Gaetano (Neuromed, Pozzilli, Italy), Augusto Di Castelnuovo (Neuromed, Pozzilli, Italy), Maria Benedetta Donati (Neuromed, Pozzilli, Italy), Licia Iacoviello (Neuromed, Pozzilli and Università dell'Insubria, Varese, Italy), Mariarosaria Persichillo (Neuromed, Pozzilli, Italy).

Dietary questionnaire validation

Mariarosaria Persichillo (Neuromed, Pozzilli, Italy) and Francesco Zito (Cardarelli Hospital, Campobasso, Italy).

Questionnaire administration

Lucia Aurisano (Epicomed Research, Campobasso, Italy), Paola Barisciano (Epicomed Research, Campobasso, Italy), Valentina Bonaccio (Epicomed Research, Campobasso, Italy), Francesca Bracone (Neuromed, Pozzilli, Italy), Francesca D Aversa (Epicomed Research, Campobasso, Italy), Francesca De Lucia (Cuore Sano Onlus, Campobasso, Italy), Giovanna Galuppo (Epicomed Research, Campobasso, Italy), Teresa Panzera (Epicomed Research, Campobasso, Italy), Filippo Petrucci (Epicomed Research, Campobasso, Italy), Anna Sciarretta (Epicomed Research, Campobasso, Italy), Angelita Verna (Epicomed Research, Campobasso, Italy).

Data management and analysis

Simona Costanzo (Neuromed, Pozzilli, Italy), Augusto Di Castelnuovo (Neuromed, Pozzilli, Italy), Marco Olivieri (Università del Molise, Campobasso, Italy).

The European Journal of Public Health, Vol. 29, No. 2, 335–340

doi:10.1093/eurpub/cky207 Advance Access published on 4 October 2018

Association between dietary patterns and metabolic syndrome in the selected population of Polish adults—results of the PURE Poland Study

Anna Czekajło[1], Dorota Różańska[1], Katarzyna Zatońska[2], Andrzej Szuba[3,4], Bożena Regulska-Ilow[1]

1 Department of Dietetics, Wroclaw Medical University, Wroclaw, Poland
2 Department of Social Medicine, Wroclaw Medical University, Wroclaw, Poland
3 Department of Angiology, Wroclaw Medical University, Wroclaw, Poland
4 Department of Internal Medicine, 4th Military Hospital in Wroclaw, Wroclaw, Poland

Correspondence: Dorota Różańska, Department of Dietetics, Wroclaw Medical University, Parkowa 34, 51-616 Wrocław, Poland, Tel: +48 71 337 23 96, e-mail: dorota.rozanska@umed.wroc.pl

Background: Dietary pattern (DP) analysis is a statistical method used to evaluate the comprehensive effect of the diet on health. The aim of the study was to assess the relationship between DPs derived in selected population of Lower Silesia and the prevalence of metabolic syndrome (MS) and its components. **Methods:** Study group consisted of 1634 individuals enrolled in the Prospective Urban and Rural Epidemiological Study Poland. Dietary intake was estimated using the data from the Food Frequency Questionnaire. DPs were identified using principal component analysis. MS prevalence was evaluated based on the criteria accepted by International Diabetes Federation, American Heart Association and National Heart, Lung and Blood Institute in 2009. **Results:** Three DPs were identified. The percentage of individuals with MS was lower in the upper quartile (Q) of the 'fruit & vegetables' DP in comparison with Q1 (40.4 vs. 48.9%). Inverse relationship was observed for 'Western' (Q4 vs. Q1: 50.7 vs. 40.8%) and 'traditional' DPs (51.0 vs. 38.3%). After adjusting for potential confounders, in Q4 of 'traditional' DP higher risk for central obesity was observed compared to Q1 (OR 1.52; 95% CI: 1.10–2.12). Individuals in Q3 of 'fruit & vegetables' DP had lower risk for raised blood pressure in comparison with the bottom Q (OR 0.54; 95% CI: 0.36–0.82). **Conclusions:** DP analysis allows to evaluate the synergistic effect of the diet on the MS prevalence. 'Fruit & vegetables' DP, in contrast to 'Western' and 'traditional' DPs, was negatively associated with the prevalence of MS and its components in the study group.

Introduction

Metabolic syndrome (MS) is defined as a cluster of various risk factors associated with the development of cardiovascular disease (CVD) and diabetes. Although over last years, different evaluation criteria has been proposed, the most recent, accepted by the International Diabetes Federation (IDF) and the American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI) in 2009, allows to diagnose MS in case of at least three abnormal findings out of following five: central obesity, raised blood pressure (BP), raised triglycerides (TG), lowered high-density lipoprotein cholesterol (HDL-C) and raised fasting glucose (FG) level.[1]

The prevalence of MS in the adult Polish population remains unclear. In the WOBASZ Study, MS was identified in 23.9% of women and 26.0% of men (according to the AHA/NHLBI 2005 definition) and in 26.8% of women and 30.7% of men (according to the IDF 2005 definition).[2] However, in IDF definition, central obesity was considered the essential component of MS, while in the American criteria, the suggested waist circumference (WC) cut-offs were higher than those currently accepted for Europids.[3,4] Instead, the prevalence of MS among 40- and 50-year-old inhabitants of Wroclaw, in compliance with the criteria from 2009, was 12.7 and 33.1% in the group of women and 30.4 and 42.1% in the group of men, respectively.[5]

All components of MS are modifiable risk factors for CVD which means that lifestyle changes may favorably impact their occurrence. Unhealthy diet has been associated with all conditions related to MS, including hypertension, impaired FG, dyslipidemia and obesity.[6–8] Nevertheless, it appears that none of the single food products or nutrients generally considered unhealthy, e.g. saturated or trans fatty acids or refined grains, is fully responsible for the entire spectrum of disorders occurring in the MS. For this reason the assessment of the cumulative effect of the diet on health, using the statistical method called DPs analysis, may contribute to determining the most unfavorable eating patterns in the population.

The aim of this study was to assess the relationship between DPs derived in the adult population of Lower Silesian Voivodship and the occurrence of MS and its components.

Methods

Study design and participants

The Prospective Urban and Rural Epidemiological (PURE) Study is an international, epidemiological cohort study involving 153 996 adults from 17 low-income, middle-income and high-income countries. Its aim is to investigate the relationship between the level of urbanization, the development of risk factors and the prevalence of CVDs. The design and main results of PURE Study have been published previously.[9,10]

The study group included inhabitants of Lower Silesia, enrolled in the Polish arm of the PURE Study in the years 2007–09. Subjects were recruited through the radio and television announcements. The study was approved by the Polish Ethics Committee (No. KB-443/2006). All individuals were volunteers and signed an informed consent form before any study procedures were performed. Inclusion criteria in the study were as follows: age 35–70 years (in accordance with the general assumptions of the PURE Study), daily energy intake 500–4000 kcal and complete medical data concerning studied variables.[9] Finally, 1634 subjects (1045 women and 589 men) were included in the analysis.

Data collection

Dietary intake was estimated based on the data from the food frequency questionnaire (FFQ). As the average consumption of different food products is culture-dependent, the FFQ used in the PURE study were country-specific. FFQ used in the PURE Poland Study was developed and validated specifically for the population of Lower Silesia.[11] It consisted of 154 food products and dishes whose frequency of consumption during 12 months preceding the study was recorded in nine 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'. In order to assess the average portion sizes of consumed food, the 'Album of photographs of food products and dishes' was used.[12]

Dietary patterns identification

To identify DPs in the study, food items from the FFQ were classified into 22 following groups: alcohol, animal fats, beverages, chips, eggs, fish, fruits, juices, milk and dairy, mixed dishes, nuts, seeds and raisins, plant fats, potatoes, poultry, processed meat, red meat, refined grains, soups, sugar and honey, sweets, unrefined grains and vegetables. Food products were categorized based on their composition and nutritional value. Mixed dishes included dishes containing meat and vegetable ingredients, such as: baked beans with meat, stuffed cabbage leaves, dumplings, sauerkraut with sausage and meat and vegetable salad.

DPs were derived *a posteriori* using principal component analysis (PCA) with *varimax* rotation. The aim of the PCA is to identify the main patterns of food consumption, explaining as much of the data variance as possible. In this method, DPs are identified based on the actual data on the usual consumption, so the results obtained may vary significantly between studied populations.[13] In this study, the Kaiser's criterion, scree plot and interpretability of derived factors were used to determine the final number of identified DPs. Values of factor loadings for food groups higher than 0.50 were accepted as the cut-off point.

Measurements

FG, TG and HDL-C levels were tested in venous blood samples. HDL-C and TG concentration were measured using the enzymatic assay SPINREACT (Sant Esteve De Bas, Girona, Spain). Blood glucose level was tested after an overnight fast, using the Ascensia Entrust Glucometer (Bayer, Germany). All studied variables were expressed in mmol/l.

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

WC was measured in the middle point between the lowest rib and the iliac crest and it was expressed in centimeters with 0.5 cm precision.

MS was diagnosed when at least three criteria of the following five were met:

- FG $\geq$5.6 mmol/l (100 mg/dl) or drug treatment for elevated glucose;
- systolic blood pressure $\geq$130 mmHg or diastolic BP $\geq$85 mmHg or antihypertensive drug treatment for previously diagnosed hypertension;
- HDL-C <1.0 mmol/l (40 mg/dl) in males and <1.3 mmol/l (50 mg/dl) in females or history of drug treatment for this abnormality;
- triglycerides $\geq$1.7 mmol/l (150 mg/dl) or history of drug treatment for this abnormality;
- WC $\geq$80 cm in females and $\geq$94 cm in males.[1]

Place of residence was classified as urban or rural and education level was recorded as follows: elementary/unknown, trade, secondary/high school or university. Physical activity level was assessed using the International Physical Activity Questionnaire and expressed as the metabolic equivalent minutes per week (MET-min/week). The number of MET-min/week lower than 600 were considered low, 600–3000—moderate and higher than 3000—high.[14] Smoking status was recorded in three following categories: never smoker, former smoker and current smoker.

Statistical analysis

All statistical analyses were conducted using the Statistica software version 12.0 PL (Statsoft Inc., USA). For each DP, study participants were divided into four groups (quartiles, Q), based on the factor scores of their diets. The socioeconomic factors and the components of MS were assessed in the group of subjects with and without MS. The percentage of subjects with abnormal values of FG, HDL-C, TG, BP and WC, as well as the percentage of individuals diagnosed with MS, were calculated in the lowest and the highest quartile of each DP. Differences between Q1 and Q4 were calculated using chi-squared test. In order to assess the risk of the MS and its components occurrence in the quartiles of identified DPs, logistic regression was applied. The values of the lowest Q were considered a reference level for each DP. Two models were created: first model based on the crude data, while second model was adjusted for

Table 1 General characteristics of the study group

Variable	Total *n*=1634	MS+ *n*=721	MS− *n*=913	*P*∗
Age (years)	54.5±9.8	56.4±9.1	53.0±10.1	<0.0001
Female (%)	64.0	60.6	66.6	0.0124
Rural place of residence (%)	43.7	54.9	34.8	<0.0001
University education level (%)	29.2	21.5	35.3	<0.0001
Current smoking (%)	21.0	23.2	19.3	0.0555
High physical activity level (%)	65.7	67.8	64.1	0.1130
WC male (cm)	100.0±12.8	106.6±12.0	93.9±10.3	<0.0001
WC female (cm)	88.8±13.7	97.6±12.0	82.6±11.2	<0.0001
Systolic BP (mmHg)	145.2±21.6	152.4±21.1	139.5±20.2	<0.0001
Diastolic BP (mmHg)	86.1±11.4	89.1±11.3	83.7±10.9	<0.0001
HDL-C male (mmol/l)	1.34±0.38	1.20±0.31	1.47±0.40	<0.0001
HDL-C female (mmol/l)	1.60±0.41	1.39±0.37	1.76±0.36	<0.0001
TG (mmol/l)	1.43±0.94	1.90±1.19	1.06±0.41	<0.0001
FG (mmol/l)	5.54±1.22	6.11±1.51	5.1±0.68	<0.0001

BP, blood pressure; FG, fasting glucose; HDL-C, high-density lipoprotein cholesterol; MS+ and MS, mean the presence and the absence of the metabolic syndrome, respectively; NS, no statistically significant difference; TG, triglycerides; WC, waist circumference.
A *P*-value of <0.05 is considered statistically significant.
∗: Statistical difference between groups MS+ and MS−.

Table 2 Factor-loading matrix for the identified dietary patterns[a]

Variable	'Western' DP	'Fruit & vegetables' DP	'Traditional' DP
Refined grains	**0.66**		
Processed meat	**0.64**		0.43
Sweets	**0.62**	0.24	
Sugar and honey	**0.57**		
Chips	0.45		0.24
Plant fats	0.44		
Animal fats	0.43		
Red meat	0.42		**0.58**
Juices	0.41		
Fruits		**0.74**	
Vegetables		**0.68**	0.35
Nuts, seeds and raisins		**0.64**	
Unrefined grains		0.44	
Milk and dairy		0.44	
Mixed dishes			**0.77**
Soups			**0.69**
Fish			**0.64**
Eggs	0.38		0.20
Poultry	0.33	0.38	0.34
Beverages		0.25	
Alcohol			
Potatoes			
Explained variance (%)	18.8	10.4	6.0

a: The absolute values of factor loadings <0.20 were not shown; the absolute values of factor loadings ≥0.50 were bold.
DP, dietary pattern.

potential confounders: age, sex, place of residence, education level, physical activity level, smoking status and total energy intake. The level of statistical significance for all analyses was set at $\alpha = 0.05$.

Results

The mean age of the study participants was 54.5 ± 9.8 years. About 44.1% of individuals (41.8% of women and 48.2% of men, $P = 0.012$) were diagnosed with MS. Compared to the subjects without MS, in the group of subjects with MS there was more older people and inhabitants of rural areas and less those having university education level. The presence of MS was associated with higher blood pressure, TG, FG level and WC, as well as lower HDL-C. The complete characteristics of the study group are presented in table 1.

In the PCA, three main DPs were identified. First pattern had high factor loadings for refined grains, processed meat, sweets and sugar and honey and it was called 'Western' DP. Second pattern, 'fruit & vegetables' was characterized by high consumption of fruits, vegetables and nuts, seeds and raisins. Last pattern, called 'traditional', was positively correlated with mixed dishes, soups, fish and red meat. Together DPs explained 35.2% of variance. The factor loading matrix for identified patterns is shown in table 2.

The characteristics of the study group across the quartiles of DPs in respect to the MS components occurrence is presented in table 3. In the upper quartile of the 'Western' DP, in comparison with the bottom quartile, there were significantly more subjects with abnormal levels of FG, HDL-C, triglycerides and WC ($P < 0.05$). Similar differences, except of HDL-C, were found between the quartiles of 'traditional' DP. Inversely, in Q4 of 'fruit & vegetables' DP, compared to Q1, lower prevalence of raised blood pressure and triglycerides was found ($P < 0.05$). 'Fruit & vegetables' DP was associated with lower percentage of subjects with MS (Q4 vs. Q1: 40.4 vs. 48.9%), while for 'Western' and 'traditional' DPs observed relationships were opposite (Q4 vs. Q1: 50.7 vs. 40.8% and 51.0 vs. 38.3%, respectively).

In the model based on the crude data analysis, participants in Q4 of 'Western' DP, compared to Q1, had significantly increased risk of abnormal FG level (OR 1.47; 95% CI 1.11–1.95), HDL-C (OR 1.62; 95% CI 1.14–2.30), TG (1.75; 95% CI 1.28–2.39) and WC (1.36; 95% CI 1.00–1.85). Subjects in Q4 of 'fruit & vegetables' DP had lower risk of raised blood pressure (OR 0.60; 95% CI 0.42–0.88) and TG (OR 0.63; 95% CI 0.46–0.87), while those in Q4 of 'traditional' DP had higher risk of abnormal FG (OR 1.60; 95% CI 1.21–2.11), TG (OR 1.48; 95% CI 1.08–2.04) and WC (OR 1.85; 95% CI 1.36–2.51). Overall, participants in Q4 of 'Western' and 'traditional' DPs had increased risk for MS (OR 1.49; 95% CI: 1.13–1.96 and OR 1.67; 95% CI: 1.26–2.20, respectively), while subjects in Q4 of 'fruit & vegetables' DP had reduced risk for MS (OR 0.71; 95% CI: 0.54–0.93). However, in a model adjusted for potential confounders (age, sex, place of residence, education level, physical activity level, smoking status and total energy intake), only 'traditional' DP was associated with higher risk for raised WC (Q4 vs. Q1: OR 1.52; 95% CI: 1.10–2.12), while 'fruit & vegetables' DP was linked to reduced risk for raised blood pressure (Q2 vs. Q1: OR 0.61; 95% CI 0.40–0.91 and Q3 vs. Q1: OR 0.54; 95% CI: 0.36–0.82) (table 4).

Discussion

DPs are defined as the quantities, variety, proportions and combinations of food products and beverages and the frequency of their consumption. DP analysis takes thus into account the synergistic effect of consumed foods on health.[15]

Table 3 Characteristics of study group across the quartiles of dietary patterns in respect to the metabolic syndrome components occurrence

Variable	'Western' DP			'Fruit & vegetables' DP			'Traditional' DP		
	Q1	Q4	*P*	Q1	Q4	*P*	Q1	Q4	*P*
FG≥5.6 mmol/l* (%)	36.9	46.3	0.006	43.3	36.8	0.056	36.4	47.8	0.001
Systolic BP ≥130 mmHg and/or diastolic BP ≥85 mmHg* (%)	82.9	78.4	0.181	86.8	79.9	0.008	80.2	81.4	0.669
HDL-C <1.0 mmol/l in males and 1.3 mmol/l in females* (%)	16.1	23.8	0.003	22.5	20.6	0.508	21.0	19.6	0.614
TG ≥1.7 mmol/l* (%)	22.0	33.1	0.000	28.9	20.3	0.005	21.5	28.9	0.015
WC ≥94 cm in males and ≥80 cm in females (%)	68.5	74.8	0.046	73.3	67.6	0.074	65.0	77.5	0.000
MS (at least three components) (%)	40.8	50.7	0.005	48.9	40.4	0.015	38.3	51.0	0.003

*: History of specific treatment for this abnormality.
BP, blood pressure; DP, dietary pattern; FG, fasting glucose; HDL-C, high-density lipoprotein cholesterol; MS, metabolic syndrome; NS, no statistically significant difference; Q1, 4, quartile 1, 4; TG, triglycerides; WC, waist circumference.
A *P*-value of <0.05 is considered statistically significant.

Table 4 Odds ratio (OR) for MS and its components occurrence across the quartiles of dietary patterns

Dietary pattern	Q	Odds ratio (95% CI)					
		Raised FG	Raised BP	Reduced HDL-C	Raised TG	Raised WC	MS
		Crude model					
'Western' DP	Q4	1.47 (1.11–1.95)[a]	0.75 (0.53–1.07)	1.62 (1.14–2.30)[a]	1.75 (1.28–2.39)[a]	1.36 (1.00–1.85)[a]	1.49 (1.13–1.96)[a]
	Q3	1.17 (0.88–1.55)	0.83 (0.59–1.19)	1.36 (0.96–1.95)	1.18 (0.85–1.62)	1.11 (0.82–1.50)	1.22 (0.92–1.61)
	Q2	0.90 (0.68–1.20)	0.93 (1.65–1.34)	1.49 (1.05–2.12)[a]	1.06 (0.76–1.47)	0.95 (0.70–1.28)	0.93 (0.70–1.24)
	Q1	1	1	1	1	1	1
'Fruit & vegetables' DP	Q4	0.76 (0.58–1.01)	0.60 (0.42–0.88)[a]	0.89 (0.64–1.25)	0.63 (0.46–0.87)[a]	0.76 (0.57–1.01)	0.71 (0.54–0.93)[a]
	Q3	0.84 (0.64–1.11)	0.48 (0.33–0.69)[a]	0.79 (0.56–1.11)	0.91 (0.67–1.23)	0.73 (0.55–0.97)[a]	0.75 (0.57–0.99)[a]
	Q2	0.85 (0.64–1.12)	0.65 (0.44–0.94)[a]	0.93 (0.67–1.30)	0.91 (0.67–1.24)	1.02 (0.80–1.27)	0.87 (0.66–1.14)
	Q1	1	1	1	1	1	1
'Traditional' DP	Q4	1.60 (1.21–2.11)[a]	1.08 (0.77–1.52)	0.92 (0.65–1.29)	1.48 (1.08–2.04)[a]	1.85 (1.36–2.51)[a]	1.67 (1.26–2.20)[a]
	Q3	1.11 (0.84–1.47)	1.14 (0.80–1.61)	1.12 (0.80–1.56)	1.43 (1.04–1.96)[a]	1.34 (1.00–1.36)	1.38 (1.04–1.82)[a]
	Q2	0.95 (0.72–1.26)	0.97–0.70–1.34)	0.90 (0.64–1.27)	1.18 (0.85–1.64)	1.11 (0.83–1.48)	1.11 (0.84–1.47)
	Q1	1	1	1	1	1	1
		*Model adjusted for potential confounders**					
'Western' DP	Q4	0.92 (0.66–1.28)	0.83 (0.55–1.27)	1.08 (0.72–1.60)	1.24 (0.84–1.83)	0.97 (0.68–1.39)	0.90 (0.65–1.25)
	Q3	0.92 (0.68–1.24)	0.93 (0.62–1.37)	1.10 (0.75–1.61)	1.00 (0.66–1.53)	0.96 (0.69–1.32)	0.96 (0.71–1.30)
	Q2	0.80 (0.59–1.08)	0.94 (0.64–1.39)	1.36 (0.95–1.96)	1.02 (0.72–1.45)	0.87 (0.64–1.19)	0.84 (0.62–1.13)
	Q1	1	1	1	1	1	1
'Fruit & vegetables' DP	Q4	1.15 (0.84–1.57)	0.66 (0.43–1.01)	1.04 (0.72–1.51)	0.97 (0.68–1.38)	0.99 (0.71–1.38)	1.13 (0.82–1.54)
	Q3	1.12 (0.83–1.51)	0.54 (0.36–0.82)[a]	0.85 (0.59–1.22)	1.22 (0.88–1.69)	0.92 (0.66–1.27)	1.05 (0.78–1.42)
	Q2	0.92 (0.68–1.23)	0.61 (0.40–0.91)[a]	0.93 (0.66–1.32)	1.06 (0.77–1.45)	1.08 (0.780–1.51)	0.97 (0.7–1.30)
	Q1	1	1	1	1	1	1
'Traditional' DP	Q4	1.23 (0.92–1.66)	0.98 (0.67–1.44)	0.78 (0.55–1.11)	1.21 (0.87–1.68)	1.52 (1.10–2.12)[a]	1.28 (0.95–1.72)
	Q3	0.88 (0.65–1.18)	1.08 (0.74–1.58)	0.99 (0.70–1.38)	1.26 (0.90–1.75)	1.15 (0.84–1.57)	1.12 (0.83–1.50)
	Q2	0.84 (0.63–1.14)	0.97 (0.67–1.42)	0.83 (0.58–1.17)	1.09 (0.78–1.53)	1.06 (0.78–1.44)	1.01 (0.76–1.35)
	Q1	1	1	1	1	1	1

*: Adjusted for: age, sex, place of residence, education level, physical activity level, smoking status and total energy intake.
a: Level of statistical significance *P*<0.05.
BP, blood pressure; DP, dietary pattern; FG, fasting glucose; HDL-C, high-density lipoprotein cholesterol; MS, metabolic syndrome; Q1, 2, 3, 4, quartile 1, 2, 3, 4; TG, triglycerides; WC, waist circumference.

Prevalence of MS and MS components were significantly associated with identified in the herein study 'Western', 'fruit & vegetables' and 'traditional' DPs. Subjects with a high factor scores for 'Western' and 'traditional' DPs were more likely to have abnormal values of most of the analyzed components, whereas 'fruit & vegetables' DP was related to lower risk of these abnormalities. It is worth mentioning that the prevalence of the MS in the study group was higher than reported in other studies, what might be related to the use of other diagnostic criteria.[2,5]

DPs derived in epidemiological studies are often named 'Western' and 'prudent/healthy' due to the widespread occurrence of these types of diets in many populations. They are usually oppositely associated with the occurrence of MS, as well as often accompanying it insulin resistance.[8,16–18] However, due to the differences in the detailed characteristics of patterns identified in different populations, observed relationships between DPs and the prevalence of MS may vary.

Choi et al.[8] observed that Korean women in the highest quintile of the 'prudent' pattern, characterized by high intake of fruits, nuts and dairy and low intake of grains, had lower risk of MS (OR 0.50; 95% CI 0.36–0.68) and all its components: central obesity (OR 0.52; 95% CI 0.41–0.65), raised BP (OR 0.72; 95% CI 0.59–0.87), raised TG (OR 0.67; 95% CI 0.52–0.85), raised FG (OR 0.64; 95% CI 0.43–0.95) and lowered HDL-C (OR 0.53; 95% CI 0.42–0.68) compared to the individuals in the lowest quintile. In a study performed by Esmaillzadeh et al.[16] subjects in the highest quintile of 'healthy' DP (high in fruits, vegetables, tea, fruit juices and whole grains) had lower odds ratio for MS while subjects in the highest quintile of 'Western' DP (mostly high in refined grains, red and processed meat, high-fat dairy and sweets)—higher odds ratio for the MS

(OR 0.61; 95% CI 0.30–0.79 and OR 1.68; 95% CI 1.10–1.95, respectively), compared with individuals in the lowest quartiles of these patterns. Arisawa et al.[17] did not found any associations between patterns identified in the Japanese population and the prevalence of MS but observed that 'prudent' DP, characterized by high consumption of vegetables and fruits, was inversely linked with reduced HDL-C level ($P = 0.04$) and raised BP ($P = 0.05$).

High intake of vegetables and fruits may have protective effect against the presence of MS and its components, possibly through C-reactive protein reduction.[6] Strong negative association observed in the herein study between 'fruit & vegetables' pattern and raised BP may also result from high potassium content in the diets belonging to the upper quartile of that pattern, compared to the bottom quartile ($P < 0.0001$).[19]

The third derived in our study DP was also characterized by relatively high content of vegetables. It was called 'traditional', due to the fact that it had the highest factor loadings for two typical for Polish cuisine items: mixed dishes and soups. However, in spite of frequent consumption of vegetables in mixed dishes and soups, high adherence to 'traditional' DP did not reduce the risk of MS, what indicates a stronger effect of other components of this pattern on analyzed outcomes. Obtained results draws attention to the differences between nutritional value of food products and dishes prepared using different cooking techniques, which may cause lower or greater losses of nutrients and antioxidant activity.[20] Based on the above results, high intake of recommended food products, such as vegetables and fish, may be insufficient to provide beneficial effect on health in the situation of simultaneous consumption of unhealthy food. At the same time, according to other studies, avoidance of not recommended food products may be less important for secondary prevention of cardiovascular events than greater consumption of healthy foods.[21]

Depending on the studied population, 'traditional' diets may have beneficial (e.g. Mediterranean diet) or harmful properties (e.g. specific ethnic patterns).[22,23] In a large study on the relationship between DPs and MS performed in the Polish population from the Kielecki Region by Suliga et al.[18] a traditional pattern high in boiled potatoes, refined grains, soups, whole milk and sugar and sweets ('traditional-carbohydrate') was also identified, together with 'healthy' and 'westernized' DPs. Both in this study and in our study patterns defined as traditional, despite significant differences in their composition, were associated with the higher risk of abdominal obesity in studied populations of two different regions in Poland.

Most of the associations between DPs and MS in the herein study became insignificant when the data were adjusted for potential confounders. Low education level, rural place of residence, low occupational class and income, inadequate alcohol consumption, smoking status and low physical activity level are considered the most important socioeconomic and lifestyle risk factors for CVD and MS.[2,24,25] However, DPs themselves are also associated with socioeconomic status and unhealthy dietary habits were often linked to unhealthy lifestyle.[26,27] In another analysis of the Polish arm of the PURE study, subjects from the upper quartile of 'traditional' pattern had significantly higher odds ratio for living in the rural areas (OR 3.04; 95% CI 2.09–4.41) whereas in the upper quartile of 'fat & sugar' DP a higher OR for current smoking (1.49; 95% CI 1.00–2.23) and a lower OR for having university education level (0.53; 95% CI 0.35–0.80) was observed (data unpublished). Such a strong relationship between diet and socioeconomic factors leads to the conclusion that increasing awareness of the role of the proper DP in MS prevention is especially important in group of subjects with lower socioeconomic status.

Some limitations of our study should be considered. Because this is a cross-sectional study, it is not possible to assess the causal relationship between identified DPs and MS and obtained results should be confirmed in prospective analyses. As DPs were derived *a posteriori* their interpretation may be somewhat subjective—however this is also the strength of our study because the results obtained using this method better correspond to the actual dietary habits of studied subjects than analysis based on the *a priori* assumptions. Study participants were volunteers recruited through the radio and television announcements which means that it was not a representative sample. Presented study was performed using standardized methods and validated FFQ of good quality.

Funding

PURE Poland sub-study was funded by the Polish Ministry of Science and Higher Education (Grant No. 290/W-PURE/2008/0), Wroclaw Medical University.

Conflicts of interest: None declared.

Key points

- DPs identified in this study allow to evaluate the synergistic effect of the diet on the occurrence of MS and its components. 'Western' and 'traditional' DPs may be associated with the increased risk of MS. Inversely, high adherence to the 'fruit & vegetables' DP may be linked with lower risk of its development.
- The healthy DP is possible to implement in practice because it is already characteristic for some individuals in the study population.
- Nutritional education should be focused on higher consumption of items characteristic for the 'fruit & vegetables' DP: fruits, vegetables, nuts, seeds and raisins.

References

1 Alberti KG, Eckel RH, Grundy SM, et al. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation* 2009;120:1640–5.

2 Sygnowska E, Piwońska A, Waśkiewicz A, Broda G. Socioeconomic factors and the risk of metabolic syndrome in the adult Polish population: the WOBASZ study. *Kardiol Pol* 2012;70:718–27.

3 IDF. IDF Consensus Worldwide Definition of the Metabolic Syndrome. Available at: https://www.idf.org/e-library/consensus-statements/60-idfconsensus-worldwide-definitionof-the-metabolic-syndrome (26 November 2017, date last accessed).

4 Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and management of the metabolic syndrome. An American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation* 2005;112:2735–52.

5 Ilow R, Regulska-Ilow B, Różańska D, et al. Prevalence of metabolic syndrome among 40- and 50-year-old inhabitants of Wroclaw, Poland. *Ann Agric Environ Med* 2012;19:551–6.

6 Esmaillzadeh A, Kimiagar M, Mehrabi Y, et al. Fruit and vegetable intakes, C-reactive protein, and the metabolic syndrome. *Am J Clin Nutr* 2006;84:1489–97.

7 Mazidi M, Pennathur S, Afshinnia F. Link of dietary patterns with metabolic syndrome: analysis of the National Health and Nutrition Examination Survey. *Nutr Diabetes* 2017;7:e255.

8 Choi JH, Woo HD, Lee JH, Kim J. Dietary patterns and risk for metabolic syndrome in Korean women: a cross-sectional study. *Medicine (Baltimore)* 2015;94:e1424.

9 Corsi DJ, Subramanian SV, Chow CK, et al. Prospective Urban Rural Epidemiology (PURE) study: baseline characteristics of the household sample and comparative analyses with national data in 17 countries. *Am Heart J* 2013;166:636–46.

10 Miller V, Yusuf S, Chow CK, et al. Availability, affordability, and consumption of fruits and vegetables in 18 countries across income levels: findings from the Prospective Urban Rural Epidemiology (PURE) study. *Lancet Glob Health* 2016;4:e695–703.

11 Dehghan M, Ilow R, Zatonska K, et al. Development, reproducibility and validity of the food frequency questionnaire in the Poland arm of the Prospective Urban and Rural Epidemiological (PURE) study. *J Hum Nutr Diet* 2012;25:225–32.

12 Szponar L, Wolnicka K, Rychlik E. *Album of Photographs of Food Products and Dishes. Warsaw*. Poland: The Food and Nutrition Institute, 2000.

13 Newby PK, Tucker KL. Empirically derived eating patterns using factor or cluster analysis: a review. *Nutr Rev* 2004;62:177–203.

14 Craig CL, Marshall AL, Sjöström M, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003;35:1381–95.

15 2015–2020 Dietary Guidelines for Americans 8th ed. Washington, DC: US Department of Health and Human Services. Available at: http://health.gov/dietaryguidelines/2015/guidelines/ (10 December 2017, date last accessed).

16 Esmaillzadeh A, Kimiagar M, Mehrabi Y, et al. Dietary patterns, insulin resistance, and prevalence of the metabolic syndrome in women. *Am J Clin Nutr* 2007;85:910–8.

17 Arisawa K, Uemura H, Yamaguchi M, et al. Associations of dietary patterns with metabolic syndrome and insulin resistance: a cross-sectional study in a Japanese population. *J Med Invest* 2014;61:333–44.

18 Suliga E, Kozieł D, Cieśla E, et al. Dietary patterns in relation to metabolic syndrome among adults in Poland: a cross-sectional study. *Nutrients* 2017;9:1366.

19 Czekajło A, Różańska D, Zatońska K, et al. Association between dietary patterns and cardiovascular risk factors in a selected population of Lower Silesia (PURE Study Poland). *Ann Agric Environ Med*, doi: 10.26444/aaem/76321.

20 Jiménez-Monreal AM, García-Diz L, Martínez-Tomé M, et al. Influence of cooking methods on antioxidant activity of vegetables. *J Food Sci* 2009;74:H97–103.

21 Stewart RA, Wallentin L, Benatar J, et al. Dietary patterns and the risk of major adverse cardiovascular events in a global study of high-risk patients with stable coronary heart disease. *Eur Heart J* 2016;37:1993–2001.

22 Rees K, Hartley L, Flowers N, et al. 'Mediterranean' dietary pattern for the primary prevention of cardiovascular disease. *Cochrane Database Syst Rev* 2013;8:CD009825.

23 Kim J, Jo I, Joung H. A rice-based traditional dietary pattern is associated with obesity in Korean adults. *J Acad Nutr Diet* 2012;112:246–53.

24 Zhan Y, Yu J, Chen R, et al. Socioeconomic status and metabolic syndrome in the general population of China: a cross-sectional study. *BMC Public Health* 2012;12:921.

25 Ramsay SE, Whincup PH, Morris R, et al. Is socioeconomic position related to the prevalence of metabolic syndrome? Influence of social class across the life course in a population-based study of older men. *Diabetes Care* 2008;31:2380–2.

26 Kell KP, Judd SE, Pearson KE, et al. Associations between socio-economic status and dietary patterns in US black and white adults. *Br J Nutr* 2015;113:1792–9.

27 Engeset D, Alsaker E, Ciampi A, Lund E. Dietary patterns and lifestyle factors in the Norwegian EPIC cohort: the Norwegian Women and Cancer (NOWAC) study. *Eur J Clin Nutr* 2005;59:675–84.

The European Journal of Public Health, Vol. 29, No. 2, 340–345

doi:10.1093/eurpub/cky184 Advance Access published on 7 September 2018

Lifestyle and cancer—a joint pairwise association of lifestyle habits with subsequent cancer diagnosis

Eira T. Roos, Jouni M. Lahti, Ossi Rahkonen

Department of Public Health, University of Helsinki, Helsinki, Finland

Correspondence: Eira Roos, Department of Public Health, University of Helsinki, Post Box 20, Helsinki 00014, Finland, e-mail: eira.roos@fimnet.fi

Background: Unhealthy behaviours increase cancer risk. However, lifestyle habits co-occur and their joint association with cancer is not known. **Methods:** A survey among midlife employees included data on lifestyle habits and covariates ($N = 8960$, response rate 67%, 80% women). The joint variables of lifestyle habits were prospectively linked with register data on cancer diagnosis (mean follow-up time 12.1 years). Cox proportional hazard model was used to calculate hazard ratios (HR), and their 95% confidence intervals. **Results:** Smoking was associated with subsequent cancer risk and the association was strengthened by inactivity (HR 1.94, 1.46–2.59) and unhealthy diet (HR 1.92, 1.43–2.57). Smoking combined with both low (HR 1.70, 1.19–2.41) and moderate (HR 1.68, 1.27–2.23) alcohol consumption was also associated with increased cancer risk, as was unhealthy diet combined with moderate alcohol consumption (HR 1.55, 1.17–2.06) and inactivity (HR 1.44, 1.10–1.88). Inactivity combined with either low (HR 1.44, 1.06–1.96) or moderate (HR 1.47, 1.11–1.95) alcohol use was associated with subsequent cancer risk. **Conclusions:** Key unhealthy behaviours have additive effects. Preventive measures should be targeted to especially smokers and those having several adverse lifestyle habits.

Introduction

Cancer has a significant effect on public health and economy. Cancer is the second most common cause of death in Western countries.[1] As life expectancy increases, cancer incidence increases.[2] Cancer prevalence is as well on the rise as evolving cancer treatments augment cancer survival. Because of the growth in both incidence and prevalence, health care resources are required increasingly to treat cancer. Albeit medical advances in cancer treatments bring hope to many cancer patients, keeping cancer in remission may require long periods of high-cost cancer treatment.[3,4] Individual and population level perspectives emphasize the need for effective cancer prevention in order to lessen suffering and financial burden.

Previous research shows that many health behaviours, such as smoking, high alcohol consumption, the lack of exercise or unhealthy diet increase cancer risk.[5,6] It has been estimated, that smoking causes 20% of all the cancer mortality,[7] and cancer incidence could be halved in industrialized countries by changing key lifestyle habits.[8] However, most of the previous research has only examined lifestyle habits individually, although in reality lifestyle habits co-occur. It is known that the effect of one risk factor can modify the effect of another risk factor and thus a joint association of two risk factors might differ from each other's individual effect. In fact, there is evidence that the joint association of lifestyle habits can be highly significant when considering cancer risk.[9–12] These studies showed, that physical activity can reduce breast cancer risk among obese[9] and the healthier lifestyle habits you have, the lower the risk for postmenopausal breast cancer,[10] colorectal cancer[12] and pancreatic cancer.[11] Research also shows that when certain lifestyle habits co-occur, their joint association to cancer mortality can be