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Association between dietary patterns and cardiovascular risk factors in a selected population of Lower Silesia (PURE Study Poland)

Anna Czekajło[1,C-D,F], Dorota Różańska[1,B-D,F], Katarzyna Zatońska[2,B,E-F], Andrzej Szuba[3,B,E-F], Bożena Regulska-Ilow[1,A-B,E-F]

[1] *Department of Dietetics, Medical University, Wroclaw, Poland*
[2] *Department of Social Medicine, Medical University, Wroclaw, Poland*
[3] *Department of Angiology, Medical University, Wroclaw, Poland; Department of Internal Medicine, 4th Military Hospital, Wroclaw, Poland*

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Abstract

Introduction. Dietary pattern analysis is used to describe the dietary habits of a selected population. In many studies, dietary patterns (DPs) have been associated with risk factors for cardiovascular disease (CVD). The aim of the study was to assess the association between dietary patterns identified in the population of Lower Silesia, Poland, with anthropometric and biochemical risk factors for CVD.

Materials and method. The study group included 2,025 participants of the Prospective Urban Rural Epidemiological (PURE) Study. Dietary intake was evaluated based on data from the Food Frequency Questionnaire (FFQ). Dietary patterns were derived using principal component analysis (PCA). The relationship between DPs and body mass index (BMI), waist circumference, waist-hip ratio, blood pressure, total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides and fasting glucose level, was assessed.

Results. Three dietary patterns identified in the study explained 35.6% of total variance. The 'fruit, vegetables & dairy' DP, characterized by a high intake of vegetables, fruits, nuts, seeds, raisins, milk and low-fat dairy, was associated with improved lipid profile and anthropometric measures, lower diastolic blood pressure and lower fasting glucose concentration. 'Traditional' and 'fat & sugar' DPs were unfavourably associated with most of the risk factors for CVD presented in this study.

Conclusions. Dietary patterns identified in this study were differently related to selected anthropometric and biochemical risk factors for CVD. 'Fruit, vegetables & dairy' DP was favourably associated with the biochemical and anthropometric CVD risk factors, and was characterized by higher nutritional value in comparison with 'traditional' and 'fat & sugar' DPs.

Key words

risk factors, cardiovascular diseases, principal component analysis, dietary patterns

INTRODUCTION

Cardiovascular disease (CVD) is a major cause of death in Europe and worldwide. Although in years 2003–2013 the mortality rate from CVD has decreased in Poland by 23.9% among men and 26.5% among women, cardiovascular diseases were responsible for 49% of deaths in Poland in 2014 [1].

The CVD risk factors have been identified for the first time in the Framingham Heart Study. Factors associated with the higher risk of CVD development were: elevated level of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and triglycerides (TG), reduced level of high-density lipoprotein cholesterol (HDL-C), high blood pressure, overweight and obesity, cigarette smoking, low physical activity, age, male sex and genetic factors [2].

The prevalence of the risk factors for CVD in Poland has changed over the years. Based on the data from the NATPOL 2011, the prevalence of hypertension increased by 2% compared to 2002 (32% vs. 30%), the prevalence of obesity – by 3% (22% vs. 19%) and the prevalence of diabetes – by 1% (5% vs. 4%). The prevalence of hypercholesterolaemia (TC ≥190 mg/dl) decreased by 9% (61% vs. 70%) [3]. The percentage of people reporting heart or circulation problems in Poland is currently the highest in Europe [1].

Proper diet plays a dual role in prevention of CVD as both independent risk factor and agent modifying other factors [4–7]. Dietary habits considered as the most unhealthy comprise: excessive intake of energy, sodium, saturated fatty acids (SFA), trans-unsaturated fatty acids and added sugar. Inversely, consumption of fruits, vegetables, legumes, nuts, whole grains and fish, as well as moderate consumption of alcohol, is recommended [8].

Due to the complexity of the diet and interactions between products and nutrients, current guidelines pay detailed attention to the synergistic effect of consumed foods on health. This rather new approach is called dietary pattern analysis. Dietary patterns (DPs) are defined as the quantities, variety, proportions and combinations of food products and beverages, as well as the frequency of their consumption. Dietary pattern analysis can be used to describe the association between habitual diet and various health outcomes [9].

Address for correspondence: Dorota Różańska, Department of Dietetics, Medical University, Wroclaw, Poland
e-mail: dorota.rozanska@umed.wroc.pl)

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OBJECTIVE

The aim of the study was to assess the relationship of dietary patterns identified in the middle-age population of Lower Silesia with anthropometric and biochemical risk factors for cardiovascular diseases.

MATERIALS AND METHOD

Study population. The study group included 2,025 adults (1276 women and 749 men) who were enrolled in the Polish section of the Prospective Urban Rural Epidemiological (PURE) Study. All subjects were volunteers and signed an informed consent form. Participants lived in the urban or rural areas of Lower Silesian Province in Poland. The inclusion criteria was a permanent place of residence and age between 35–70 years. The study was approved by the Polish Ethics Committee (No. KB-443/2006) and performed in the years 2007–2009.

The PURE Study is an international prospective cohort study which involving 153,996 adults from 17 countries, classified as low, middle or high income. The aim of the PURE Study is to explain the reasons for the increased incidence of non-communicable diseases in countries with various levels of development. The methodology and main results of the PURE Study have been published previously [10, 11].

Measurement of cardiovascular risk factors. Blood glucose, triglycerides, total cholesterol, HDL cholesterol and LDL cholesterol levels were measured in venous blood samples. HDL-C and TG concentration were measured using the enzymatic assay SPINREACT (Sant Esteve De Bas, Girona, Spain). LDL-C was calculated among participants with a TG concentration lower than 400 mg/dl based on the Friedewald formula (LDL-C = TC – HDL-C – TG/5). TC, HDL-C and TG concentration were analyzed for 738 men and 1,258 women, while LDL-C was analyzed for 725 men and 1,250 women. Blood glucose level was tested after an overnight fast for 592 men and 1,045 women, using the Ascensia Entrust Glucometer (Bayer, Germany). All serum lipids were expressed in mmol/l while fasting blood glucose concentration was expressed in mg/dl.

Systolic and diastolic blood pressure were measured for 744 men and 1,268 women using a certified digital sphygmomanometer (Omron HEM-711 IntelliSense, Tokyo, Japan) and expressed in mmHg. Patients were instructed to rest for 5 minutes before blood pressure measurement. In the analyzes were included the average values of blood pressure measured twice in each participant.

Body height (H) was measured without shoes, with an accuracy of 0.5 cm using a stadiometer. Body weight (W) was measured without shoes and outer garments, using a calibrated scale with an accuracy of 0.1 kg. Body mass index (BMI) was calculated based on the weight in kilograms and height in meters according to the formula: $BMI=W(kg)/H^2(m^2)$. Waist circumference was measured in the middle-point between the lowest rib and the iliac crest and expressed in centimeters with 0.5 cm precision. Hip circumference was measured at the widest lateral extension of the hips and also expressed in centimeters with 0.5 cm precision. Waist-hip ratio (WHR) was calculated by dividing the waist circumference by the hip circumference. BMI and waist circumference were analyzed for 749 men and 1,276 women, and WHR was analyzed for 748 men and 1,273 women.

Dietary assessment. Dietary intake was assessed based on data from the Food Frequency Questionnaire (FFQ) validated for the population aged 35–70 years of Lower Silesian Province [12]. The FFQ consists of 154 food items classified into 8 groups: milk and dairy products, fruits, vegetables, meat and eggs, cereal products, mixed dishes, beverages and snacks. Frequency of consumption was recorded in 9 categories: 'never or less than once a month', '1 – 3 times a month', 'once a week', '2 – 4 times a week', '5 – 6 times a week', 'once a day', '2 – 3 times a day', '4 – 5 times a day', 'more than 6 times a day'. The portion sizes of the consumed foods, e.g. glass of juice, spoon of mayonnaise or slice of bread, were determined using the *Album of Photographs of Food Products and Dishes* [13]. Dietary interview included the one year period before the study. The average content of macronutrients, vitamins and minerals in analyzed diets was determined using database of the US Department of Agriculture and Polish Food Composition Tables [14, 15].

Dietary patterns identification. In order to identify the dietary patterns in the study group, food items from the FFQ were classified into 24 groups: 1) milk and low fat dairy, 2) high-fat cheese and cream, 3) fats, 4) chips, 5) potatoes, 6) eggs, 7) red meat, 8) processed meat, 9) low fat and unprocessed poultry, 10) high fat and processed poultry, 11) fish, 12) unrefined grains, 13) refined grains, 14) mixed dishes, 15) soups, 16) alcohol, 17) sweets, 18) sweetened beverages, 19) sugar and honey, 20) nuts, seeds and raisins, 21) fruits, 22) juices, 23) cooked vegetables and 24) raw vegetables. The main criterion for inclusion of the food product in the group was its composition and nutritional value. Products that do not provide any energy, such as unsweetened coffee and tea, were excluded from the analysis. Characteristics of the food groups is presented in Table 1.

Dietary patterns were identified *a posteriori* using principal component analysis (PCA) with varimax rotation. Six factors had eigen values ≥1 (the Kaiser's criterion); however, based on the Scree plot and interpretability of derived factors, 3 dietary patterns were determined in the final analysis. Values of a factor loadings higher than 0.5 were accepted as the cut-off point.

Statistical analysis. All statistical analyses were conducted using Statistica software version 12.0 PL (Statsoft Inc., USA). For each dietary pattern, the study participants were divided into 4 groups (quartiles), based on the factor scores of their diet. Mean values of age, cholesterol, triglycerides and fasting blood glucose level, blood pressure, waist circumference, WHR and BMI, as well as selected nutrients content in the diet, were calculated for each quartile of derived DPs. Due to the differences in the normal values of HDL-C, waist circumference and WHR, those variables were calculated separately for both male and female individuals. Selected nutrients intake was calculated per 1,000 kcal because higher energy intake is usually associated with the increased macronutrients content in the diet. Differences between quartiles of DPs were calculated using the Kruskal-Wallis test. The level of statistical significance for all analyses was set at $\alpha=0.05$.

Table 1. Characteristics of food groups

Food group	Products
Milk and low-fat dairy	low-fat milk, milk, buttermilk, cocoa with milk, cottage cheese, quark, low-fat yoghurt, yogurt, kefir
High-fat cheese and cream	Feta cheese, hard cheese, cheese "fromage", cream
Fats	butter, lard, margarine, mixed fat, mayonnaise
Chips	chips
Potatoes	potatoes
Eggs	eggs
Red meat	beef steaks, pork cutlets, organ meat, boiled pork, beef and pork cutlets
Processed meat and poultry	ham, frankfurter, luncheon meat, sausages, head cheese, tinned chicken pate
Low-fat poultry	boiled chicken (skinless), roast turkey
High-fat poultry	chicken fillets, fried chicken
Fish	cod fillets, smoked mackerel, herring
Unrefined grains	wheat-rye bread, pasta, buckwheat groats, pearl barley groats, porridge
Refined grains	wheat bread and rolls, rice, cornflakes
Mixed dishes	baked beans with meat, stuffed cabbage leaves, dumplings, sauerkraut with sausage and meat, vegetable salad
Soups	vegetable soups, broth
Alcohol	beer, red wine, vodka
Sweets	cakes, cookies, chocolate, halva, drops
Beverages	fruit drinks, soft drinks
Sugar and honey	sugar, honey
Nuts, seeds and raisins	walnuts and other nuts, seeds, raisins
Fruits	fruits
Juices	fruit juices, carrot juice
Cooked vegetables	cooked vegetables, tomato sauce, canned sweet corn, canned peas
Raw vegetables	raw vegetables

Table 2. General characteristics of the study group

Variable	Males		Females		*P*
	n	*X±SD*	*n*	*X±SD*	
Age, years	749	54.3±10.0	1276	54.6±9.7	Ns
BMI, kg/m^2	749	28.5±4.5	1276	27.9±5.4	0.0004
Waist circumference, cm	749	99.3±12.4	1276	88.4±13.6	<0.0001
WHR	748	0.96±0.07	1273	0.84±0.08	<0.0001
Systolic blood pressure, mmHg	744	150.9±20.1	1268	142.0±21.6	<0.0001
Diastolic blood pressure, mmHg	744	89.1±11.6	1268	84.2±10.9	<0.0001
TC, mmol/l	738	4.99±1.05	1258	5.13±0.99	0.0003
HDL-C, mmol/l	738	1.34±0.38	1258	1.60±0.40	<0.0001
LDL-C, mmol/l	725	2.93±0.90	1250	2.91±0.93	Ns
TG, mmol/l	738	1.62±1.12	1258	1.37±0.82	<0.0001
Fasting glucose, mg/dl	592	101.41±24.41	1045	98.81±20.38	0.0230

P value <0.05 is considered statistically significant
BMI – body mass index; WHR – waist-hip ratio; TC – total cholesterol; HDL-C – HDL cholesterol; LDL-C – LDL cholesterol; TG – triglycerides; X ± SD – mean ± standard deviation; Ns – no statistically significant difference

RESULTS

Table 2 illustrates the sample characteristics, stratified by gender. The mean age of the study participants was similar in the group of men (54.3 ± 10.0 years) and women (54.6 ± 9.7 years). The mean BMI, waist circumference, WHR, systolic and diastolic blood pressure, HDL-C, TG and fasting glucose concentration in blood were significantly higher in the group of men compared to women. Inversely, TC was significantly higher in the group of women in comparison with men. No difference in LDL-C was found between gender groups.

Three dietary patterns identified in PCA explained 35.6% of total variance. The first DP was characterized by high factor loadings of mixed dishes (0.70), red meat (0.67), soups (0.61), processed meat (0.61) and fish (0.58), and accounted for 19.3% of variance. Due to the frequent consumption of these products in the typical Polish diet, this pattern was called 'traditional'. The second DP in the analysis was associated with higher factor loadings of raw vegetables (0.73), fruits (0.71), cooked vegetables (0.66), nuts, seeds and raisins (0.58) and milk and low-fat dairy (0.51). It explained 10.5% of variance and was called the 'fruit, vegetables & dairy' DP. The third DP, called 'fat & sugar", characterized by high factor loadings of fats (0.67), sugar and honey (0.59), sweets (0.58), refined grains (0.58) and high-fat cheese and cream (0.57), and explained 5.8% of variance. The factor-loading matrix for the dietary patterns is presented in Table 3.

Table 3. Factor-loading matrix for identified dietary patterns[a]

Variable	"Traditional" DP	"Fruit, vegetables & dairy" DP	„Fat & sugar" DP
Mixed dishes	**0.70**		
Red meat	**0.67**		0.29
Soups	**0.61**	0.26	
Processed meat	**0.61**		0.47
Fish	**0.58**		
Low-fat poultry	0.48		
High-fat poultry	0.44	0.31	
Alcohol	0.26		
Raw vegetables	0.23	**0.73**	
Fruits		**0.71**	
Cooked vegetables	0.39	**0.66**	
Nuts, seeds and raisins		**0.58**	
Milk and low-fat dairy		**0.51**	0.25
Unrefined grains		0.40	
Beverages			
Fats			**0.67**
Sugar and honey			**0.59**
Sweets		0.20	**0.58**
Refined grains	0.26		**0.58**
High-fat cheese and cream		0.28	**0.57**
Chips	0.31		0.39
Eggs	0.24		0.32
Juices	0.20		0.32
Potatoes			0.22

[a] – absolute values of factor loadings < 0.2 not shown; absolute values of factor loadings ≥ 0.5 in bold; DP – dietary pattern

Tables 4, 5 and 6 show the characteristics of anthropometric and biochemical CVD risk factors in quartiles of dietary patterns. Compared to participants in the lowest quartile of the 'traditional' dietary pattern, participants in the highest quartile had significantly higher diastolic blood pressure, waist circumference, WHR, BMI, TG and fasting glucose level. Moreover, women in Q4 had significantly lower HDL-C than women in Q1 of the 'traditional' DP. Inversely, subjects in the upper quartile of 'fruit, vegetables & dairy' DP, despite

Table 4. Characteristics of CVD risk factors by quartiles of "traditional" dietary pattern (X±SD)

Variable		"Traditional" DP			
		Q1	Q2	Q3	Q4
Age, years		54.8±9.5	54.7±9.8	54.2±10.3	54.5±9.6
Systolic blood pressure, mmHg		144.5±20.5	145.4±21.5	144.3±22.3	146.9±21.6
Diastolic blood pressure, mmHg		84.9±10.5	85.9±11.6	85.6±11.4	87.4±12.1[a]
Waist circumference, cm	Females	84.5±12.3	88.0±12.8	90.1±13.4	92.1±14.9[a]
	Males	97.9±11.6	99.4±11.1	97.5±12.1	101.4±13.5[a]
WHR	Females	0.82±0.06	0.84±0.08	0.85±0.08	0.86±0.08[a]
	Males	0.95±0.07	0.97±0.07	0.96±0.08	0.97±0.07[a]
BMI, kg/m^2		27.2±5.0	28.0±5.0	28.2±4.9	29.1±5.3[a]
TC, mmol/l		5.05±0.98	5.03±0.99	5.08±0.98	5.16±1.1
HDL-C, mmol/l	Females	1.63±0.38	1.62±0.40	1.57±0.42	1.58±0.40[a]
	Males	1.33±0.33	1.35±0.48	1.37±0.34	1.32±0.36
LDL-C, mmol/l		2.91±0.90	2.86±0.92	2.92±0.93	2.99±0.93
TG, mmol/l		1.34±0.76	1.41±0.84	1.50±0.96	1.59±1.16[a]
Fasting glucose, mg/dl		98.1±20.1	96.9±19.1	100.2±21.1	103.7±26.3[a]

[a] – statistically significant differences between quartiles of DP (p <0.05)
X ± SD – mean ± standard deviation; DP – dietary pattern; Q1 – quartile 1; Q2 – quartile 2; Q3 – quartile 3; Q4 – quartile 4; WHR – waist-hip ratio; BMI – body mass index;
TC – total cholesterol; HDL-C – HDL cholesterol; LDL-C – LDL cholesterol; TG – triglycerides

Table 5. Characteristics of CVD risk factors by quartiles of "fruit, vegetables & dairy" dietary pattern (X±SD)

Variable		"Fruit, vegetables & dairy" DP			
		Q1	Q2	Q3	Q4
Age, years		53.8±9.9	54.4±10.2	54.2±9.9	55.8±8.7[a]
Systolic blood pressure, mmHg		146.7±21.6	145.7±21.5	143.8±21.3	144.9±21.4
Diastolic blood pressure, mmHg		87.5±11.9	85.6±11.2	85.4±11.0	85.3±11.5[a]
Waist circumference, cm	Females	90.2±15.0	89.8±13.3	87.8±13.6	86.9±12.7[a]
	Males	100.5±12.9	99.4±13.5	98.7±10.3	96.7±10.9
WHR	Females	0.85±0.08	0.85±0.08	0.84±0.08	0.83±0.07[a]
	Males	0.97±0.08	0.96±0.08	0.96±0.07	0.95±0.07
BMI, kg/m^2		28.4±5.2	28.2±5.1	28.0±5.1	28.0±4.9
TC, mmol/l		5.11±1.07	5.09±0.98	5.11±1.01	5.01±1.01
HDL-C, mmol/l	Females	1.55±0.42	1.58±0.40	1.64±0.41	1.61±0.37[a]
	Males	1.34±0.37	1.33±0.33	1.33±0.47	1.37±0.34
LDL-C, mmol/l		2.98±0.95	2.95±0.90	2.93±0.92	2.82±0.90[a]
TG, mmol/l		1.58±1.14	1.44±0.83	1.41±0.84	1.41±0.93[a]
Fasting glucose, mg/dl		102.8±26.4	100.2±23.4	97.3±17.5	98.6±18.7[a]

[a] – statistically significant differences between quartiles of DP (p <0.05)
X ± SD – mean ± standard deviation; DP – dietary pattern; Q1 – quartile 1; Q2 – quartile 2; Q3 – quartile 3; Q4 – quartile 4; WHR – waist-hip ratio; BMI – body mass index; TC – total cholesterol; HDL-C – HDL cholesterol; LDL-C – LDL cholesterol; TG – triglycerides

Table 6. Characteristics of CVD risk factors by quartiles of "fat & sugar" dietary pattern (X±SD)

Variable		"Fat & sugar" DP			
		Q1	Q2	Q3	Q4
Age, years		55.3±8.7	55.0±9.2	54.1±9.9	53.7±11.2[a]
Systolic blood pressure, mmHg		147.6±20.7	146.7±21.4	144.8±21.5	142.0±22.0[a]
Diastolic blood pressure, mmHg		86.8±11.3	86.4±11.4	85.2±10.6	85.5±12.3
Waist circumference, cm	Females	88.1±12.5	86.7±12.2	88.5±14.3	90.3±15.0
	Males	99.3±12.7	98.7±11.6	97.8±11.4	101.2±13.3
WHR	Females	0.83±0.07	0.83±0.07	0.84±0.08	0.86±0.09[a]
	Males	0.96±0.07	0.96±0.07	0.95±0.08	0.97±0.07
BMI, kg/m^2		28.6±5.0	28.0±4.7	27.9±5.1	28.1±5.4
TC, mmol/l		4.98±0.99	5.15±1.09	4.98±0.96	5.21±1.01[a]
HDL-C, mmol/l	Females	1.59±0.40	1.63±0.38	1.60±0.40	1.59±0.41
	Males	1.31±0.33	1.33±0.34	1.36±0.46	1.35±0.38
LDL-C, mmol/l		2.86±0.90	2.95±0.93	2.90±0.89	3.02±0.95[a]
TG, mmol/l		1.40±0.83	1.52±1.04	1.37±0.81	1.54±1.08[a]
Fasting glucose, mg/dl		100.5±22.2	97.4±23.5	99.9±20.8	101.1±21.3[a]

[a] – statistically significant differences between quartiles of DP (p <0.05);
X ± SD – mean ± standard deviation; DP – dietary pattern; Q1 – quartile 1; Q2 – quartile 2; Q3 – quartile 3; Q4 – quartile 4; WHR – waist-hip ratio; BMI – body mass index;
TC – total cholesterol; HDL-C – HDL cholesterol; LDL-C – LDL cholesterol; TG – triglycerides

being older, had significantly lower diastolic blood pressure, LDL-C, TG and fasting glucose level in comparison with the bottom quartile. Women in Q4 had also lower waist circumference and WHR and higher HDL-C than women in Q1. Participants who had higher factor scores for the 'fat & sugar' DP tended to be younger and have lower systolic blood pressure than those who had lower factor scores for that pattern. However, they also had higher TC, LDL-C, TG, fasting glucose level (overall) and WHR (women).

Comparison of selected nutrients intake across the quartiles of derived dietary patterns is presented in Table 7. Subjects in Q4 of 'traditional' and 'fat & sugar' DPs had a lower intake of dietary fibre and potassium, and higher intake of SFA and cholesterol in comparison with Q1. Sodium intake was higher in Q4 of "traditional" DP and lower in Q4 of

Table 7. Comparison of selected nutrients intake across the quartiles of dietary patterns (X±SD)

Variable	"Traditional" DP		"Fruit, vegetables & dairy" DP		"Fat & sugar" DP	
	Q1	Q4	Q1	Q4	Q1	Q4
SFA, %	12.1± 3.8[a]	12.5± 3.1	12.3± 3.5	11.8± 3.2	10.9± 2.8[a]	14.0± 3.3
Cholesterol, mg/1000 kcal	114.9± 38.5[a]	150.5± 39.7	146.8± 42.3[a]	119.5± 37.9	125.6± 37.9[a]	147.6± 38.9
Dietary fiber, g/1000 kcal	16.3± 4.3[a]	14.8± 3.7	13.5± 3.4[a]	17.6± 4.1	18.0± 4.0[a]	12.7± 3.0
Folate, µg/1000 kcal	198.4± 43.8	195.4± 38.2	189.3± 31.4[a]	210.5± 48.1	220.6± 46.6[a]	174.7± 24.6
Potassium, mg/1000 kcal	1932.4± 419.2[a]	1822.5± 376.0	1645.4± 296.8[a]	2114.4± 405.8	2178.3± 412.0[a]	1586.2± 225.8
Sodium, mg/1000 kcal	1462.0± 317.7[a]	1732.1± 283.0	1685.3± 279.4[a]	1552.6± 334.5	1666.0± 359.1[a]	1600.8± 241.7

[a] – statically significant difference between Q1 and Q4 (p <0.05)
X ± SD – mean ± standard deviation; DP – dietary pattern; Q1 – quartile 1; Q4 – quartile 4; SFA – saturated fatty acids

"fat & sugar" DP, in comparison with Q1. The 'fat & sugar' DP was also inversely associated with folate intake. For the 'fruit, vegetables & dairy' DP, the observed relationships were opposite, except for SFA intake, for which no statically significant difference between Q1 and Q4 was found.

DISCUSSION

Three dietary patterns identified in the presented study were linked differently with the anthropometric and biochemical risk factors for cardiovascular diseases. Significant differences in the nutritional value between quartiles of derived dietary patterns were also observed.

The 'fruit, vegetables & dairy' DP was associated with improved lipid profile and anthropometric measures, lower diastolic blood pressure and lower fasting glucose concentration. These results are consistent with other studies in suggesting that the pattern characterized by a high consumption of vegetables, defined in some studies as 'healthy' or 'prudent', may improve cardiovascular risk factors [16, 17].

Greater adherence to the 'fruit and vegetables' DP was linked with a higher intake of fibre, folate and potassium. Dietary fibre, as well as other bioactive compounds found in fruits and vegetables, including flavonoids and antioxidant vitamins, may protect against the development of various non-communicable diseases. Although the cardioprotective properties of those substances still remain not fully explained, their intake has been associated with lower risk of CVD development and mortality [18–21]. Also, the consumption of fruit and vegetables itself had a beneficial effect on CVD prevention [22, 23].

Since 2016, fruit and vegetables are on the bottom layer of the 'Pyramid of healthy nutrition and physical activity', developed and endorsed by The National Food and Nutrition Institute. According to Polish recommendations, vegetables and fruits may be eaten in unlimited quantities, in proportion of 3:1 [24]. Nonetheless, in the WOBASZ II Study, fruits and vegetables were consumed in recommended doses (>400 g per day) only by 50% of men and 51% of women [25].

The 'traditional' DP was unfavorably associated with most of the risk factors for CVD presented in this study. The relationships between selected health outcomes and 'traditional' DP identified in different populations strongly depend on the dietary habits of these populations. For instance, in the European Prospective Investigation into Cancer (EPIC) – Netherlands Study, the 'traditional' DP was significantly associated with coronary heart disease (hazard ratio (HR) 1.25; 95% CI: 1.07–1.47 or 1.29; 95% CI: 1.11–1.50, depending on the statistical method) [26]. In a cross-sectional study performed in Brazil, the 'traditional' DP had a negative effect on obesity indicators, lipids and fasting plasma glucose [27]. Inversely, the 'traditional Chinese food' pattern was associated with decreased blood pressure and cholesterol level, and the 'Japanese' pattern was related to decreased blood pressure [28, 29].

In the presented study, the 'traditional' DP was characterized by higher consumption of mixed dishes and meat and, as a result, higher intake of SFA, cholesterol and sodium. In other studies, consumption of saturated fatty acids was associated with increased levels of cholesterol in blood [30]. In a meta-analysis of observational studies, no associations were found between SFA intake and the risk of CVD or type 2 diabetes, all-cause mortality and CVD mortality; nonetheless, according to the Scientific Report on the 2015 Dietary Guidelines Advisory Committee, every 1% of energy intake from SFA replaced with polyunsaturated fatty acids (PUFA), may reduce the incidence of coronary heart disease by 2–3% [31, 32]. According to current guidelines, SFA should thus provide less than 10% of energy and should be replaced by PUFA. Moreover, based on European recommendations, dietary cholesterol intake should not exceed 300 mg per day, but those limitations are not mentioned in the 2015–2020 Dietary Guidelines for Americans [8, 9, 33].

Meat and meat products are common constituents of the habitual Polish diet. Based on the data from 2014, 57% of Polish men and women consume meat and its products a few times a week and 34% chose meat every day [34]. In a meta-analysis, processed meat consumption was associated with a 42% higher risk of coronary heart disease and 19% higher risk of diabetes, but no association was observed with reference to the red meat intake [35]. However, the relationship between unprocessed red meat consumption and coronary heart disease remains unclear and some authors have reported such an association [36]. The main difference in the nutritional value between red and processed meat was observed with reference to sodium content – an important risk factor for hypertension [37, 38].

The 'fat & sugar' DP had high factor loadings for solid fats, sugary products and refined grains and was unfavorably associated with the majority of studied risk factors. Surprisingly, greater adherence to the 'fat & sugar' DP was associated with lower systolic blood pressure. These results were not consistent with the current knowledge on this topic [39]. However, subjects in Q4 of the 'fat & sugar' DP, despite similar BMI and waist circumference and lower sodium intake, were younger ($P=0.0006$) and had higher physical activity level ($P < 0.0001$) than subjects in Q1, which may partially explain the observed relationships.

In other studies, high consumption of refined grains, sugar and sweets was related to higher waist circumference, blood pressure, fasting blood glucose level, LDL-C and TG concentration and increased risk of diabetes and coronary heart disease [40–43]. A significant relationship between added sugar consumption and CVD mortality was also observed [44].

Sweets are consumed every day by 19% and a few times a week by 36% of Polish men and women [34]. Only 3% of Polish men and 1% of Polish women reported consuming the recommended free sugars intakes [45]. Sugar is a source of carbohydrates and energy, but it does not provide any other nutrients. Refined grain products contain less dietary fibre, vitamins and minerals than whole grains and they have higher glycemic index [14, 46]. Moreover, various sweetened desserts are also a source of invisible fat containing not recommended fatty acids [8, 9].

Is this dietary patterns analysis a better tool for evaluating the associations between diet and health, than analysis concerning only single dietary components? The effect of single food products or nutrients on health outcomes may sometimes be too small to investigate and, what is more, individual nutrients may intercorrelate with each other, which makes their separate properties difficult to detect. That is why studies concerning single nutrients or foods often fail to find significant relationships with health outcomes, while the approach that includes the cumulative effect of various components of the diet, may lead to another look at these associations [47].

Following that line of reasoning, the beneficial effects of certain food products and nutrients (e.g. in particular vegetables), may be supported by the properties of the other components of the dietary pattern, including other fruits and vegetables. Based on the dietary patterns analysis, it is known that people who eat a lot of vegetables, usually also consume a lot of fruits and whole grains, and generally have healthier dietary habits. On the other hand, the inconclusive and often contradictory results of some studies, even if they are adjusted for known confounding factors, may result from the overall effect of the entire diet, which is the confounder itself.

Unhealthy DPs, associated mainly with high consumption of processed meat, solid fats, refined grains and sugar, may be thus an important cardiovascular risk factor. That is why current guidelines recommend consuming a healthy eating pattern, characterized by a variety of vegetables, fruit, grains, low-fat or fat-free dairy, protein foods and oils, in order to reduce cardiovascular risk factors [9, 48]. Greater adherence to a healthy DPs may play a key role in the prevention of cardiovascular diseases and may be more important than only the avoidance of products typical for unhealthy DPs [49].

CONCLUSIONS

Dietary pattern analysis is a useful tool to assess the association between habitual dietary habits and health because it takes into account the complexity of the diet. In this study, greater adherence to the 'fruit, vegetables & dairy' DP was favourably associated with biochemical and anthropometric CVD risk factors. For the 'traditional' and 'fat & sugar' DPs, the observed relationships were the opposite. The consumption of fruit, vegetables and low-fat dairy products was also linked with higher nutritional value of the diet in comparison with a high intake of meat and meat products, sugar and fats. According to the results of this study, the 'fruit, vegetables & dairy' DP may be recommended for the prevention of cardiovascular diseases among the inhabitants of Lower Silesia.

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