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Original article

Impact of nutritional education on the nutrient intake of type 2 diabetes mellitus patients

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Summary. *Introduction:* Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder affecting the metabolism of carbohydrates and characterized by hyperglycemia, inadequate secretion of insulin, and/or peripheral insulin resistance. The most common method of T2DM treatment is still pharmacotherapy, due to its convenience. However, diet is one of the most important factors in the development and progression of this disease, and can make an important contribution to the treatment of T2DM. *Purpose:* The aim of the research was to evaluate the effects of nutritional education on the nutrient intake of T2DM patients. *Material and methods:* A total of 149 patients were enrolled (99 women and 59 men) aged 36-88, all diagnosed with T2DM or glucose metabolism disturbances. Nutrient intakes per subject were evaluated based on 24h dietary recall from the previous three days. Anthropometric measurements were also performed. *Results:* Intakes of various nutrients in the diet of T2DM, both under the care of a dietician and not, did not usually meet dietary recommendations. The diets of T2DM patients under the care of a dietician, despite significant dietary mistakes, provided significantly more nutrients with potential positive effects on carbohydrate and lipid metabolism: fiber, EPA, DHA and PUFA, minerals: K, Mg, Fe, Cu and Mn as well as vitamins and smaller amounts of the nutrients which are nutritional risk factors for the development and progression of T2DM: total amount of fat, SFA, Na and P. *Conclusion:* Nutritional education has a positive impact on the nutrient intake of T2DM patients. Routine dietitian care for people suffering from this disease should be recommended.

Key words: diabetes mellitus type 2, dietician, nutritional education, nutrient intake

Introduction

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder affecting the metabolism of carbohydrates and characterized by hyperglycemia, inadequate secretion of insulin and/or peripheral insulin resistance (1). Chronic hyperglycemia is associated with long-term damage, dysfunction and failure of different organs, especially the eyes, kidneys, nerves, heart, and blood vessels (2).

The amount of people with diabetes is constantly increasing. Globally, 425 million adults are living with diabetes, and the number is projected to rise to over 629 million by 2045 (3). 90-95% are patients who suffer from T2DM. Currently, approximately 2.4 million people with T2DM are treated in Poland, that is 5% of the total population (3). This epidemic has been attributed to urbanization and environmental transitions, including work pattern changes from heavy labor to sedentary occupations, increased computerization and mechanization, and improved transportation. Reduced physical activity and incorrect eating habits caused by drastic changes in food production, processing, distribution systems and increased accessibility of food with low nutritional value, lead to overweight and obesity, which contribute directly to the development of insulin resistance and T2DM. The meta-analysis conducted by Abdullah (4) provided proof of a close association between being overweight and obesity and the progression of this disease.

Complete treatment of T2DM includes pharmacotherapy and complementary actions such as a well-balanced diet, physical activity and generally leading a healthy lifestyle. The most common method of T2DM treatment is still pharmacotherapy, due to its convenience. However, diet is one of the most important factors in the development and progression of this disease, and can make an important contribution to the treatment of T2DM and the maintenance of a healthy body weight (5, 6).

According to The Polish Diabetic Association (PDA), specialist diabetes hospital units should also contain a qualified dietitian, whose nutritional advice could have a significant impact on the eating habits and progression of the disease. The nutritional education of patients and their increased awareness of the role of a well-balanced diet on treatment could directly increase the amount of patients with a lower rate of disease progression (5, 7).

Epidemiological studies underline the beneficial role of nutritional education in reducing the development of T2DM. This is manifested by an improvement in biochemical markers, which are important in the assessment of the progression of the disease, and anthropometric parameters, which enable assessment of the nutritional status of patients (8-10). However, information regarding the association between nutritional education and nutrient intake are scarce (11, 12).

The aim of the research was to evaluate the effects of nutritional education on the nutrient intake of T2DM patients.

Subjects and Methods

The study participants were 149 patients (99 women and 59 men) with T2DM or peripheral insulin resistance, from 3 medical facilities in Lower Silesia. The study subjects were interviewed using an anonymous questionnaire, which consisted of questions concerning comprehensive socio-demographic details, physical activity, stimulants used (alcohol, cigarettes), dietary supplements and types of pharmacotherapy. Patients were also asked whether they were under the care of a dietician.

Nutrient intakes

The 24h dietary recall method was used to collect diet-related data from the previous three days. Nutrient intakes were calculated with DIETA 5.0 software (IŻŻ National Food and Nutrition Institute, Warsaw, Poland) and compared with the Estimated Average Requirements (EAR). Intake of β-carotene was compared with upper level (UL), intakes of Na, K, Ca, Mn, vitamin E and D were compared with adequate intake (AI), and the intake of α-linolenic acid (ALA) was compared with the Recommended Dietary Allowance(RDA) (5, 13).

Statistical Analysis

The data were analyzed using STATISTICA v. 12.0 software (StatSoft, Tulsa, OK, USA); p values of <0,05 were considered statistically significant. Most of the obtained results did not present the features of normal distribution, as was confirmed by the Shapiro-Wilk test. To evaluate the differences in distribution of dietary nutrient intakes between the educated (EG) and non-educated groups (N-EG), the Student t-test (for parametric data) and the U-Mann Whitney test (for nonparametric data) were performed. Differences in the percentages of EG and N-EG whose intake of nutrients was below the cut-off points were evaluated with the Chi^2 test. All parameters are presented as median and range. For all statistical procedures, the significance level was considered to be <0.05.

Results

Baseline characteristics of T2DM patients

The baseline demographic, anthropometric and dietetic characteristics of the T2DM patients who participated in the study are presented in Table 1.

Subjects (n=149) were distributed into EG (those who were under the care of a dietician) and N-EG (those who were not under the care of a dietician). The groups were sex-and age-matched. The majority of EG and N-EG had secondary education and lived in a big city.

Table 1. Baseline characteristics of T2DM patients

Variables	n	Educated group (EG)	n	Non-educated group (N-EG)
Gender; W/M; number	59	67.8/32.2	90	65.5/34.45
Age; years [median (min-max)]	59	62.0 (36.0-84.0)	90	68.0 (39.5-88.0)
Sociodemographic parameters				
Education: Primary/Secondary/Professional/University [%]	59	16.9/52.5/20.3/10.2	90	23.3/40/26.7/10
Place of residence: village/small town/big city [%]	59	**1.7/16.9/81.4[a]**	90	**20/16.7/63.3[a]**
Anthropometric parameters				
BMI [kg/m^2] [median (min-max)]	56	30.9 (21.1-49.2)	90	30.9 (20.9-48.1)
Normal weight/ overweight/ obesity [%]	56	12.5/33.9/53.6	90	7.7/33.3/58.9
Weight; kg; [median (min-max)]	58	84 (52-134)	90	80.5 (47-150)
WHR [median (min-max)]	46	0.96 (0.67-1.05)	64	0.96 (0.79-1.15)
AC; cm; [median (min-max)]	48	**33 (25.5-43)[a]**	64	**31.5 (25-40)[a]**
BFP; %; [median (min-max)]	44	37.8 (9.5-54.4)	64	36.35 (5.7-48)
Physical activity				
Low/medium/high [%]	59	**15.3/76.3/8.5[a]**	90	**36.7/58.9/4.4[a]**
Alcohol consumption				
Yes/No [%]	59	**45.8/54.2[a]**	90	**21.1/78.9[a]**
Frequency of alcohol consumption: regularly/ occasionally [%]	27	77.8/22.2	19	63.2/36.8
Wine/ /vodka/bear/champagne/liqueur/ cognac* [%]	27	23.7/20.3/13.5/6.8/3.4/3.4	19	36.8/52.6/15.8/5.3/10.5/10.5
Smoking cigarettes				
Yes/no [%]	59	10.2/89.8	90	13.3/86.7
Antihyperglycemic drugs				
Medications: yes/no [%]	59	91.5/8.5	90	96.7/3.3
Medications: metformin/sulphonylurea/insulin acarbose/ other* [%]	54	64.8/33.3/35.2/9.2/3.7	87	62.1/40.2/39.1/5.7/0
Dietary supplementation				
Dietary supplements: yes/no [%]	59	55.9/44.1	90	46.7/53.4
Taking medications and supplements simultaneously: yes/ no [%]	33	33.3/66.7	42	45.2/54.8
Reason for taking dietary supplements: dietician/ own choice/ physician/ disease/ commercials [%]	33	27.3/36.4/33.3/9.1/3		0/42.8/47.6/9.5/2.4

**Percentages do not add up to 100% due to the multiplicity of responses; a- statistically significant differences in the baseline characteristics between EG and N-EG: chi^2 test, $p < 0.05$; W- women; M–man; BMI- body mass index (kg/m^2); WHR- waist-hip ratio; AC- arm circumference; BFP- body fat percentage*

The median BMI values of both groups were the same - 30.9, however we observed a slight tendency towards a higher percentage of overweight or obese patients in the N-EG group: 92% vs 87,5%. The median WHR in both groups was 0.96, however in N-EG we observed this parameter moving to a higher range. EG had a significantly higher AC than N-EG, moreover we found an unexpected bias towards a higher body fat percentage in this subgroup compared to N-EG. Most of the patients from both groups declared a medium level of physical activity, however EG was more active.

Significantly more EG patients answered the question about alcohol consumption positively than N-EG: 45.8% vs 21.1 %, respectively. Regular alcohol consumption (>1 portion/month) was declared by 78% of EG and 63% of N-EG. Almost 90% of EG and 87% of N-EG answered the questions about cigarette smoking negatively.

The majority of patients from both groups were under pharmacotherapy for T2DM: about 92% of EG and 97% of N-EG. The most commonly taken drug was metformin, followed by insulin in EG and sulphonylurea in N-EG.

Almost 56% of EG and 47% of N-EG took dietary supplements, and 33% of EG and 45% of N-EG took medication and supplements simultaneously. The most popular reasons for taking dietary supplements were as follows: their own choice and a physician's recommendation.

Nutrient intakes

The contribution of macronutrients to dietary energy provision is presented in Table 2. We did not observe statistical differences in total carbohydrates, saccharose, total fat, MUFA or PUFA contributions to energy provision between EG and N-EG, however there were significant differences in protein-energy, as well as SFA-energy, between the analyzed groups. N-EG provided a significantly higher amount of energy from protein when compared with the EG's diet: 85.6% vs 33.9% of respective groups with protein-energy >20%. Similarly, the N-EG diets provided a significantly higher amount of energy from SFA than those of the educated ones: 61.1% vs 42.2% of the respective groups, with SFA-energy >10%.

Table 2. Macronutrient contribution to energy provision in the diet

Components	**% of energy**	**% EG (n=59)**	**% N-EG (n=90)**	**p**
Total protein	<15 15-20 >20	8,5 57,6 33,9	10 4,4 85,6	<0,001
Total carbohydrates	<40 40-50 >50	5,1 32,2 62,7	3,3 38,9 57,8	0,65
Saccharose [g]	<10 >10	84,7 15,3	81,1 18,9	0,57
Total fat	<30 30-35 >35	62,7 23,7 13,6	50 26,7 23,3	0,23
SFA	<10 >10	57,6 42,4	38,9 61,1	0,02
MUFA	<10 10-15 >15	40,7 45,7 13,6	38,9 52,2 8,9	0,59
PUFA	<6 6-10 >10	66,1 28,8 5,1	70 25,6 4,4	0,88

SFA- saturated fatty acids; MUFA- monounsaturated fatty acids; PUFA- polyunsaturated fatty acids

Interestingly, a similarly high percentage of the groups took a high amount of energy from carbohydrates: in both groups the percentages of patients who took more than 50% of their energy from carbohydrates oscillated around 60%. A high percentage of patients, regardless of nutritional education, avoided high consumption of saccharose: more than 80% of both groups took less than 10% of their energy from this macronutrient. The majority of patients in EG (62,7%) and half of N-EG were supplied with total fat in amounts providing less than 30% of the energy consumed daily.

The contribution of MUFA and PUFA in energy provision was insufficient in both groups. Only about 14% of EG and 9% of N-EG consumed MUFAs in amounts providing more than 15% of energy. About one fourth of patients from both groups consumed the recommended amounts of PUFAs (6-10% of daily energy).

Particular nutrient intakes of T2DM patients in terms of their education by dieticians are presented in Table 3.

We did not observe statistical differences in energy, dietary fiber, ALA, cholesterol, Na, K, Ca, P, Mg, Fe, Zn, Cu, Mn, vitamin A (retinol and β-karoten), vitamin B group consumption or ratio of omega-6 to omega-3 between EG and N-EG, however there were significant differences in EPA, DHA, LC-PUFA, Mn, vitamin E, vitamin D, folic acid and vitamin C consumption between the analyzed groups. N-EG consumed significantly higher amounts of EPA, however EG consumed significantly higher amounts of DHA, LC-PUFA, Mn, vitamin E, vitamin D, vitamin C and folic acid.

Additionally we found a significantly lower percentage of EG than N-EG consuming Mg, Fe and vitamin C below EAR cut off points: and vitamin E below AI cut off points.

Discussion

This study focused on evaluation of the effects of nutritional education on the nutrient intake of T2DM

Table 3. Nutrient intake of T2DM patients

Components	EG (n=59)			N-EG (n=90)		
	Median (min-max)	% of EAR Median (min-max)	% of patients with nutrient intake below the cut-off point	Median (min-max)	% of EAR Median (min-max)	% of patients with nutrient intake below the cut-off point
Energy [kcal]	1068.6 (498.2-2892.2)	42.6 (13.1-85.1)	100.0	1150.4 (547.7-3283.0)	46.3 (22.6-131.3)	97.8
Dietary Fiber [g]	18.9 (10.3-36.7)	75.4 (41.3-147.0)	79.7	16.4 (3.4-42.8)	65.7 (13.8-171.2)	83.3
ALA C18:3 [g]	0.7 (0.2-3.1)	35.8 (12.0-153.6)	96.6	0.7 (0.2-25.0)	34.4 (10.5-1247.9)	94.4
EPA C20:5 [g]	**0,0**[a] **(0.0-0.5)**	-	-	**0.0**[a] **(0.0-0.6)**	-	-
DHA C22:6 [g]	**0.1**[a] **(0.0-1.3)**	-	-	**0.0**[a] **(0.0-1.1)**	-	-
LC-PUFA [g]	**0.1**[a] **(0.0-1.9)**	**48.6 (0.0-951.9)**[b]	62.7	**0.1**[a] **(0.0-1.7)**	**25.6 (0.0-846.4)**[b]	76.7
Cholesterol [mg]	174.4 (31.0-560.0)	58.1 (10.3-186.7)	11.9*	150.1 (21.8-893.1)	50.0 (7.3-297.7)	14.4*
omega-6/omega-3	6.1 (0.9-22.4)	-		6.6 (0.5-29.7)	-	
Na [mg]	2578.8 (1244.9-10054.2)	192.8 (88.9-718.2)	94.9*	2901.0 (1048.7-7980.2)	221.2 (74.9-570.0)	97,8*
K [mg]	2493.1 (1355.9-4974.0)	71.2 (38.7-142.1)	86.4	2490.0 (958.8-5345.6)	71.1 (27.4-152.7)	93.3
Ca [mg]	344.1 (155.7-977.2)	26.5 (12.0-75.20)	100.0	347.0 (107.6-930.4)	27.1 (8.3-76.4)	100.0
P [mg]	875.8 (501.5-2000.4)	151.0 (86.5-344.9)	89.8*	901.6 (285.7-2555.0)	155.4 (49.3-440.5)	80,0*
Mg [mg]	252.2 (147.0-501.9)	88.6 (50.5-143.4)	**64.4**[#]	240.3 (96.4-745.3)	77.9 (36.4-281.2)	**78.91**[#]
Fe [mg]	9.0 (5.1-17.0)	149.6 (82.8-283.9)	**10.2**[#]	8.1 (2.7-35.1)	134.0 (45.4-438.2)	**24.4**[#]
Zn [mg]	7.6 (3.7-15.9)	102.3 (39.7-184.1)	40.7	7.8 (2.7-25.0)	96.4 (40.1-307.5)	55,6
Cu [mg]	1.0 (0.6-1.6)	136.8 (79.5-225.7)	22	0.9 (0.2-2.1)	123.9 (33.2-304.9)	26.7
Mn [mg]	5.5 (1.8-11.5)	**267.0 (79.3-640.7)**[b]	1.7	4.5 (1.3-15.1)	**195.8 (56.5-658.1)**	8.9
Vitamin A [μg, eq. retinolu]	680.5 (270.8-3417.3)	136.1 (43.0-683.5)	18.6	698.6 (222.6-7028.8)	129.0 (44.5-1405.8)	30.0
Retinol [μg]	219.4 (57.9-2935.4)	10.1 (2.0-195.7)	98.3	225.0 (31.0-5994.1)	12.1 (1.0-399.6)	97.8

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Table 3. Nutrient intake of T2DM patients

Components	EG (n=59)		N-EG (n=90)	
	Median (min-max)	% of EAR Median (min-max) / % of patients with nutrient intake below the cut-off point	Median (min-max)	% of EAR Median (min-max) / % of patients with nutrient intake below the cut-off point
β- karoten [µg]	2764.7 (593.3-13385.1)	39.5 (8.5-191.2) / 91.5	2640.3 (367.4-9628.3)	37.7 (5.2-137.5) / 94.4
Vitamin E [µg, eq. α-tokoferolu]	**6.3[a] (3.2-15.6)**	**73.6 (32.8-187.0)[b] / 78[#]**	**5.0[a] (1.5-22.7)**	**58.2 (18.3-226.5)[b] / 90.0[#]**
Vitamin D [µg]	**2.7[a] (0.3-14.5)**	**17.8 (2.2-96.4)[b]** / 100.0	**2.0[a] (0.2-10.3)**	**13.3 (1.1-68.8)[b]** / 100.0
Vitamin B_1 [mg]	0.9 (0.4-2.2)	94.5 (40.6-196.4) / 57.6	0.8 (0.3-3.1)	87.2 (30.5-283.0) / 68.9
Vitamin B_2 [mg]	1.0 (0.5-2.2)	105.5 (45.1-202.3) / 42.4	1.0 (0.4-2.8)	103.8 (39.4-274.6) / 45.6
Vitamin B_3 [mg]	14.4 (4.5-35.1)	123.7 (40.7-29.4) / 32.2	12.6 (3.9-33.0)	109.5 (35.4-275.0) / 41.1
Vitamin B_6 [mg]	1.4 (0.7-2.9)	108.2 (54.2-204.9) / 42.4	1.4 (0.5-3.6)	104.1 (39.3-255.1) / 42.2
Vitamin B_{12} [µg]	2.0 (0.5-9.0)	101.9 (23.8-450.4) / 49.2	1.7 (0.2-17.8)	87.2 (10.5-888.2) / 57.8
Folic acid [µg]	**206.9[a] (105.6-368.8)**	**64.6 (33.0-115.2)[b]** / 89.8	**183.5[a] (66.1-402.1)**	**57.3 (20.6-125.7)[b]** / 94.4
Vitamin C [mg]	**73.9[a] (17.3-213.0)**	**108.2 (23.1-355.0)[b] / 47.5[#]**	**52.4[a] (11.3-165.9)**	**80.3 (18.8-237.3)[b] / 64.4[#]**

ALA- αlinolenic acid; EPA- eicosapentaenoic acid; DHA- docosahexaenoic acid; *- value over EAR (% of participants); a- statistically significant differences in the supply of nutrients between educated and non-educated patients demonstrated by the U-Mann-Whitney test, p <0.05; b - statistically significant differences in the meeting of recommendations between educated and non-educated patients demonstrated by the U test -Mann-Whitney, p <0.05; #- statistically significant differences in the percentages of patients providing minerals in the diet below the recommendations between educated and non-educated patients

patients. In this study, almost 1/3 of the T2DM patients used the help of dieticians. Surprisingly, intakes of various nutrients in the diets of T2DM, both under the care of a dietician and not, usually did not meet dietary recommendations. However, the diets of EG, despite significant dietary mistakes, provided higher amounts of nutrients with potentially positive effects on carbohydrate and lipid metabolism: fiber, EPA, DHA, and PUFA, minerals: Mg, Fe, Cu and Mn as well as vitamins and smaller amounts of nutrients, which are nutritional risk factors for the development and progression of T2DM: total amount of fat, SFA, Na and P.

Świrska et al. (14) found that knowledge of basic dietary recommendations for diabetes among the majority of T2DM patients (64%) was unsatisfactory. The most significant deficit included lack of acquaintance with glycemic index and carbohydrate exchanges, thus making it impossible to use those recommendations in preparing everyday meals. Similar deficiencies in knowledge have also been demonstrated in other studies (15-17), which emphasises the need for specialist diabetes hospital units to include a qualified dietician.

Insufficient intakes of energy in both EG and N-EG could be related with being on a low-calorie diet. Overweight or obesity occurred in about 87% of EG and about 92% of N-EG. Current nutritional therapy recommendations from various organizations for diabetes management support intensive lifestyle interventions to achieve modest weight-loss and weight-maintenance (18). In addition to the recommendations, a factor of major importance is the total calorie content of the diet, which should be adjusted to the patient's age, actual body weight, and level of physical activity, allowing a gradual but systematic body weight reduction. A reduction in the total energy intake (by 500–1000 kcal/day) should enable gradual but systematic body weight reduction (by about 0.5–1 kg/week) (5). The benefits of weight loss include improvements in glycemic control, risk factors for cardiovascular disease (CVD), quality of life, and other obesity-related coexisting illnesses (19). A meta-analysis of prospective cohort studies (20) suggested that the risk associated with a higher waist circumference is slightly stronger than the risk associated with a higher BMI. In clinical practice, it is important to monitor both BMI and waist circumference in the patients. In the presented study we monitored BMI and WHR in all patients. We observed a slight tendency to a higher percentage of overweight or obese patients (BMI >24.9 kg/m^2) and WHR moving to a higher range in N-EG.

The current nutrition recommendations for T2DM adults do not indicate the prescription of protein restriction. In most diabetic patients, similarly to the general population, proteins should provide 15–20% of total calorie intake (about 1–1.5 g/kg body weight/day). In the T2DM patients, and people with excessive body weight, it is important to maintain or increase protein intake (a low-calorie diet may contain 20–30% of protein) because an inadequate protein intake can cause lean muscle loss, and problems with enzyme production and antibodies (5, 18, 21, 22). The current recommendations for protein intake by T2DM patients with diabetic kidneys are differ between various organizations. According to The Polish Diabetic Association (15), in patients with chronic kidney disease protein intake should be about 0.8–1 g/kg body weight/day. The Canadian Diabetes Association (CDA) (21) also recommends considering the prescription of a protein restriction. Lopez et al. (23) evaluated the effect of a protein restriction diet on renal function and metabolic control in TD2M patients with or without nephropathy. All patients were randomly assigned to receive either a low protein diet (LPD) (0.6-0.8 g/kg per day) or a normal protein diet (NPD) (1.0-1.2 g/kg per day) for a period of 4 months. A moderated protein restriction diet improved renal function in T2DM patients and macroalbuminuria. HbA1c decreased significantly among microalbuminuric patients on both diets, and among macroalbuminuric patients who received NPD. In contrast to this observation, the American Diabetes Association (ADA) recommends against protein restriction (22). A meta-analysis conducted by Pan et al. (24) did not show beneficial renal effects from low-protein diets in the T2DM patients. The majority of N-EG diets provided energy from protein above the recommendations (above 20%). This could be related with their obesity, glycemic control or lack of knowledge about the possibility of the progression of kidney problems. Campos-Nonato performed a randomized clinical trial (25) about the effect of a High-Protein Diet (HPD) versus a Standard-Protein Diet (SPD) on weight loss and the biomarkers of metabolic syndrome. They found that the participants with a stronger adherence rate in the HPD group lost significantly more weight than adherent participants in the SPD group. Additionally, a meta-analysis of randomized controlled trials (RCT) suggested that various dietary patterns such as high-protein and also low-carbohydrate, low-GI and Mediterranean diets were effective in improving glycemic control and CVD risk factors in the T2DM patients (26). In clinical practice, it is important to help patients to lose weight and remind them about a well-balanced diet with proper macronutrient proportions, especially with a proper amount of protein.

According to the Polish Diabetic Association recommendations there is no need to limit animal protein intake, although substituting plant protein for animal protein may be beneficial in some patients (5). In the EPIC (27) (European Prospective Investigation Into Cancer and Nutrition) study, the long-term association between total, animal and plant protein intake and T2DM incidence was evaluated. The study demonstrated an association between high total and animal protein intake and a modest elevated risk of T2DM in a large cohort of European adults. It has also shown that the high intake of animal protein and its effect on the T2DM may be related to the supply of SFA which is found in the meat (27). In the presented study, N-EG diets provided a significantly higher amount of energy from SFA than those of the educated group, which could indicate increased meat consumption by this group and therefore high animal protein provision in the diet.

The quality of fat is more important than total fat intake, and diets that favor plant-based fats over animal fats are more advantageous (18). According to the Polish Diabetic Association (5) recommendations for the general population, the average total fat intake should provide 30% to 35% of total calories. Saturated fats should provide less than 10% of the total calorie intake, and less than 7% of the total calorie intake in patients with serum LDL cholesterol level ≥ 100 mg/dL (≥ 2.6 mmol/L). Monounsaturated fats should provide 10–15% of the total calorie intake, and polyunsaturated fats should provide about 6–10% of the total calorie intake.

A significantly higher percentage of EG diets provided the proper amount of energy from SFA in comparison with N-EG. Western diets, which are rich in SFA, can cause insulin resistance, disturbances in secretion of insulin, and increased levels of circulating free fatty acids (FFAs). In addition, they contribute to β-cell failure in genetically predisposed individuals (28). Short-term high levels of FFAs in the blood inhibit glucose metabolism, which results in increased insulin secretion. The opposite effect is observed during long-lasting increases in FFA serum concentration, a situation in which pancreatic secretion of insulin is inhibited. FFAs cause beta-cell apoptosis and may thus contribute to progressive β-cell loss in T2DM. The mass of this organ's cells is reduced, and they lose their ability to compensate for insulin resistance (28, 29). The T2DM is associated with another long-term problem - coronary heart disease. According to the "Seven Country Study" (30), mortality due to coronary heart disease was shown to be positively correlated with mean cholesterol levels and average SFA consumption. To reduce serum LDL cholesterol levels, which coexist particularly in T2DM patients, low glycemic index carbohydrates and monounsaturated fats should be substituted for SFA (31).

More than half of all participants showed an insufficient intake of LC-PUFA. Dietary supplementation with EPA/DHA is recommended, especially for individuals with determined dietary deficiencies in LC-PUFAs (32). A significant amount of epidemiological evidence has found that increased n-3 PUFA consumption in intervention studies may alleviate metabolic and cardiovascular risk and progression of T2DM (33). LC-PUFAs affect lipid-carbohydrate metabolism and exhibit insulinotropic and anti-inflammatory activity through membrane receptors (34). They also inhibit the expression and activity of pro-inflammatory cytokines, and decrease the activity of the pro-inflammatory nuclear factor β (NF-β), which promotes the expression and increases the activity of many pro-inflammatory genes and molecules, e.g. cytokines and chemokines that induce insulin resistance (35). An increased intake of LC-PUFAs (EPA, DHA) also elicits an increase in skeletal muscle membrane fluidity, number of insulin receptors and insulin action (32, 36). Moreover, Chen et al. (37) performed a meta-analysis concerning the effects of omega-3 fatty acid supplementation on glucose control. They found that the ratio of EPA/DHA and early intervention with omega 3 fatty acids may have effects on glucose control and lipid levels, although no statistical significance was identified. On the other hand, the meta-analysis conducted by Wu et al. (38) showed that EPA +DHA from fish and seafood support neither major harm nor benefits regarding the development of diabetes, and suggest that ALA may be associated with a modestly lower risk of T2DM. In particular, replacing saturated fat with omega-6 PUFA was related to a lower risk of developing diabetes (39, 40).

T2DM patients are usually characterized by a lower serum concentration of Mg compared to normal subjects, as a result of an inadequate supply of this mineral from food and/or increased elimination from the body (41). However, the percentage of patients who showed insufficient intake of Mg in the EG was significantly lower compared to N-EG. The EG probably knew about the requirement to increase the intake of foods which are good sources of Mg. A proper supply of this nutrient from food or supplementation may have a beneficial effect on glycemic control in T2DM patients (42). Mg is actively involved in a number of metabolic reactions as an important co-factor, with a special emphasis on carbohydrate metabolism. The meta-analysis conducted by Mooren (43) suggested that reduced dietary Mg intake serves as a risk factor for the incidence of both impaired glucose regulation and T2DM. Sinka et al. (44) demonstrated a negative correlation between serum levels of glucose and serum levels of Mg in diabetic subjects. Mg intake may be particularly beneficial in offsetting the risk of developing diabetes among those at high risk (45).

The percentage of patients who showed insufficient intake of Fe in the EG was significantly lower compared to N-EG. Both deficiency and excess Fe in the diet are dangerous. Insufficient Fe intake from the diet may lead to anemia, while excessive consumption (excessive dietary supplementation or medication intake) may lead to diarrhea, nausea and vomiting (13). Fe is increasingly recognized to influence glucose metabolism on multiple levels. Body Fe stores should be considered a potential target for therapy in subjects with T2DM, or those at risk for developing T2DM (46). Fe also seems to modulate β-cells, insulin secretion and thereby glucose homeostasis. In the pathogenesis of diabetes, an excessive intake of Fe generates reactive oxygen species (ROS) by participating in the Fenton chemistry, which can induce oxidative damage and apoptosis (47).

Mn is an activator of numerous enzymes involved in the synthesis of proteins, nucleic acids and fatty acids. Mn is also a part of the group of superoxide dismutase enzymes (MnSOD), which catalyse the superoxide anion dismutation into hydrogen peroxide and oxygen (48). In a cross-sectional survey, lower concentrations of Mn were reported in blood and scalp hair samples of type 2 diabetic patients compared to healthy controls, while Mn levels in urine were higher in T2DM patients, which can be evidence of increased elimination of Mn from their body (49). We can find in the EFSA report (50) that a low intake of Mn can cause disorders in lipid and carbohydrate metabolism (hypercholesterolemia and insulin resistance). EG provided significantly higher amounts of Mn than N-EG, which proved the beneficial effects of dietary consultation on patients' diets.

The Na intake of T2DM patients, both in the EG and N-EG, exceeded the recommendations established for this mineral. However the EG take in a slightly lower amount of sodium, but with no significant differences. Salt intake from all sources should not exceed 5 g per day and the current Na intake recommendation for diabetes management is < 2300 mg/d (5, 22). If reasonable, patients with hypertension may be advised more strict salt intake limitations according to the DASH diet principles (5). In one observational study, high Na intake was associated with increased mortality in T2DM people (51). Excess Na in the diet can significantly affect the blood pressure of patients, by increasing it, and thus increasing the risk of cardiovascular complications, which are particularly high in T2DM patients (13).

The majority of differences in dietary intakes between EG and N-EG concerned vitamins. Dietary deficiencies in vitamin D were shown in almost all the patients from both the EG and N-EG. However, comparing vitamin D intake between two groups shows that the dietary consultations had an impact on higher supplies of this vitamin, closer to the AI recommendations. In connection with insufficient dietary intake and the scarcity of sources of vitamin D, supplementation of vitamin D is widely recommended (5). Vitamin D plays an important role in the proper secretion and activity of insulin. Specific receptors for vitamin D are located on the surface of islet β cells, and binding vitamin D to them may enhance insulin secretion. Vitamin D is also known to be involved in maintaining the proper extracellular concentration of calcium ions and their flow into the pancreatic β cells. An increased concentration of calcium ions in the cytosol of β cells promotes the release of insulin (32). Kuchay et al. (52) assessed the relationship between the intake of vitamin D and the risk of progression of diabetes. It was found that supplementation of the diets of people with prediabetes with vitamin D can help to regulate carbohydrate metabolism. After a period of 12 months in the group supplementing with vitamin D there was significantly lowered fasting plasma glucose, 2h plasma glucose and HBA1c levels. Another study (53) showed a relationship between vitamin D deficiency and insulin resistance. However, the direct effect of deficiency of this vitamin on carbohydrate metabolism was not confirmed. The deficiency of vitamin D, which positively correlated with insulin resistance, was mostly found in people with obesity, which also promotes this disorder. In our groups problems also occur with overweight and obesity, which may additionally increase requirements for vitamin D.

In the present study, the EG consumed significantly larger amounts of vitamin E, and a significantly higher percentage of them met the EAR than N-EG. In view of the fact that vitamin E plays an important role in delaying the prevalence of diabetes and slows down its progression, it is necessary to supply an adequate amount of vitamin E. Baburao et al. (54) observed a decrease in postprandial glucose values and total cholesterol level and a reduction of increased blood pressure in the group of patients who take vitamin E supplementation compared to the control group. Shinde et al. (55) demonstrated a reduction in oxidative stress and an improvement in antioxidant enzyme activity and vascular endothelial function in T2DM patients treated with anti-diabetic agents supplemented with vitamin E, as compared with patients treated only with glucose-lowering drugs. In turn, vitamin E supplementation by T2DM patients can also help to reduce the risk of developing CVD by preventing the oxidation of low-density lipoproteins.

EG provided higher amounts of vitamin C, and therefore a lesser percentage of them did not meet the EAR of vitamin C, which proved the beneficial effects of dietary consultation on patients diets. EG probably consumed more vegetables and fruits than N-EG. Vitamin C plays the role of cofactor in many enzymatic and metabolic reactions, including the synthesis of collagen, the structure of the skin, bones and blood vessels. It is also an antioxidant, which reduces oxidative processes in the body (13). In the Darshike et al. study (53), it was demonstrated that the supplementation of T2DM patients with high doses of vitamin C - 2,000 mg / day for at least 90 days had a beneficial effect on the reduction of fasting glucose and HbA1c. Li et al. (56) examined the association between dietary vitamin C intake and T2DM. The study showed a significant negative correlation between dietary vitamin C intake and T2DM prevalence.

The EG diets provided significantly higher amounts of folic acid, which may confirm the beneficial effects of dietary intervention. Folates are responsible for proper cell division, functioning of the nervous system and hematopoietic system, and determining proper homocysteine metabolism. Disturbances in homocysteine metabolism are some of the key factors regulating the risk of CVD, therefore proper dietary folate has been proven to be necessary in alleviating the risk of CVD. (57). Folate deficiencies may increase during pharmacotherapy with metformin. About 60% of patients in both groups in the presented study took metformin, and it was the most popular drug among T2DM patients. In one of the studies, the importance of folate supplementation on diabetes parameters in obese men with T2DM using metformin was evaluated. The authors showed that supplementation with folic acid at the amount of 5mg /day may positively affect carbohydrate metabolism. Significant increases in folate and vitamin B12 concentrations and decreases in homocysteine, fasting glucose and HbA1C were observed in the above-mentioned study. Based on the above results, it can be concluded that supplementation with folic acid improves the parameters of diabetes and eliminates the negative effect of metformin on folate body content. In the above study folate supplementation has also been shown to improve glycemic control by reducing concentrations of glycosylated hemoglobin, fasting blood glucose, serum insulin and insulin resistance, as well as homocysteinemia in the T2DM patients (58).

Conclusion

In the present study, variations in nutrient supply in the diet of individual T2DM patients were demonstrated, both in the educated and non-educated groups. Despite this, the diet of educated patients was more balanced compared to the diet of non-educated patients. It can therefore be concluded that nutritional education has a positive impact on the nutrient intake of T2DM patients. Routine dietitian care for people suffering from this disease should be recommended.

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