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ORIGINAL ARTICLE

A preliminary case–control study on nutritional status, body composition, and glycemic control of Greek children and adolescents with type 1 diabetes

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Abstract

Background: Because scientific data on the diet of diabetic Greek youngsters are scarce, diabetic experts use findings from international studies. However, because of diet variations between countries, this may result in problems in diabetes control. The aim of the present pilot study was to assess body composition, nutritional status, and diabetes control in Greek youngsters with type 1 diabetes mellitus (T1DM).

Methods: Twenty-four children and adolescents with diabetes, aged 4–16 years, and the same number of age- and sex-matched controls participated in the study. Anthropometry included stature, weight, and body fat determined by bioelectrical impedance analysis. Body mass index (BMI), fat mass index (FMI), fat-free mass index (FFMI), and *z*-scores were calculated. Diabetes control was evaluated through glycosylated hemoglobin (HbA1c) and dietary intake was recorded for 3 days.

Results: The FFMI, BMI *z*-score and weight-for-age *z*-score were lower in controls compared with diabetic youngsters ($P \leq 0.001$, $P \leq 0.02$, and $P \leq 0.01$, respectively). Three diabetic participants were overweight (12.5%) and two controls were underweight (8.3%). The energy and nutrient intake was similar between the two groups, and all participants consumed a diet high in fats and proteins at the expense of carbohydrates. Dietary fat was highly correlated with BMI in both groups. The consumption of vitamin D was inadequate in the diabetic participants, but they had a higher intake of antioxidant vitamins, vitamin B_6, and folate compared with the control group.

Conclusions: In conclusion, youngsters with T1DM failed to adhere to the macronutrient recommendations for diabetes, but dietary patterns were similar in both the diabetic and control groups. The control of diabetes was not associated with any nutrient or anthropometric variable.

Keywords: dietary intake, energy intake, glycosylated hemoglobin, growth, obesity, overweight.

Introduction

The effect of insulin treatment on the body composition of patients with type 1 diabetes mellitus (T1DM) has been well documented in the literature. Insulin treatment, especially an intensive regimen, has been linked with weight gain,[1] and an increased prevalence of overweight has been identified among adolescent diabetics.[2] Percentage body fat has been correlated with glycemic control in adolescent girls, with high

body fat levels coinciding with higher levels of glycosylated hemoglobin (HbA1c);[3] however, studies in children have failed to demonstrate a similar link.[4] Diabetic girls exhibit low bone mineral content[5] and this has been linked with poor diabetes control in adolescence,[6] a factor that may limit peak bone mass acquisition and increase the risk of osteoporosis in later life.

In terms of dietary intake and adherence to the diabetic diet regimen, a positive association between poor diet and high blood glucose levels was identified in 33 children with T1DM.[7] Dietary fat is correlated with HbA1c in children[4] and adequate fiber intake and regular meal patterns have been demonstrated to lower HbA1c in adolescents.[8] Overall, the consumption of several nutrients is inadequate in diabetic youngsters and this finding appears to be consistent across the published research.[7–9]

Data on diet, anthropometry, and glycemic control exist in literature; however, research on Greek youngsters is limited. As a result, endocrinologists and dieticians use data from international studies; however, because diets vary widely between countries, this practice may result in problems with diabetes control. Thus, the aims of the present pilot case-control study were to: (i) determine whether Greek youngsters with T1DM are aligned with nutritional guidelines for diabetes; (ii) identify any differences in diet and body composition between diabetic youngsters and healthy controls; and (iii) assess the relationships between nutrition, anthropometry, and diabetes control.

Methods

Participants

Twenty-four children and adolescents with T1DM, aged 4–18 years, formed the study group. There was an equal number of boys and girls in the study group and the mean duration of T1DM and insulin treatment was 3.7 ± 2.0 years. The control group consisted of age- and sex-matched children who had not been diagnosed with any metabolic disorder and who had been chosen at random from unpublished data collected in the same calendar year from public schools in the city. All subjects were inhabitants of the Thessaloniki metropolitan area. Patients were selected randomly from the outpatients who visited the Papageorgiou Hospital during the study period. Guardians and parents gave oral consent for the children to participate in the study. The study conformed fully with the Declaration of Helsinki for biomedical research on human subjects. The characteristics of the study population are given in Table 1.

Procedures

Anthropometric measurements were performed in the morning, after an overnight fast. The weight of the participants was measured using a Seca 710 scale (Seca, Hamburg, Germany); stature was measured using a Holtain stadiometer with a high-speed Veeder-Root counter (Holtain, Crymych, UK). Body fat was measured with a Maltron 907 bioelectrical impendence analyser (Maltron International, Essex, UK) according to the manufacturer's instructions.[10] Body mass index (BMI) was calculated as total weight (in kg) divided by height squared (m^2); the fat mass index (FMI) was calculated as fat weight (in kg) divided by height squared (m^2); and the fat-free mass index (FFMI) was calculated as fat-free weight (in kg) divided by height squared (m^2).[11] Height-for-age (HAZ), weight-for-age (WAZ) and BMI-for-age (BMIZ) *z*-scores were calculated for each participant in accordance with Centers for Disease Control (CDC) anthropometric standards.[12]

Diabetes control was estimated for each patient through HbA1c, measured quarterly (i.e. once every 3 months), with a DCA 2000 analyzer (Bayer, Elkhart, IN, USA). The last three HbA1c measurements (i.e. spanning a period of 6 months) for each patient were recorded and the mean value used. Although diurnal blood glucose was also recorded for half the participants (One Touch Ultra glucometer; LifeScan,

Table 1 Characteristics of the study population

	Type 1 diabetes mellitus		Control group	
	Boys ($n = 12$)	Girls ($n = 12$)	Boys ($n = 12$)	Girls ($n = 12$)
Weight (kg)	55.08 ± 19.78	34.75 ± 12.35	52.63 ± 18.02	28.75 ± 11.69
Stature (m)	1.57 ± 0.20	1.35 ± 0.23	1.54 ± 0.18	1.30 ± 0.20
EER (MJ/day)	11.78 ± 3.02	7.06 ± 1.27	11.22 ± 2.79	7.01 ± 1.30

Data are the mean ± SD.
EER, estimated energy requirements.

Milpitas, CA, USA) in order to verify results obtained using HbA1c, these data were not used because recent research has suggested that mean blood glucose levels are highly correlated with HbA1c.[13]

Parents and guardians were advised on how to fill in a 3-day food diary, the last day of which coincided with the day on which the last HbA1c measurement was made. Printouts of food models[14] were used to facilitate the estimation of portion sizes. Data recorded were analyzed using the US Department of Agriculture (USDA) 19 HealtheTec SR computer program (Nutrient Data Laboratory, Human Nutrition Research Center, USDA, Beltsville, MD, USA) and, in the absence of Greek reference nutrient intake values, nutrient intake was compared with the dietary reference intakes (DRI)[15] for the appropriate age and sex. Nutrient intakes below 70% of the DRI were considered inadequate.

Statistical analyses

Paired-sample *t*-tests were used to analyse data between the two groups. Pearson's correlation matrix was used to identify significant relationships between variables and linear regression analysis was performed for correlated variables. All statistical analyses were performed with SPSS v.12 (SPSS, Chicago, IL, USA) and graphs were plotted with ORIGIN 7.0 (OriginLab, Northampton, MA, USA). Significance was set at $P < 0.05$.

Results

Mean HbA1c levels in the T1DM group were $7.6 \pm 1.5\%$. If the HbA1c was subdivided into "good" (<5.5%; $n = 2$) or "elevated" (≥5.5%; $n = 22$),[16] no differences were observed in the energy or macronutrient intake of participants in either category. There were no differences in HbA1c levels between girls and boys (7.5% and 7.7%, respectively) or between children (7.7%; $n = 11$) and adolescents (7.4%; $n = 13$).

Energy and macronutrient intakes are presented in Table 2 and data for selected micronutrients as a percentage of the DRI are given in Table 3. The HbA1c was not correlated with any nutrient. No differences were observed in the energy, protein, fat, fiber, or cholesterol intake of the participants. The consumption of fiber was inadequate for all participants. The DRI were reached for all micronutrients, except for vitamin D in the T1DM group and vitamin E in the control group. Diabetic patients had a higher intake of vitamins E, B_6 ($P \leq 0.01$), C ($P \leq 0.001$), and folate ($P \leq 0.02$) compared with the control group, but the control group had a higher intake of vitamin D ($P \leq 0.03$) and niacin ($P \leq 0.04$).

Table 4 lists the anthropometric characteristics of all study participants. The FFMI was lower in the control group ($P \leq 0.001$) but all recorded *z*-scores were significantly higher in the T1DM group and within normal growth ranges for both groups ($-2.0 < z\text{-score} < 2.0$). No correlation was found between HbA1c and any anthropometric variable. In the T1DM group, FFMI and BMI were highly correlated

Table 2 Energy and macronutrient intake

	T1DM ($n = 24$)	Control group ($n = 24$)	*P*-value
EI (MJ/day)	8.80 (4.78, 14.35)	7.43 (4.63, 14.34)	NS
Protein (g/kg)	2.06 (1.22, 4.98)	1.95 (0.96, 7.74)	NS
Protein (% EI)	17.0 (12.5, 27.3)	15.2 (9.7, 31.0)	NS
Carbohydrate (% EI)	44.6 (35.7, 58.8)	47.4 (27.0, 66.6)	NS
Fat (% EI)	37.8 (31.5, 46.8)	38.6 (22.6, 52.0)	NS
Fiber (g/day)	16.5 (8.1, 37.4)	15.2 (4.9, 29.3)	NS
SFA (g/day)	32.1 (15.0, 52.6)	29.8 (11.3, 60.7)	NS
Cholesterol (mg/day)	0.29 (0.14, 0.49)	0.28 (0.07, 0.55)	NS

Data are shown as the median, with minimum and maximum values given in parentheses. Significance was examined by paired *t*-test.
T1DM, type 1 diabetes mellitus; EI, energy intake; SFA, saturated fatty acids.

Table 3 Micronutrient intake, as a percentage of dietary reference intakes[15]

	T1DM ($n = 24$)	Control group ($n = 24$)	*P*-value
Vitamin A	146 ± 215	137 ± 88	NS
Vitamin D	63 ± 46	118 ± 109	0.03
Vitamin E	97 ± 84	46 ± 40	0.01
Thiamin	176 ± 90	154 ± 46	NS
Riboflavin	230 ± 87	213 ± 57	NS
Niacin	159 ± 78	229 ± 125	0.04
Vitamin B_6	208 ± 104	135 ± 56	0.01
Folate	113 ± 62	75 ± 43	0.02
Vitamin B_{12}	315 ± 208	216 ± 104	NS
Vitamin C	459 ± 288	196 ± 160	0.001
Calcium	93 ± 37	95 ± 33	NS
Iron	127 ± 65	136 ± 69	NS
Magnesium	115 ± 66	103 ± 45	NS
Phosphorus	138 ± 73	126 ± 46	NS
Zinc	129 ± 50	107 ± 39	NS

Data are the mean ± SD. Significance was examined by paired *t*-test.
T1DM, type 1 diabetes mellitus.

Table 4 Growth and anthropometric indices

	T1DM ($n = 24$)	Control group ($n = 24$)	*P*-value
BMI (kg/m^2)	20.02 ± 3.31	18.83 ± 4.53	NS
FMI (kg/m^2)	3.53 ± 1.73	4.3 ± 1.70	NS
FFMI (kg/m^2)	16.48 ± 2.91	14.53 ± 2.81	0.001
% Body fat	17.88 ± 7.59	21.27 ± 6.46	NS
z-scores			
BMI	0.77 ± 0.82	0.04 ± 1.40	0.02
Height-for-age	0.49 ± 0.90	0.17 ± 1.74	NS
Weight-for-age	0.79 ± 0.84	0.16 ± 1.02	0.01

Data are the mean ± SD. Significance was examined by paired *t*-test.
T1DM, type 1 diabetes mellitus; BMI, body mass index; FMI, fat mass index; FFMI, fat-free mass index.

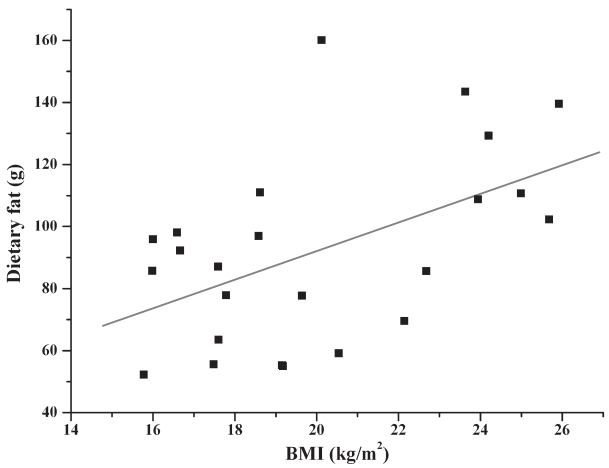

Figure 1 Linear regression of dietary fat intake plotted against the body mass index (BMI) of the type 1 diabetes mellitus group.

with the dietary intake of fat ($r = 0.518$ and $P \leq 0.009$; and $r = 0.509$ and $P \leq 0.011$, respectively). When BMI was plotted against dietary fat intake (Figs 1 and 2), regression analysis showed that 26% of the recorded BMI was predicted from fat intake for the diabetic ($r = 0.509$; $r^2 = 0.259$; $P \leq 0.011$) and healthy ($r = 0.550$; $r^2 = 0.303$; $P \leq 0.005$) participants. Three diabetic participants were diagnosed as overweight (12.5%) and two controls were diagnosed as underweight (8.3%) according to CDC growth charts.[12]

Discussion

In the present study, the diet of diabetic and non-diabetic participants was similar, with excess fat (>35% energy intake [EI]) and protein (>15% EI) intake,

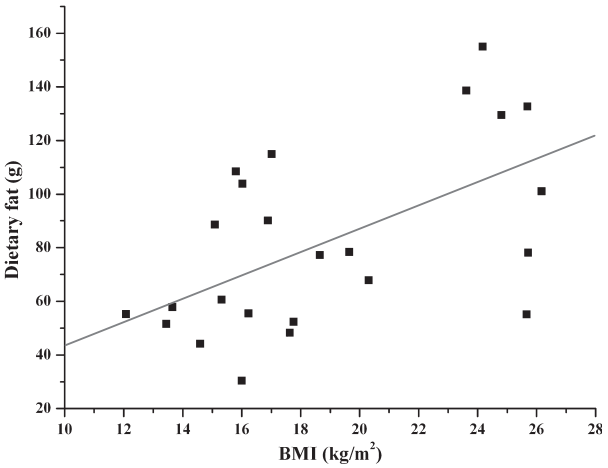

Figure 2 Linear regression of dietary fat intake plotted against the body mass index (BMI) of the control group.

a finding consistent with previous research.[9,17,18] In our hospital, each diagnosis of diabetes is followed by nutritional counseling and a brief session with the dietician is part of each outpatient visit to the hospital thereafter (quarterly). However, because the findings of the present study indicated a similar diet for diabetic and non-diabetic subjects, it appears that nutritional counseling is not effective in altering food choices in Greek youngsters with diabetes. Dietary recommendations for children and adolescents with diabetes are based on healthy eating recommendations for the non-diabetic population.[19,20] The similar dietary patterns observed for the two groups in the present study suggest that diabetes does not appear to affect children's eating choices; thus, health professionals need to be mindful of the potential impact of a typical adolescent diet on diabetes control.[21] Previous research[22,23] suggested that diabetic children and adolescents recognize diabetes as an opportunity to live a healthier life; however, the results of the present study suggest that this is not applicable to Greece. The inability of youngsters with chronic illness to adhere to health advice has been linked to their association with peers who demonstrate negative health behaviors.[24] Thus, diabetic children mimic the dietary patterns of their healthy peers instead of adhering to a healthy eating regimen for diabetes control.

Research has demonstrated that children and adolescents with T1DM tend to adopt a more atherosclerosis-prone diet[25] and the results of the present study are in accordance with these observations. An important finding of the present study was the wide range in protein and fat intake, often reaching very high values. For example, protein, as a percentage of energy intake,

ranged from 12.5% to 27.3% in the diabetic group, whereas fat ranged from 31.5% to 46.8%. The consumption of protein and fat by non-diabetic control subjects reached 31% and 52% of total energy intake, respectively. It has been suggested that a high intake of protein in patients with diabetes may be a risk factor for the future onset of renal complications,[21] whereas low carbohydrate consumption is common in diabetes[7] and coincides with elevated blood glucose levels. The findings of the present study into the diet of Greek youngsters are alarming and indicate the adoption of an unhealthy, Westernized dietary pattern, as suggested by others.[26] It is highly likely that previous studies also uncovered similarly extreme results; however, if the data were presented as the mean ± SD, the magnitude of the problem would have been masked and underestimated. The findings of the present study also indicate the need for the collection of diet diaries during outpatient visits to the hospital. The diaries would help identify any dietary habits that need to improve, as well as set the basis for more effective nutritional counseling for each diabetic patient.

Dietary fat was correlated with HbA1c in Australian children[4] and was suggested to be a good predictor for changes in the percentage body fat of adolescent girls with T1DM.[27] In the present study, fat intake was correlated with BMI and FFMI, but not glucose control. Excessive fat intake results in elevated body fat and obesity,[28] but the present study is the first to demonstrate a relationship with FFMI. The FFMI–dietary fat correlation may have been coincidental owing to the small diabetic sample, because it does not appear to be valid in the control group. Conversely, a high correlation between BMI and dietary fat was also demonstrated in the control group, verifying the relationship between BMI and dietary fat intake in Greek youngsters.

Fiber intake was inadequate for all participants, and all participants reported a high consumption of saturated fat and cholesterol, in agreement with existing literature.[7,8,17,29] In terms of micronutrient intake, low vitamin D intake was found for T1DM patients. Diets low in vitamin D increased the risk of T1DM in a cohort of Finish children;[30] however, the present study was set in a country with plenty of sunshine, where adequate amounts of cholecalciferol can be synthesized daily. The differences in vitamin intakes between the groups could be attributed to different food choices. Overall, the T1DM group consumed significantly more antioxidant vitamins (E and C) compared with the control group. Because most biochemical pathways that increase oxidative stress are closely related to hyperglycemia,[31,32] the high intake of antioxidant vitamins could be the result of either dietary counseling or simply the choice to eat citrus fruits, which are one of the most cultivated products in the Mediterranean region.

It has been proposed that T1DM may adversely affect growth and development in children,[33,34] but this can be altered if patients achieve good glycemic control.[35] Overall, patients with T1DM had higher WAZ and BMIZ scores compared with the healthy controls, which was first demonstrated for Swedish children.[36] However, the small sample size of the present study does not allow for generalizations. No correlations were identified between body fat and glycemic control, as demonstrated in previous research,[4,27] although bioelectrical impedance analysis (BIA) is considered to be valid in children.[37]

Although results of similar studies have been published before, data on Greek youngsters is lacking. The present preliminary paired case–control study is the first to identify dietary and anthropometric factors associated with T1DM in Greek children. The mixture of adolescents and children in the present study is statistically correct because controls and patients were matched for age and sex. A better study design would have paired diabetic children with their healthy siblings in order to diagnose the possible effect of the environment on diet and obesity. Future studies could also assess differences between children and adolescents. Although the most significant limitation of the present study is its small sample size, it should be kept in mind that the present study was a pilot investigation used to set hypotheses for research in a larger Greek sample.

It has been suggested that youngsters with diabetes are prone to biased reporting;[9] thus, daily observation of each participants' dietary intake would have controlled for this factor. The results of the present study showed both similarities and differences compared with previously publications and this could be attributed to the different methods used to determine glycemic control (blood glucose levels versus HbA1c), the different settings, or different anthropometric methods used (calipers, BIA, or dual-energy X-ray absorptiometry). The present study failed to find a correlation between glycemic control and either nutrition or anthropometric variables in a population consisting of both children and adolescents, although correlations may have been found if a larger sample had been used. In studies in which HbA1c was dichotomously categorized as ''good'' or ''bad'' glycemic control, cut-off points were not unanimous;[4,16,37] thus, it is possible that the use of scaled HbA1c in the present study produced better results.

Conclusions

Although the diet of the T1DM group was similar to that of the control group, the two groups demonstrated differences in anthropometric and growth indices. Overall, the diabetic participants failed to adhere to the macronutrient recommendations for diabetes and adopted a Westernized dietary pattern, with extremes in protein and fat intake. No association was demonstrated between diabetes control and nutrient or anthropometric variables.

Disclosure

The authors verify that this paper has not been published or submitted elsewhere. There are no relationships with companies that may have a financial interest in the information contained in the manuscript.

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