has a protective effect on the central nervous system by improving blood flow in the cerebral vessels [22]. In the presented study, as many as 68% of post-menopausal women consumed insufficient amounts of magnesium. There is also evidence that a higher consumption of magnesium may also decrease the level of cholesterol and triglycerides, and improve diabetes control. All these dietary components may prevent or reduce vascular and structural changes in the brain, which co-occur with the decrease in cognitive functions. The beneficial effect of these dietary components on the state of vascular changes may also be related with counteracting an inflammatory state. A decrease in the risk of a local inflammatory condition (by reduction in body weight, improvement in the regulation of glucose and arterial hypertension), may decrease the risk of cognitive disorders.

In the presented study, as many as 45% of postmenopausal women consumed an excessive amount of calories daily. An increased supply leads to the development of obesity, diabetes, and metabolic syndrome. However, not only an increased BMI and all pathological conditions related with it, exert an unfavourable effect on the state of health. Coin, in her study, observed that BMI<25 is associated with worse results in cognitive functions in the MMSE study [23]. Also, Bagger reports that the larger the loss of body weight, and consequently loss of fatty tissue, the worse the results of cognitive functions in older women, which is probably related with a decreased exposure to endogenous estrogen [24].

Considering the above-mentioned information and poor quality of diet of the post-menopausal women in the study, who were characterized by a considerable decrease in cognitive functions, despite the lack of relationships with individual dietary components, it should be presumed that strategies aimed at changing diet and nutritional habits leading to a decrease in the risk of cardiovascular diseases, undoubtedly have a positive effect on health, and may exert an adequate effect on cognitive functioning.

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