

# Dietary intake of vitamins B<sub>6</sub>, B<sub>12</sub> and folate in relation to homocysteine serum concentration in the adult Polish population – WOBASZ Project

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## Abstract

**Background:** Increased homocysteine (Hcy) levels predispose to atherosclerosis. Vitamin B<sub>6</sub>, B<sub>12</sub> and folate play an important role in Hcy metabolism.

**Aim:** To assess vitamin B<sub>6</sub>, B<sub>12</sub> and folate intake and describe the relationship between these vitamins intake and Hcy level in the Polish population.

**Methods:** Within the framework of the National Multicentre Health Survey (WOBASZ), a representative sample of the whole Polish population aged 20-74 was screened in the years 2003-2005. In each province of Poland 6 communities were randomly selected and in each of them a sample of 100 men and 100 women was randomly selected from the personal identification number (PESEL) database. In a sample of 50% of subjects (3004 men and 3401 women) Hcy level and nutrients were assessed according to the study protocol.

**Results:** Average intake of vitamin B<sub>6</sub> was 2.26 mg/day in men and 2.03 mg/day in women, of vitamin B<sub>12</sub> – 5.85 µg/day and 3.69 µg/day, and folate 258 µg/day and 211 µg/day, respectively. The recommended levels of intake were not achieved by 16% of men and 36% of women for vitamin B<sub>6</sub>, 32% and 51% for vitamin B<sub>12</sub>, and 78% and 90% for folate, respectively. The Hcy level (after adjustment for age, smoking, coffee and alcohol consumption) and prevalence of hyper-Hcy ( $\geq 12$  µmol/l) decreased with increasing number of quartile of vitamins B<sub>6</sub> and B<sub>12</sub> in both genders and folate in men. In multivariable linear regression analysis an inverse association between the Hcy level and intake of vitamin B<sub>6</sub> and folate in both genders, and vitamin B<sub>12</sub> in men, was demonstrated.

**Conclusions:** In the Polish population insufficient folate intake was common (deficiency was noted in nearly 80-90% of the population) and despite the correct average, a high proportion of subjects did not fulfil B<sub>6</sub> and B<sub>12</sub> intake recommendations; an inverse association between vitamins B<sub>6</sub>, B<sub>12</sub> and folate consumption and Hcy concentration and prevalence of hyper-Hcy was observed.

**Key words:** vitamin B<sub>6</sub>, vitamin B<sub>12</sub>, folate, homocysteine, Polish population

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## Introduction

Homocysteine (Hcy) is a sulfur-containing amino acid which is derived from the demethylation of exogenous methionine. Many observational epidemiological studies and several clinical case-control studies have confirmed a relationship between high levels of Hcy and exacerbation of atherosclerosis, coronary heart disease (CAD), peripheral vein thrombosis and stroke [1-6].

Elevated serum levels of Hcy can be precipitated by genetic factors (decreased activity of the enzymes participating in the catabolism of Hcy) [7-8] and nutritional factors (deficit of vitamins acting as coenzymes in the Hcy metabolic pathways) [9-11]. Some medical conditions, medications as well as gender, age, alcohol and coffee intake or smoking can affect Hcy levels [12-13].

The fact that folates and vitamins B<sub>6</sub> and B<sub>12</sub> play an important role in the metabolic pathways of Hcy contributed to the increased interest in their dietary intake and in the association between their intake and Hcy levels. The database of the WOBASZ project (National Multicentre Population Health Survey), including a representative sample of the Polish adult population allowed analysis of this issue across the whole population, of the country. It is especially important since according to our results the Polish adult population has high mean Hcy levels (10.2 µmol/l in men and 8.8 µmol/l in women) and 26% of men and 16% of women have elevated levels of this amino acid (above 12.0 µmol/l) [14].

The aim of our study was to estimate vitamins B<sub>6</sub>, B<sub>12</sub> and folate intake and to assess the relationship between

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content of these vitamins in the diet and Hcy serum levels in the adult population of Polish citizens.

## Methods

We analysed the data provided by the WOBASZ project, which was carried out between 2003 and 2005 by the National Institute of Cardiology in Warsaw in cooperation with the Medical Universities of Gdańsk, Katowice, Łódź and Poznań and with Jagiellonian University in Krakow. A representative randomised sample of Polish citizens between 20 and 74 years of age was included in the study. The aims and methods of the WOBASZ project as well as the sampling procedure are described in detail in previously published papers [15-16].

To sum up, sampling was two-staged and stratified with regards to region and community categories. In each region 6 communities were sampled (2 small, 2 average and 2 large communities) and among each community 100 men and 100 women were sampled from the PESEL (Personal Identification Number) database resources. A wide range of common risk factors was assessed in all respondents on the basis of questionnaires, laboratory tests, anthropometric studies and blood pressure measurement. Dietary intake and serum Hcy level analysis was performed in 50% of sampled subjects. Finally, after excluding subjects without Hcy levels taken due to technical problems or without reliable dietary data, 3004 men and 3401 women were included in the analysis.

Dietary intake was estimated by means of a 24-hour recall method in which responders were asked to list all food products, meals and drinks consumed within 24 h before the study. An album with over 200 photos of the most common dietary products provided by the National Food and Nutrition Institute served as a helpful tool to determine the amount of food portions. Content of vitamins B<sub>6</sub>, B<sub>12</sub> and folate in the diet in each subject was calculated on the basis of the amount of food consumed, using Polish tables of content and nutritional values of food products [17]. Loss of vitamins during technological processing and meal preparation was included in the analysis [18]. The amount of nutritional factors derived from vitamin supplementation was calculated on

the basis of the interview and the database including 260 pharmaceutical products. According to the obtained data the mean intake of vitamins B<sub>6</sub>, B<sub>12</sub> and folate among adult citizens of Poland was calculated together with the percentage of people whose diet provided recommended daily intake of these components [19]. Vitamin intake with food and supplements was included in all analyses.

Measurement of serum Hcy levels was carried out by means of an immunoenzymatic method, by competitive immunoassays, with use of the chemiluminescent phenomenon and alkaline phosphatase-labelled anti-SAH (S-adenosylhomocysteine) antibody as an enzyme. IMMULITE 1 analyser and DPC reagents were used.

## Statistical analyses

We used SAS software (version 9.2) for all statistical analyses. Because distribution of plasma Hcy concentration was other than normal, logarithmic and inverse transformations were carried out so that the geometric mean of Hcy levels could be obtained.

Differences in Hcy levels between quartiles of intake of the analysed vitamins were calculated using a covariance model with adjustment for all confounding variables which could possibly affect Hcy levels according to previously published reports. Frequency of hyper-Hcy was assessed by  $\chi^2$  test.

## Results

Mean vitamin B<sub>6</sub>, B<sub>12</sub> and folate content of the average daily food ration of adult Polish citizens and the percentage of people whose diet provided the recommended daily intake of these components are presented in Table I. Supplementation covered from 1.5% of vitamin B<sub>12</sub> and folate intake in men up to 26% of vitamin B<sub>6</sub> in women of the total intake. The percentage of subjects whose diet provided the recommended value of vitamin B<sub>6</sub>, B<sub>12</sub> and folate ranged from 49 to 84%. In the case of folates, the recommended daily intake was provided only in 10% of women and in 22% of men.

Homocysteine levels and frequency of hyper-Hcy decreased with an increase of vitamins B<sub>6</sub> and B<sub>12</sub> intake

**Table I.** Vitamins B<sub>6</sub>, B<sub>12</sub> and folate content (dietary intake plus supplementation) in daily food ration of an adult population of Polish citizens and the percentage of responders meeting dietary requirements for analysed components

Vitamins	Men					Women				
	Dietary intake	Supplementation	Total	Recommendation per EAR*	% of subjects meeting the requirements	Dietary intake	Supplementation	Total	Recommendation per EAR*	% of subjects meeting the requirements
Vitamin B <sub>6</sub> [mg]	2.15	0.11	<b>2.26</b>	1.25	84	1.50	0.53	<b>2.03</b>	1.20	64
Vitamin B <sub>12</sub> [µg]	5.77	0.08	<b>5.85</b>	2.0	68	3.53	0.16	<b>3.69</b>	2.0	49
Folate [µg]	254	4	<b>258</b>	320	22	197	14	<b>211</b>	320	10

\* estimated average requirement [19]

**Table II.** Homocysteine concentration and the incidence of hyperhomocysteinaemia in quartiles of vitamin B<sub>6</sub>, B<sub>12</sub> and folate intake in males and females

Vitamin intake quartiles	Men			
	Homocysteine levels [ $\mu\text{mol/l}$ ]		Incidence of hyperhomocysteinaemia [%]	
	model A*	model B**	Hcy $\geq 10 \mu\text{mol/l}$	Hcy $\geq 12 \mu\text{mol/l}$
<b>Vitamin B<sub>6</sub> [mg/day]</b>				
Q1 (< 1.48)	10.76	10.73	58.9	34.5
Q2 (1.48-2.07)	10.24	10.28	51.1	26.9
Q3 (2.08-2.77)	10.14	10.16	46.6	24.6
Q4 (> 2.77)	9.84	9.82	38.5	20.0
p	< 0.0001	<0.0001	< 0.0001	< 0.0001
<b>Vitamin B<sub>12</sub> [<math>\mu\text{g/day}</math>]</b>				
Q1 (< 1.71)	10.65	10.64	55.9	32.1
Q2 (1.71-2.76)	10.26	10.27	50.7	27.6
Q3 (2.77-4.65)	10.08	10.09	46.3	22.5
Q4 (> 4.65)	9.97	9.98	42.1	23.8
p	0.0002	0.0004	< 0.0001	< 0.0001
<b>Folate [<math>\mu\text{g/day}</math>]</b>				
Q1 (< 174)	10.53	10.52	56.9	31.8
Q2 (174-235)	10.34	10.35	51.1	28.2
Q3 (236-309)	10.02	10.04	45.1	22.0
Q4 (> 309)	10.06	10.05	41.9	23.9
p	0.0067	0.0079	< 0.0001	< 0.0001
<b>Vitamin B<sub>6</sub>, vitamin B<sub>12</sub>, folate</b>				
Q1 (B <sub>6</sub> < 1.48 mg and B <sub>12</sub> < 1.71 $\mu\text{g}$ and folate < 174 $\mu\text{g}$ )	11.25	11.25	67.2	40.1
Q4 (B <sub>6</sub> > 2.77 mg and B <sub>12</sub> > 4.65 $\mu\text{g}$ and folate > 309 $\mu\text{g}$ )	9.77	9.75	34.4	17.2
p	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Vitamin intake quartiles	Women			
	Homocysteine levels [ $\mu\text{mol/l}$ ]		Incidence of hyperhomocysteinaemia [%]	
	model A*	model B*	Hcy $\geq 10 \mu\text{mol/l}$	Hcy $\geq 12 \mu\text{mol/l}$
<b>Vitamin B<sub>6</sub> [mg/day]</b>				
Q1 (< 1.03)	9.05	9.04	34.1	18.0
Q2 (1.03-1.45)	8.83	8.82	31.7	15.3
Q3 (1.46-2.00)	8.78	8.79	33.5	15.9
Q4 (> 2.00)	8.54	8.55	27.4	12.5
p	0.0018	0.0035	0.0139	0.0184
<b>Vitamin B<sub>12</sub> [<math>\mu\text{g/day}</math>]</b>				
Q1 (< 1.19)	9.11	9.10	36.9	19.9
Q2 (1.19-1.95)	8.90	8.89	31.6	15.2
Q3 (1.96-3.22)	8.66	8.66	29.8	13.3
Q4 (> 3.22)	8.54	8.56	28.5	13.2
p	<0.0001	0.0002	0.0110	0.0002
<b>Folate [<math>\mu\text{g/day}</math>]</b>				
Q1 (< 136)	8.93	8.91	34.5	19.0
Q2 (136-181)	8.78	8.78	31.3	14.7
Q3 (182-245)	8.80	8.81	33.1	14.0
Q4 (> 245)	8.69	8.71	27.6	13.9
p	0.347	0.505	0.0147	0.0083
<b>Vitamin B<sub>6</sub>, vitamin B<sub>12</sub>, folate</b>				
Q1 (B <sub>6</sub> < 1.03 mg and B <sub>12</sub> < 1.19 $\mu\text{g}$ and folate < 136 $\mu\text{g}$ )	9.28	9.27	42.1	24.5
Q4 (B <sub>6</sub> > 2.00 mg and B <sub>12</sub> > 3.22 $\mu\text{g}$ and folate > 245 $\mu\text{g}$ )	8.24	8.26	23.6	11.3
p	< 0.0001	< 0.0001	< 0.0001	< 0.0001

model A\* – after adjustment for age

model B\*\* – after adjustment for age, smoking, coffee and alcohol intake

in both genders and with an increase of folate intake in men (Table II). This correlation was preserved after adjustment for confounding variables (age, smoking, coffee and alcohol intake). Mean level of Hcy in the fourth quartile of vitamin intake was 5 to 9% lower depending on sex and vitamin as compared to the first quartile. Also, the frequency of hyper-Hcy (Hcy  $\geq$  12  $\mu$ mol/l) decreased in men by 42% between the highest and the lowest quartile of vitamin B<sub>6</sub> intake and by 25% in the case of vitamin B<sub>12</sub> and folate intakes, whereas in women the incidence of hyper-Hcy decreased by 31% and by 34% between the highest and the lowest quartile of vitamins B<sub>6</sub> and B<sub>12</sub> intake respectively. The comparison of the first quartile of the lowest intake of all vitamins with the fourth quartile of the highest intake of all vitamins revealed a two-fold lower incidence of hyper-Hcy (Hcy  $\geq$  12  $\mu$ mol/l) in the fourth quartile in both men and women.

In multivariable linear regression analysis inverse correlations between Hcy levels and vitamin B<sub>6</sub> and folate intake in both genders as well as between Hcy levels and vitamin B<sub>12</sub> intake in women were confirmed (Table III). Other significant factors were: age, smoking in both genders, and coffee and alcohol intake in men.

## Discussion

The importance of diet and some dietary components in the prevention of the cardiovascular diseases has been studied for years. Recently, attention has been paid to vitamins B<sub>6</sub>, B<sub>12</sub> and folate because of their potential impact on cardiovascular conditions. These vitamins play an important role in metabolic pathways of the amino acid Hcy, elevated levels of which are an accepted independent risk factor for atherosclerosis.

The results of our study showed that although the average daily food ration of an adult Polish citizen provided recommended daily intake of vitamins B<sub>6</sub> and B<sub>12</sub>, the percentage of people whose diet did not cover the recommended intake of these components was high and ranged from 16 to 51% depending on gender and the vitamin. With regards to folate, the situation was worse, with a low

average intake and almost 80 and 90% of subjects with folate insufficient intake in men and women, respectively.

Average vitamin B<sub>6</sub>, B<sub>12</sub> and folate contents of the daily food ration of Poles were similar to values reported for populations of Europe and USA. The average daily intake of vitamin B<sub>6</sub> in the adult population of Poland was 2.0-2.3 mg a day and was in concordance with the national recommendation of 1.2 mg a day [19]. Slightly lower intake was noted in the Netherlands [20], in France [21] (men – about 2.0 mg/day, women 1.6 mg/day), in USA [22] (2.0 vs. 1.3 mg/day respectively), among teachers in Baltimore [23] (1.6 mg/day) and among Warsaw citizens [24] (1.5 mg/day for both men and women).

Estimated daily intake of vitamin B<sub>12</sub> was 5.8  $\mu$ g in men and 3.5  $\mu$ g in women in the WOBASZ project, whereas in other European countries daily vitamin B<sub>12</sub> intake ranged from 2.6 to 11.0  $\mu$ g in men and from 2.5 to 7.1  $\mu$ g in women (after excluding vegans) [9]. Recommended daily intake of vitamin B<sub>12</sub> ranged from 1.5  $\mu$ g in Ireland to 3.0  $\mu$ g in Germany, while in Poland the recommended daily intake is 2  $\mu$ g [19], and in most countries intake of this vitamin met national daily requirements.

The highest vitamin B<sub>12</sub> daily intake (> 5  $\mu$ g) was noted in Sweden [25], in France [21] and in Spain [26-27]; average intake was found in Denmark [28] and in the Netherlands [20]; lowest intake (< 2.5  $\mu$ g) was reported in Greece [29]. Data from other projects carried out in Poland demonstrated vitamin B<sub>12</sub> daily intake of 4.5  $\mu$ g/day among Warsaw citizens [24] and 2.9  $\mu$ g/day among women living in the region of Dolny Śląsk [30].

Average daily intake of folates among Poles was inadequate (254  $\mu$ g in men and 197  $\mu$ g in women), whereas in other European countries it was 205-431 and 186-465  $\mu$ g, respectively [9]. Recommended daily intake of folate in Europe ranges from 200 to 400  $\mu$ g a day [31]; in Poland it is 320  $\mu$ g [19]. With regards to this vitamin a high intake (> 350  $\mu$ g) was noted in Great Britain [32]; average intake (250-350  $\mu$ g) was reported in Finland [33], Germany [34], France [21], Italy [35] and Greece [29]; and low intake (< 250  $\mu$ g) was found in Denmark [28], Spain [26], Sweden [25] and Norway [36]. In most of the studies,

**Table III.** Multivariable linear regression analysis coefficients between selected factors and homocysteine levels

Factor	Men		Women	
	Regression coefficient	p	Regression coefficient	p
Vitamin B <sub>6</sub>	-0.01	0.0103	-0.003	0.0340
Vitamin B <sub>12</sub>	-0.0002	NS	-0.002	0.0081
Folate	-0.0001	0.0082	-0.0001	0.0021
Age	0.006	< 0.0001	0.008	< 0.0001
Smoking	0.043	0.0003	0.040	0.0017
Coffee intake	-0.00007	0.0291	-0.00005	NS
Alcohol intake	0.0013	0.0002	-0.001	NS

including our country, citizens' folate intake was insufficient – it was 145 µg/day among adult citizens (both men and women) of Warsaw [24], in women in the region of Dolny Śląsk [30] it was 221 µg/day, and in pregnant women [37] it ranged from 180 to 222 µg/day. Only folate intake of 341 µg/day in women of childbearing potential was accurate [38]; however, it included supplementation.

When comparing vitamin content of the diet in varied populations it should be noted that the final result may be affected by the different methods used to assess vitamin intake, differences in national tables of nutritional values of food products which serve to calculate data, and by the different approaches regarding whether to include fortification and supplementation of the vitamins.

Insufficient intake of vitamins B<sub>6</sub>, B<sub>12</sub> and folate can be the cause of elevated Hcy serum levels. Homocysteine is derived in the human organism from the demethylation of methionine, an amino acid obtained from alimentary protein, and its levels are maintained within a very narrow range by the reactions of remethylation or trans-sulfuration. Homocysteine remethylation to non-toxic methionine or its catabolism to cysteine prevents accumulation of Hcy in the blood. Folate serves as a methylene group donor for methyltransferase, an enzyme responsible for Hcy methylation, and vitamin B<sub>12</sub> acts as a cofactor of methyltransferase. Vitamin B<sub>6</sub> as a pyridoxal phosphate serves as a cofactor of cystathionine-β-lyase in the catabolic pathways of Hcy through cystathionine to cysteine.

The results of the WOBASZ project demonstrated that in the adult population of Poland Hcy concentrations are associated with vitamins B<sub>6</sub> and B<sub>12</sub> intake in both men and women and with folate intake in men. The higher the number of quartile of vitamin intake, the lower the concentration of Hcy (after adjustment for confounding variables) and the lower the percentage of subjects with elevated Hcy levels (for both Hcy ≥ 12 and ≥ 10 µmol/l). In general most of the projects reported an inverse correlation between these vitamins and Hcy concentrations. However, most commonly these correlations refer to the vitamin concentration in the blood rather than to its content in the diet. In the WOBASZ project blood levels of vitamins were not assessed, but since the association between intake of vitamins and their serum levels had been demonstrated [36], obtained data were referred indirectly also to the data on the vitamin serum concentrations.

Results similar to those of the WOBASZ project were obtained in the Framingham Offspring study [13], in which higher intake of vitamin B<sub>6</sub> and folate significantly decreased Hcy concentrations after adjustment for age, gender, creatinine, other analysed vitamins, alcohol and caffeine. Also Mennena et al. [21] in France noted a drop in Hcy levels with increasing number of quartile of vitamin B<sub>6</sub> intake with regards to women and of folate with regards to men after adjustment for confounding variables. In the Dutch project MORGEN [20] Hcy concentration was dependent on the

folate intake in both men and women, while in Danish women [39] an association between folate intake and Hcy concentration was found only for young women. Also in the NHANES III trial [22] and among Singapore citizens [40] folate intake affected Hcy levels – Hcy concentrations in the fourth quartile of folate intake were 12% lower compared with the first quartile. In both studies such a correlation was not established with regards to vitamins B<sub>6</sub> and B<sub>12</sub>. Among citizens of the Caribbean Islands [26], with increasing number of quartile of folate intake the incidence of hyper-Hcy decreased in both men and women and Hcy concentrations dropped in women. There was no such an association in the case of vitamin B<sub>12</sub>.

Regarding the relationship between folate serum concentrations and the levels of Hcy, an inverse correlation was noted between those variables in Norway [36], while in Finland [41], USA [11] and the Caribbean Islands [26] a drop in Hcy levels was associated with an increase in the number of tertile and quartile of folate levels. Also in Italy [35] and in the NHANES study [42] an inverse correlation between folate or vitamin B<sub>12</sub> serum levels and Hcy concentration was reported and in the case of folates this correlation was stronger.

The results of the WOBASZ project confirmed that diet providing an adequate intake of vitamins B<sub>6</sub>, B<sub>12</sub> and folate can reduce Hcy levels and the incidence of hyper-Hcy. This is clearly visible when comparing subjects with the highest and the lowest intake of all analysed vitamins (the fourth and the first quartile respectively). The incidence of hyper-Hcy is almost two-fold lower in the fourth quartile. It should also be noted that among adult citizens in our country there was a large proportion of subjects with inadequate vitamins B<sub>6</sub>, B<sub>12</sub> and folate intake, and in the case of folate the recommended daily intake was not provided in 80-90% of the population. Since there is such a common deficit of folate in the diet of Poles, it seems justified to add folate to flour as a commonly consumed foodstuff. Other countries' experience has shown that such a decision contributed to a drop in mean Hcy serum concentrations in the population [43]. Currently despite many initiatives there is no obligatory flour fortification with folic acid. In this situation it is necessary to promote in the population lifestyle changes to increase the intake of products which are natural sources of folate, mainly vegetable and whole-grain products and products fortified with this component, such as cereals, juices and some types of flour.

## Conclusions

The results of the conducted study showed that among adult citizens of Poland:

- an inadequate folic acid intake (in 80-90% of the population) and a high percentage of people not meeting the minimum dietary requirements for vitamins B<sub>6</sub> and B<sub>12</sub> intake (despite normal mean values) were observed;

- an association between intake of analysed vitamins and Hcy concentrations as well as the incidence of hyper-Hcy was noted.

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# Zawartość w diecie witamin B<sub>6</sub>, B<sub>12</sub> i folianów oraz jej związek ze stężeniem homocysteiny w surowicy w populacji dorosłych mieszkańców Polski – badanie WOBASZ

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## Streszczenie

**Wstęp:** Witaminy B<sub>6</sub>, B<sub>12</sub> oraz foliany odgrywają istotną rolę w przemianach homocysteiny (Hcy), toteż wielkość ich spożycia powinna mieć wpływ na stężenie tego aminokwasu w surowicy.

**Cel:** Oszacowanie spożycia witamin B<sub>6</sub>, B<sub>12</sub> i folianów oraz ocena związku pomiędzy ich zawartością w diecie a stężeniem Hcy w surowicy w populacji dorosłych mieszkańców Polski.

**Metody:** W ramach badania WOBASZ przeprowadzonego w latach 2003–2005 przebadano reprezentatywną próbę mieszkańców Polski w wieku 20–74 lat. W każdym województwie wylosowano do badania 6 gmin, a w każdej z nich z bazy PESEL próbę 100 mężczyzn i 100 kobiet. Pomiar stężenia Hcy oraz ocenę sposobu żywienia przeprowadzono w 50-procentowej próbie osób wylosowanych do badania, łącznie oba te parametry oznaczono u 3004 mężczyzn i 3401 kobiet. Ocenę sposobu żywienia przeprowadzono metodą wywiadu ze spożycia żywności w czasie 24 godz. poprzedzających badanie, uwzględniono również pobranie witamin z suplementami.

**Wyniki:** W populacji dorosłych mieszkańców Polski przeciętne pobranie witamin wynosiło: witamina B<sub>6</sub> u mężczyzn 2,26, u kobiet 2,03 mg/dzień (norma 1,2 mg/dzień), witamina B<sub>12</sub> 5,85 vs 3,69 µg/dzień (norma 2,0), foliany 258 vs 211 µg/dzień (norma 320). Udział osób o niedoborowym spożyciu w przypadku witaminy B<sub>6</sub> wahał się od 16% wśród mężczyzn do 36% wśród kobiet, witaminy B<sub>12</sub> odpowiednio od 32 do 51%, a folianów od 78 do 90%. Zanotowano spadek stężenia Hcy (także po wyeliminowaniu wpływu czynników zakłócających, takich jak: wiek, palenie tytoniu, konsumpcja kawy i alkoholu) oraz częstości występowania hiper-Hcy (Hcy  $\geq$  12 µmol/l) wraz ze wzrostem numeru kwartyli pobrania witamin B<sub>6</sub> i B<sub>12</sub> u obu płci oraz folianów w grupie mężczyzn. Średnie stężenie Hcy w czwartym kwartylu spożycia analizowanych witamin w porównaniu z pierwszym wynosiło w przypadku witaminy B<sub>6</sub> u mężczyzn 9,82 vs 10,73 µmol/l, u kobiet 8,55 vs 9,04 µmol/l, witaminy B<sub>12</sub> odpowiednio 9,98 vs 10,64 µmol/l oraz 8,56 vs 9,10 µmol/l oraz folianów 10,05 vs 10,52 µmol/l wśród mężczyzn. Także częstość występowania hiper-Hcy w najwyższym kwartylu w odniesieniu do najniższego rosła w przypadku witaminy B<sub>6</sub> z 20 do 35% w grupie mężczyzn i z 13 do 18% w grupie kobiet, w przypadku witaminy B<sub>12</sub> odpowiednio z 24 do 32% oraz z 13 do 20%, a folianów z 24 do 32% i z 14 do 19%. Porównano także dwie grupy osób – u których spożycie wszystkich analizowanych witamin było niskie (pierwszy kwartył zawartości wszystkich witamin) i u których było wysokie (odpowiednio czwarty kwartył). Częstość występowania hiper-Hcy w najwyższym kwartylu w odniesieniu do najniższego była ponad dwa razy niższa i wynosiła w grupie mężczyzn 17 vs 40%, a w grupie kobiet 11 vs 25%. W wieloczynnikowej analizie regresji liniowej potwierdzono ujemny związek pomiędzy pobraniem witaminy B<sub>6</sub> i folianów u obu płci oraz witaminy B<sub>12</sub> u kobiet a stężeniem Hcy.

**Wnioski:** Wyniki przeprowadzonego badania wykazały, że dorośli mieszkańcy Polski spożywają niedostateczne ilości folianów (niedobory tej witaminy notowano u blisko 80–90% osób). Wysoki odsetek osób nie realizuje norm przyjmowania witaminy B<sub>6</sub> i B<sub>12</sub>. Zanotowano związek pomiędzy wielkością spożycia analizowanych witamin a stężeniem Hcy i częstością występowania hiper-Hcy.

**Słowa kluczowe:** witamina B<sub>6</sub>, witamina B<sub>12</sub>, foliany, homocysteina, populacja polska

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