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Diabetes Nutrition and Complications Trial: adherence to the ADA nutritional recommendations, targets of metabolic control, and onset of diabetes complications. A 7-year, prospective, population-based, observational multicenter study

The Diabetes and Nutrition Study Group of the Spanish Diabetes Association (GSEDNu)*,[1]

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Abstract

Objective: To know the adherence to the ADA nutritional recommendations and its relation to targets of metabolic control and onset of diabetic complications in a sample of diabetic people in Spain. **Research Design and Methods:** The Diabetes Nutrition and Complications Trial (DNCT) is a prospective, population-based, observational multicenter study designed to know the nutritional pattern, based on the 7-day food diaries, of a population with long-standing diabetes mellitus (93/99 type 1/type 2 diabetic patients, 20/18 years of duration of diabetes, and 6.9%/6.4% HbA_{1c} values) and its relation with the onset of microvascular and macrovascular diabetes complications between 1993 and 2000. **Results:** After a median follow-up period of 6.5 years, more than 55% of diabetic people complied with the recommendation of protein intake between 15% and 20%, but only 27% consumed less than 10% of saturated fatty acids (SFAs), the 13% achieved up 10% of polyunsaturated fatty acids (PUFAs) intake, the 39% consumed more than 60% from carbohydrate and monounsaturated fatty acids (MUFAs), and the 30% consumed <300 mg/day of cholesterol. In spite of these, more than 90% had an optimal HDL cholesterol and non-HDL cholesterol level, and triglycerides level, while less than 41% of diabetic people had an HbA_{1c} value >7.5%. Moreover, more than 69% consumed a MUFAs-to-SFAs ratio >1.5 and the 46% a PUFAs-to-SFAs ratio >0.4. Nonadherence to nutritional recommendation, but MUFAs/SFAs ratio >1.5 and PUFAs/SFAs ratio >0.4, was associated with a reduction between 3.4- and 8.2-fold in the risk of onset of diabetic complications. **Conclusions:** The adherence to ADA nutritional recommendations for people with diabetes in Spain is rather poor except for the protein consumption. Only PUFAs/SFAs >0.4 and MUFAs/SFAs>1.5 were associated to near-optimal targets of metabolic control and a reduction in the risk of the onset of diabetic complications. These data suggest that other nutritional recommendations should be taken in mind.

Keywords: P/S ratio; M/S ratio; Fat consumption; Diabetes complications

1. Introduction

The last goal of nutrition therapy is to assist diabetic people to attain and maintain optimal values of metabolic outcomes in order to prevent the chronic diabetes complications (American Diabetes Association, 2003a; Franz et al., 2002). Nutritional management is the cornerstone of successful diabetes treatment and should be based upon their usual eating and exercise pattern. When metabolic goals are not achieved, changes must be made in nutritional plan. The current ADA nutritional recommendations with several evidence levels in order to achieve these goals include that monounsaturated fatty acids (MUFAs) and carbohydrates should provide the 60–70% of energy intake, a protein intake between 15% and 20% with a B-level evidence, whereas the energy from saturated fatty acids

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(SFAs) should account for less than 10% of the overall consumption, with a A-level evidence, and up to 10% from polyunsaturated fatty acids (PUFAs) with a C-level evidence. However, the adherence to these recommendations was considered as scarce (Close et al., 1992; The Diabetes and Nutrition Study Group of the Spanish Diabetes Association & Diabetes Nutrition and Complications Trial (DNCT), 1998; Toeller et al., 1996), and the prevention of vascular complications with nutrition therapy remains to be demonstrated (Houtsmuller, van Hal-Ferwerda, Zahn, & Henkes, 1980; Howard-Williams et al., 1985; Möllsten, Dahlquist, Stattin, & Rudberg, 2001; Riley & Dwyer, 1998; The Diabetes and Nutrition Study Group of the Spanish Diabetes Association (GSEDNu), 2004a).

The DNCT is a prospective, population-based, observational multicenter study designed to know the nutritional habits based on 7-day food diaries in diabetic people of Spain and their connection with the development of diabetes complications. In this article, we report the adherence to the ADA nutrition recommendations and its relationship with targets for diabetes control and the onset of vascular diabetes complications.

2. Research design and methods

2.1. Patients

A total of 192 diabetic subjects attending four centers (HCSC, CSCH, CPH, and HGA) between 1993 and 2000 completed the study. Ninety-three had type 1 diabetes mellitus (41 men, 34.7±15.1 years old and 20.1±9.5 years of diabetes duration; 52 women, 36.7±12.8 years old and 18.9±10.1 years of diabetes duration), and 99 had type 2 diabetes (42 men, 66.6±8.6 years old and disease duration of 17.1±7.7 years; 57 women, 66.3±11.0 years old and diabetes duration of 18.0±8.6 years). Selection criteria were the following: have been diagnosed of diabetes and have been treated at the same center for at least 1 year before the beginning of the study; capable to correctly fulfill the 7-day food diaries; and able to give their written informed consent to participate in the study. The study was approved by the Clinical Trials Board and was carried out in accordance with the principles expressed in Helsinki Declaration. A wide description of the experimental design has been previously reported (GSEDNu, 1997; GSEDNu, 2004b).

At baseline (1993) and at follow-up (2000), body weight, blood pressure (after 3 min in a supine position, taken with an appropriately sized armlet), and waist and hip perimeter were determined, and a blood sample was obtained after a 10-h fasting period in order to determine the DCCT standardized HbA_{1c} value, total cholesterol and triglycerides (enzymatic autoanalyzer), apolipoprotein A_1 and B (immunonephelometry), and HDL cholesterol (enzymatic method modified with PEG—cholesterol oxidase, cholesterol esterase and peroxidase), and albumin-to-creatinine ratio was also assessed in three first-morning urine samples.

2.2. Assessment of microvascular complications status

Diabetic nephropathy was diagnosed on the basis of the albumin-to-creatinine ratio in three first-morning urine samples. Microalbuminuria was considered if albuminuria (mg/g creatinine) was between 30 to 299 in at least two out of the three first-morning urine samples, and macroalbuminuria if albuminuria was greater or equal to 300 mg/g creatinine.

Nephropathy progression was considered when patients were normoalbuminurics in 1993 and microalbuminurics in 2000 or if they had microalbuminuria in 1993 and macroalbuminuria in 2000.

Diabetic retinopathy was diagnosed in each center by standard signs after direct ophthalmic examination, nonmidriatic photography, and/or fluorescein angiography. Three levels were considered: no retinopathy, nonproliferative retinopathy, or proliferative retinopathy. Retinopathy progression was considered when patients were without retinopathy in 1993 and retinopathy in 2000, or if they suffered from nonproliferative retinopathy in 1993 and proliferative retinopathy in 2000 or had been treated with laser between 1993 and 2000.

Diabetic distal neuropathy was diagnosed based on neuropathy disability score ≥ 6. Progression was considered with a score <6 in 1993 and ≥ 6 in 2000.

The primary end point was a composite of microvascular complications status (MVCS) defined as presence of diabetic nephropathy and/or diabetic retinopathy and/or diabetic distal neuropathy in order to attain statistical power to detect an association between MVCS and nutritional pattern. Progression in the composite of MVCS was considered when patients developed some microvascular variables evaluated or evolved into a more severe form between 1993 and 2000. Presence in the composite of MVCS was considered when patients had some of these microvascular complications at baseline and did not change in the year 2000.

Similarly, progression in the composite of cardiovascular complications status (CVCS) was considered when patients suffered a peripheral vascular surgical procedure and/or a foot ulcer, and/or stroke, and/or ischemic heart disease between 1993 and 2000. If patients had some of these at baseline, presence of CVCS was considered.

2.3. Statistical methods

The statistical analysis used were descriptive statistics (mean, S.D., median, and quartiles Q1 and Q3) for describing the studied variable in each of the analyzed groups; parametric (one-way analysis of variance and Student–Newman–Keuls test for means comparisons) and nonparametric (Mann–Whitney and Kruskal–Wallis) tests to

Table 1
Adherence to nutrition recommendations for people with diabetes mellitus in the year 2000

	Type 1 diabetes mellitus		Type 2 diabetes mellitus		
	Men ($n=41$)	Women ($n=52$)	Men ($n=42$)	Women ($n=57$)	Overall
Carbohydrate and MUFAs ≥60%	17 (41.5)	25 (48.1)	11 (26.2)	21 (36.8)	74 (38.5)
SFAs <10%	6 (14.6)	9 (17.3)	20 (47.6)	16 (28.1)	51 (26.6)
PUFAs ≤10%	8 (19.5)	7 (13.5)	6 (14.3)	4 (7.0)	25 (13.0)
Cholesterol <300 μg/day	4 (9.8)	17 (32.7)	8 (19.0)	27 (47.4)	56 (29.2)
Protein 15–20%	27 (65.9)	36 (69.2)	22 (52.4)	22 (38.6)	107 (55.7)
Fiber >15 g/day	24 (58.5)	23 (44.2)	29 (69.0)	38 (66.7)	114 (59.4)
PUFAs/SFAs >0.4	18 (43.9)	21 (40.4)	24 (57.1)	26 (45.6)	89 (46.4)
MUFAs/SFAs >1.5	24 (58.5)	39 (75.0)	31 (73.8)	39 (68.4)	133 (69.3)

Results are expressed as n (%).

determine whether there are significant differences between the two or more independent groups; and contingency table analysis for determining if two factors were related.

3. Results

The proportion of diabetic patients with adherence to each ADA nutrition recommendation by gender and type of diabetes is shown in Table 1. Less than 13% of diabetic patients consumed the recommended up 10% from PUFAs, less than 27% consumed <10% from SFAs, and less 39% consumed >60% from MUFAs and carbohydrates, while about 60% of patients had a protein consumption between 15% and 20% and a fiber intake of >15 g/day. In addition to adherence to ADA recommendations, we also estimated the proportion of diabetic patients that consumed a ratio of PUFAs/SFAs >0.4 and MUFAs/SFAs >1.5 (46% and 69%, respectively). Table 2 shows the proportion of patients that achieved the targets of metabolic control. Despite that the number of diabetic patients with an adequate metabolic control increased between 1993 and 2000, less than 35% achieved the optimal LDL value and less than 45% had optimal blood pressure values and HbA_{1c} level <7%, but more than 85% of patients achieved optimal HDL cholesterol and triglycerides levels. In a similar way, a non-HDL cholesterol of <130 mg/dl was achieved by more than 90% of diabetic patients.

The adherence to each ADA nutritional recommendation was not associated to a reduction in the onset or progression of diabetes complications, but MUFAs/SFAs ratio >1.5 and PUFAs/SFAs ratio >0.4 were associated with a reduction of between 3.4- and 8.2-fold in the risk of onset of each diabetic complication. Table 3 shows the rates of progression for each diabetes complication for individuals with and without adherence to MUFAs/SFAs >1.5, PUFAs/SFAs >0.4, and SFAs <10%.

4. Discussion

According to the data obtained in this study, the adherence to the ADA nutritional recommendations could be considered low, except for the protein consumption. Despite that less than 27% consumed <10% daily calories from SFAs, diabetic patients included in this study have near-optimal HDL cholesterol and non-HDL cholesterol and triglycerides levels. In addition, more than 50% of diabetic

Table 2
Targets of metabolic control of people with diabetes mellitus

	Type 1 diabetes mellitus				Type 2 diabetes mellitus			
	Men ($n=41$)		Women ($n=52$)		Men ($n=42$)		Women ($n=57$)	
	2000	1993	2000	1993	2000	1993	2000	1993
Cholesterol (mg/dl)								
LDL <100	16 (39.0)	10 (24.4)	15 (28.8)	8 (15.4)	13 (31.0)	0 (0)	11 (19.3)	4 (7.0)
HDL >40/50 (M/W)	35 (85.4)	25 (61.0)	46 (88.5)	13 (25)	39 (92.9)	17 (40.5)	44 (77.2)	15 (26.3)
Non-HDL <130	36 (87.8)	27 (65.9)	50 (96.2)	24 (46.2)	42 (100)	21 (50)	55 (96.5)	34 (59.6)
Triglyceride <150 mg/dl	40 (97.6)	27 (65.9)	49 (94.2)	26 (50)	34 (81.0)	21 (50)	43 (75.4)	33 (57.9)
sBP <130 mm Hg	22 (53.7)	19 (46.3)	31 (59.6)	29 (55.8)	5 (11.9)	12 (28.6)	5 (8.8)	9 (15.8)
dBP <80 mm Hg	23 (56.1)	21 (51.2)	35 (67.3)	31 (59.6)	9 (21.4)	11 (26.2)	16 (28.1)	18 (31.6)
HbA_{1c}								
<7.5%	25 (61.0)	20 (48.8)	25 (48.1)	18 (34.6)	30 (71.4)	26 (61.9)	33 (57.9)	30 (52.6)
<7%	20 (48.8)	16 (39.0)	18 (34.6)	14 (26.9)	27 (64.3)	22 (52.4)	29 (50.9)	25 (43.9)
<6.5%	12 (29.3)	10 (24.4)	14 (26.9)	10 (19.2)	23 (54.8)	19 (45.2)	28 (49.1)	21 (36.8)
Waist circumference								
<102/88 cm (M/W)	31 (75.6)	26 (63.4)	42 (80.8)	27 (51.9)	17 (40.5)	16 (38.1)	11 (19.3)	9 (15.8)

Results are expressed as n (%). sBP, systolic blood pressure; dBP, diastolic blood pressure; M/W, men/women.

Table 3
Cumulative rate and relative risks for complication progression by fat consumption

	MUFAs/SFAs >1.5			PUFAs/SFAs >0.4			SFAs <10%		
	Yes	No	RR	Yes	No	RR	Yes	No	RR
Neuropathy	3.20	12.24	3.83	1.20	9.89	8.24	6.66	5.42	0.81
Nephropathy	7.92	28.90	3.65	4.29	22.85	5.33	10.26	14.85	1.45
Retinopathy	11.01	43.75	3.77	7.79	31.25	4.01	18.40	18.45	1.00
Composite MVCS	19.23	82.14	4.27	13.33	57.89	4.33	25.00	35.87	1.43
Composite CVCS	4.10	19.23	4.69	3.53	12.12	3.43	8.70	8.59	0.99

Cumulative rates were calculated by dividing the number of patients with complications and adherence nonadherence to recommendations × 100 by the number of diabetic patients with adherence or nonadherence to recommendations. RR was estimated by dividing the cumulative rate of diabetic patients with no adherence by diabetic patients with adherence. RR, relative risk.

patients reached an HbA_{1c} value considered at low microvascular risk (European Diabetes Policy Group, 1999) as well as maintain a reasonable body weight and body fat distribution, and a salutary blood pressure values (European Diabetes Policy Group, 1999; American Diabetes Association, 2003b). Taking this into account, we could not consider inadequate the nutrition pattern of this sample of diabetic people in Spain. Moreover, when diabetic patients with adherence to each nutrition recommendation are compared with those without adherence, unexpectedly they do not reach in a higher proportion the targets of diabetes management, suggesting that nutrition recommendations might be reviewed. In addition, a reduction in the onset or progression of some vascular diabetes complications was not associated with the adherence to some nutrition recommendations.

Nutrition therapy is the cornerstone of successful global diabetes management and could be based on treatment goals and what diabetic patients are able to do (American Diabetes Association, 2003a; Franz et al., 2002). The overall goal is to assist diabetic subjects in making changes in their usual nutrition pattern, leading to an improvement of the metabolic control in order to prevent the chronic complications of diabetes. The current evidence-based ADA nutrition recommendations suggest that less than 10% of energy intake should be from SFAs with A-level evidence, but a specific recommendation for total fat intake and MUFAs and PUFAs intake is not stated or is variable. Moreover, several identified modifiable vascular risk factors (Gaede et al., 2003; Ohkubo et al., 1995; Pastors, Franz, Warshaw, Daly, & Arnold, 2003; Tesfaye et al., 2005; The Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications Research Group, 2000; The Diabetes Control and Complications Trial Research Group, 1993; UK Prospective Diabetes Study (UKPDS) Group, 1998a; UKPDS Group, 1998b; Wake et al., 2000), including body mass index, waist circumference, triglycerides, HDL and LDL cholesterol, and apolipoprotein B levels, as well as glycemic control, are influenced by nutritional habits, particularly by fat consumption (Houtsmuller et al., 1980; Howard-Williams et al., 1985; Möllsten et al., 2001; Riley & Dwyer, 1998). In fact, substituting MUFAs and PUFAs consumption for SFAs improves all these parameters (Friedberg, Janssen, Heine, & Grobbee, 1998; Garg, 1998; Summers et al., 2002).

We have previously reported that MUFAs intake higher than 20% of total calories may be recommended in order to improve diabetes metabolic control (The Diabetes and Nutrition Study Group of the Spanish Diabetes Association & DNCT, 1998). More recently (GSEDNu, 2004a), our group has reported a stronger association between MUFAs/SFAs and PUFAs/SFAs ratios and regression of microalbuminuria in both type 1 and type 2 diabetic patients than with absolute MUFAs and PUFAs consumption, as well as cardiovascular mortality decrease, as published by other groups (Hu, 2003; Tricopoulou, Costacou, Bania, & Trichopoulos, 2003).

In the current study, diabetic subjects with some vascular complications compared with those with absence of the same vascular complications had similar HbA_{1c} values (7.0% with composite MVCS vs. 7.1% with absence composite MVCS), both considered as low microvascular risk, suggesting that the onset of diabetes complications might reflect the increasing cumulative exposure to a more or less healthy diet. Other factors that could be operative in the results of the current study have been analyzed. Physical activity level was light and there were no differences among any group. In similar way, the use of lipid-lowering drugs and low-pressure agents was more frequent in diabetic subjects who had some diabetes complications, as expected.

According to the data obtained in this study, between 73% and 95% of diabetic patients without vascular complications consume a MUFAs/SFAs >1.5, while between 33% and 46% of diabetic patients with progression of some vascular complication do. In a similar way, PUFAs/SFAs >0.4 was consumed by between 50% and 73% of diabetic patients without vascular complications vs. between 10% and 23% of diabetic patients with vascular complications. Therefore, a consumption of MUFAs/SFAs <1.5 increases between 3.6- and 4.7-fold the vascular risk complications, and a consumption of PUFAs/SFAs <0.4 increases between 3.4- and 8.2-fold the vascular risk complications. As a result, both ratios are the nutritional variables that allow clear differentiation of diabetic patients that are going to progress in their vascular complications. To our knowledge, this is the first study that shows

a microvascular complications decrease associated with some nutritional variables. Despite that several studies (Houtsmuller et al., 1980; Howard-Williams et al., 1985; Möllsten et al., 2001; Riley & Dwyer, 1998) have reported an association between some nutritional variables, particularly fat consumption, and microvascular diabetes complications, they failed to find out any decrease in the onset of such complications. Several differences with our study may be operative. First, the median of HbA_{1c} levels in our study is <7.5%, considered at low microvascular risk (European Diabetes Policy Group, 1999). Probably, at HbA_{1c} levels >7.5%, beneficial effects of nutritional variables could be not observed. Moreover, ratios as studied in the present study were not evaluated.

Data obtained from this study are potentially important. Risk factors besides hyperglycemia are probably involved in the onset and progression of diabetic complications. Identifying them, particularly if they are modifiable, might lead to new strategies. Previous studies have demonstrated that an increase in MUFAs and/or PUFAs consumption, in spite a high SFAs consumption, favorably modifies the lipid profile, and reduces their oxidative capacity, inflammation, and some proatherogenic factors (Belury, 2002; Brown & Hu, 2001; Rasmussen, Thomsen, Ingerslev, & Hermansen, 1994). Strict glycemic and blood pressure control should be a priority, but diabetic complications can develop despite intensive control of these (Gaede et al., 2003; Ohkubo et al., 1995; The Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications Research Group, 2000; The Diabetes Control and Complications Trial Research Group, 1993; UKPDS Group, 1998a; UKPDS Group, 1998b; Wake et al., 2000). When these goals are reached, other therapeutic measures such as substituting MUFAs and PUFAs for SFAs consumption could increase the prevention of micro- and macrovascular diabetes complications. Bearing in mind that the nutrition management is the base of integral diabetes treatment, a more specific statement for MUFAs and PUFAs consumption, namely, a PUFAs/SFAs ratio of >0.4 and a MUFAs/SFAs ratio of >1.5, could be recommended.

Appendix A. The Diabetes and Nutrition Study Group (GSEDNu)

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