Rocz Panstw Zakl Hig 2022;73(3):303-313
http://wydawnictwa.pzh.gov.pl/roczniki_pzh/ https://doi.org/10.32394/rpzh.2022.0222

ORIGINAL ARTICLE

ASSESSMENT OF NUTRITIONAL STATUS, DIETARY INTAKE AND ADHERENCE TO DIETARY RECOMMENDATIONS IN TYPE 1 DIABETIC CHILDREN AND ADOLESCENTS

Sanaa El–Jamal[1], Houda Elfane[1], Hamid Chamlal[1], Khadija Sahel[1], Imane Barakat[1], Mohamed Mziwira[1,2], Aziz Fassouane[1,3], and Rekia Belahsen[1]

[1]Laboratory of Biotechnology, Biochemistry and Nutrition, Training and Research Unit on Nutrition and Food Sciences, Department of Biology, Faculty of Sciences, Chouaib Doukkali University, El Jadida 24 000, Morocco
[2]Higher Normal School, Hassan II University, Casablanca, Morocco
[3]Ibn Zohr University, Agadir, Morocco

ABSTRACT

Background. Currently, T1D is one of the most common chronic diseases in children and adolescents. The International Diabetes Federation (IDF) estimates that more than 1.1 million children and adolescents are living with (T1D). A few studies have evaluated the relationship between dietary intake and glycemic control (GC) in people with T1D, and in particular, children and adolescents.

Objective. The aim of this study was to evaluate the relationship between anthropometric characteristics, lipid profile, inflammation, dietary intake and GC in comparison with international guidelines.

Materials and methods. The study included a sample of 240 children, aged 15 years old or less with T1D. A structured questionnaire was used to collect information on the socio-demographic status, disease characteristics, and diet of the participants. Weight, height, and WC were measured and WHtR and BMI were calculated. Biochemical measurements were determined. Dietary intake was assessed using three 24-hour recalls.

Results. Saturated fat intake was five times higher than recommended. Only 8.3% of participants reached the recommended level of fiber. Overweight, obesity, TC, TG, HDL and CRP were significantly higher in children with poor GC to those with good GC. In addition, participants with poor GC had significantly low intakes of calories, carbohydrates, fiber, MUFAs, and PUFAs and high intakes of fat and SFAs. The use of Bivariate correlation analyses showed that calorie, protein, fat and fiber intake were positively correlated with weight, height, WC, and GO, whereas carbohydrate intake was negatively associated with these parameters. On the contrary, CO showed a negative correlation with calorie, protein, fat and fiber intake and a positive correlation with carbohydrate intake.

Conclusions. The results revealed that the dietary quality was poor and adherence to dietary recommendations was low with insufficient fiber intake and excess SFA. These results suggest that GC can be improved by a healthy, balanced diet by increasing fiber intake and limiting SFA intake.

Key words: *type 1 diabetes; overweight, obesity, lipid profile, dietary intake, glycemic control*

Abbreviations:

T1D: Type 1 diabetes; **GC**: glycemic control; **IDF**: International Diabetes Federation; **CVD**: cardiovascular diseases; **SFA**: Saturated Fatty Acids; **WHO**: World Health Organization; **HbA_1c**: Glycated hemoglobin; **WC**: Waist circumference; **WHtR**: Waist-to-Height ratio; **BMI:** Body Mass Index; **GO**: general obesity; **CO**: central obesity; **SD**: standard deviations; **FBG**: Fasting blood glucose; **PPG**: Postprandial blood glucose; **TC:** Total cholesterol; **LDL**: Low density lipoproteins; **HDL**: high density lipoproteins; **TG:** triglycerides; **CRP**: C-reactive protein; **TEI**: Total Energy Intake; **PUFA**: Polyunsaturated fatty acids; **MUFA**: Monounsaturated fatty acids; **ADA**: American Diabetes Association; **ISPAD**: International Society for Paediatrics and Adolescent Diabetes.

Corresponding author: Rekia Belahsen, Laboratory of Biotechnology, Biochemistry and Nutrition, Training and Research Unit on Nutrition and Food Sciences, Department of Biology, Faculty of Sciences, Chouaib Doukkali University, El Jadida 24 000, Morocco, Phone: +212664971616, e-mail: rbelahsen@yahoo.com or b.rekia@gmail.com

INTRODUCTION

Type 1 diabetes (T1D) is an autoimmune disease characterized by the destruction of beta cells in the islets of Langerhans of the pancreas that are responsible for insulin production [1]. Currently, T1D is one of the most common chronic diseases in children and adolescents [2]. The International Diabetes Federation (IDF) estimates that more than 1.1 million children and adolescents are living with T1D [1].

Young people with T1D have an increased risk of cardiovascular disease (CVD) [3]. Nutrition therapy is one of the cornerstones of the management of T1D. The main objectives of this therapy are the maintenance of stable blood glucose levels, with a reduction in complications, and the frequency of hypoglycemic and hyperglycemic episodes [4, 5].

In addition, the diet for children and adolescents with T1D is similar to that of the general population [6]. However, studies conducted to assess their dietary intake have shown that they do not meet dietary guidelines and their diets are less healthy than those of children without diabetes [7]. Indeed, research has shown that poor glycemic control (GC) was associated with low carbohydrate and high fat intake, particularly saturated fatty acids (SFAs) [8]; higher added sugar intake with insufficient fiber, fruits, vegetables and whole grains [9, 10]. However, results are conflicting; some studies have shown that better GC was associated with low carbohydrate intake [11]. Other studies have shown no association [12].

On the other hand, diabetes is often accompanied by a high prevalence of overweight/obesity and altered lipid profile [13]. Unfortunately, rates of overweight and obesity are steadily increasing, not only among the healthy population, but also among adolescents with T1D [14]. Furthermore, excessive weight is associated with an increased risk of CVD [15]. In Morocco, as in other developing countries, the prevalence of childhood obesity has increased in alarming proportions. Thus, according to the World Health Organization (WHO), Morocco is ranked among the countries with a prevalence of overweight/obesity of 10 to 14.9%, alongside Algeria and Tunisia [16]. This increase can be explained in part by changes in dietary habits in the general Moroccan population, whose consumption of high-calorie foods and beverages is increasing in association with an increase in sedentary behaviour [17].

It is also well known that inflammation is more claimed in people with T1D [18]. Unfortunately, few studies have evaluated the relationship between dietary intake and GC in people with T1D, and in particular, children and adolescents. Moreover, to our knowledge, there are no studies in a Moroccan population that have evaluated the same topic. Therefore, the objective of this study was to evaluate the relationship between anthropometric characteristics, lipid profile, inflammation, dietary intake and GC in Moroccan children and adolescents with T1D in comparison with international guidelines.

MATERIALS AND METHODS

Study population

This is a prospective descriptive study conducted at the level of the pediatric unit of the Mohamed V Provincial Hospital of El Jadida over a period from January 2018 to December 2020. The target population was 240 diabetic children, aged 15 years or less, with T1D for 12 months to avoid the remission period due to the residual secretion of endogenous insulin during recent diabetes.

A structured questionnaire was used and completed with the patients or their parents to collect data on the socio-demographic and socio-economic characteristics, family history, the disease characteristics (duration of diabetes, fasting and postprandial blood glucose), measurement of the HbA_1c level on the same day, diabetes management (number of daily insulin injections and frequency blood glucose self-monitoring per day), lipid profile and anthropometric measurements were also measured (weight, height, WC, sum of skinfolds, WHtR and BMI).

The interview was conducted with the parents (or the participant's guardian) when the child's age was less than 11 years and with the child him/herself when the child's age was 11 years or older. Treating physicians and medical records were also used as sources of data.

Socio-demographic and socio-economic characteristics

Data collected on participants' socioeconomic status (SES) and sociodemographic status are collected through structured interviews included, age, sex, area of residence, parental education and household income.

Anthropometric measurements

These parameters were measured on participants in the pediatrics unit on the day of the interview according to the World Health Organization (WHO) standards [19]. Weight was measured in kilogram to the nearest 100 g, on children lightly dressed and without shoes, on a mechanical scale. The height was measured in the participants to the nearest 0.1 centimeter using a wall scale with heels joined, legs straight, arms dangling and shoulders relaxed.

Waist circumference (WC) was measured on respondents standing with feet 2.5 cm apart, legs

straight, arms dangling and shoulders relaxed, the measuring tape was placed uncompressed at midway between the iliac crest and the last rib, at the end of expiration. The Waist-to-Height Ratio (WHtR) was calculated and the WHtR cut-off of 0.5 is used to define abdominal obesity for both boys and girls [20].

The amount and distribution of body fat were assessed by measuring the thickness of the subcutaneous adipose tissue with a Lange Skinfold Calliper (Cambridge Scientific Industries, Inc. Cambridge, Maryland). The Skinfold thickness was measured on the left side of the body at four sites: biceps and triceps (limb), sub scapular and supra-iliac (trunk). The sum of the four skinfold thickness measures were considered as an indicator of total subcutaneous fat.

Finally, the body mass index (BMI), a measure that estimates the fat mass of individuals, was calculated by dividing the weight in kg by the square of the height expressed in meters (kg/m2): BMI = Weight (kg)/Height^2 (m^2). The references established by WHO in 2007 are used to calculate Z Score values for BMI for age using WHO software, AnthroPlus (Version 1.0.4, 2010), to assess the growth of children and adolescents worldwide [21]. Children under five years old are considered underweight when Z score < −2 standard deviations (SD), overweight when a Z score > +2 SD and obese if Z score > +3 SD [22]. For the children aged 5 to 19 years, they were classified into 3 categories: underweight when Z Score < −2 SD, overweight if Z Score > +1 SD and obese if Z Score > +2 SD [23, 24].

HbA_1c

Metabolic control was assessed by HbA_1c levels. The level of this parameter was measured by boronate affinity chromatography, with the same assay kits (A_1C EZ 2.0; Bio-Hermes). According to ISPAD recommendations, HbA_1c level is optimal if <7.5%; suboptimal if $7.5\% \leq HbA_1c \leq 9.0\%$; and high risk when $HbA_1c > 9.0\%$ [25]. The patients were divided into two groups: a poor GC group if $HbA_1c > 9.0\%$; and a group with good GC when $HbA_1c \leq 9.0\%$.

Biochemical measurements

Venous blood samples were collected by venepuncture after a minimum of 10 hours of overnight fasting, except for postprandial blood glucose, which was collected 2 hours after eating. All analyses were performed on the day of blood collection using a Dirui automated system (CS-1200 Package; Dirui). Blood tests included fasting blood glucose (FBG), postprandial blood glucose (PPG), triglycerides (TG), total cholesterol (TC), low density lipoproteins (LDL), high density lipoproteins (HDL), and C-reactive protein (CRP).

FBG and PPG were measured using a glucose oxidase enzymatic method. TG and TC used an enzymatic method with glycerol phosphate oxidase and cholesterol esterase and cholesterol oxidase respectively. HDL cholesterol was measured, by the direct method, and LDL cholesterol was calculated using the Friedewald formula [LDL = TC− (HDL+TG/5)]. CRP was quantified in serum by turbidimetry and nephelometry.

On the basis of the biochemical data, the occurrence of lipid disorders was assessed in each patient. Abnormal values were identified with high TC ≥ 200 mg/dl, high LDL cholesterol with concentrations ≥ 100mg/dl, high TG with concentrations ≥ 150 mg/dl and low HDL cholesterol with concentrations ≤ 40mg/dl [26]. Serum concentrations of > 5 mg/l CRP were considered to indicate acute inflammation [27].

Dietary intake assessment

Dietary intake data are collected by the three 24-hour dietary recalls technique to list all foods ingested and participant's macronutrient and micronutrient intake (including two weekdays and one weekend day). Each respondent is asked to describe precisely everything they consumed (drunk and eaten) in the previous 24 hours, from rising the night before until the same time on the day of the survey. The respondent was also asked to quantify the foods described, with her own measures (household measures), using an iconographic manual [28]. Dietary intakes were converted to estimate energy and their composition in nutritional intakes using the BILNUT software (SCDA NUTRISOFT-BILNUT, version 2.01). The values obtained were then compared to the reference dietary intakes.

A semi-quantitative food frequency questionnaire (FFQ) was also completed in the participants to this study to transcribe their food consumption habits. The food frequency is composed of two parts: a closed list of foods and a section where consumption frequencies can be indicated (for example, several times a day, 3 to 4 times a week, 1 to 2 times a week, 1 to 2 times a month...) and a section with more detailed questions about the size the portion consumed and its composition.

Dietary intakes were compared to the International Society for Paediatric and Adolescent Diabetes (ISPAD) guidelines for fat intake (30-35% of total energy intake (TEI)) with saturated fatty acids (SFA) (<10% of TEI), polyunsaturated fatty acid (PUFA) intake (<10% of TEI), monounsaturated fatty acid (MUFA) intake (>10% of TEI, up to 20%), protein intake (15% to 20% of TEI) and carbohydrate intake (45-50% of TEI). The adequate fiber intake of children aged 1 year or more is 14 g/1000 kcal/day, while for

children aged > 2 years, the fiber intake is equal to: the child's age in years + 5 [4].

Statistical analysis

Data analysis was performed using SPSS for Windows (Statistical Package for the Social Sciences) software version 23.0. A descriptive analysis was conducted to describe the characteristics of the participants in this study, namely socio-demographic variables and anthropometric and biological measures. T test and *Chi*-square tests are applied for comparison of means ± SD and proportions with percentages of continuous and categorical variables, respectively. P values below 0.05 are considered statistically significant for all tests. In addition, Pearson correlations between macronutrients and anthropometric and biochemical variables were performed.

Ethical aspects

The questionnaire used in this study was validated by a scientific committee of the Chouaib Doukkali University of El Jadida and data collection began after obtaining an authorization from the Regional Health Directorate of the Casablanca-Settat region in Morocco. For each child, free and informed written consent was obtained from the parents or guardians before starting the survey. The procedures and objectives of the study were also clearly explained to the participants. The confidentiality and anonymity of the information collected were also respected.

RESULTS

Socio-demographic, anthropometric and biological characteristics by HbA_1c level

The results in Table 1 show that the proportions of diabetic children aged 11 to 15 years, patients living in rural areas, patients with mothers never attended, and children of low-income parents were significantly higher in T1D children with poor GC compared to those with good GC. In addition, there was a significant association between GC and disease duration. GC was associated with family history of diabetes, number of insulin injections, and self-monitoring of blood glucose ($P \leq 0.001$).

The table data show that BMI, sum of skinfolds, FBG, HbA_1C, TC, TG, HDL and CRP were also significantly higher in diabetic children with poor GC than those with good GC. In addition, overweight and obesity were significantly higher in children with poor than good GC ($P \leq 0.001$).

Association of dietary intake with GC

Dietary intake, including food group intake, is presented in Table 2. Compared with children with T1D of good GC, participants with poor GC had low calorie, carbohydrate, MUFA, and PUFA intakes, slightly high protein intakes, and higher fat and SFA intakes. All of these differences were significant.

Poorly balanced T1D patients also had lower fiber, Calcium, Zinc, Iron and Vit C intake and higher Sodium, Potassium and Phosphorus intake than those with good GC.

On the other hand, children with T1D with good GC had significantly higher intakes of cereals, vegetables/legumes and fish and lower intakes of potatoes, meat/poultry, and oils/fats.

Dietary intakes of macro- and micro-nutrients compared to dietary recommendations

Table 3 shows the mean dietary intake and the number (%) of participants adhering to recommended intakes for all nutrients assessed.

The mean energy intake was 1448.04±484.12 kcal/day. According to ISPAD guidelines for nutritional management, the contribution to TE of the mean carbohydrate intake represented 52% (higher than recommended), that of protein intake is approximately 14% (slightly lower than recommended). The mean fat intake was about 34% of TEI (in line with recommendations) and saturated fat intake averaged 48% of TEI which is significantly higher than recommended. The mean ± SD intake of fiber was 11.78±7.09 g/d with only 8.3% of the participants reaching the recommended level.

On the other hand, about three quarters of the respondents had inadequate Sodium and Phosphorus intake. However, Vit E and Potassium intake was very low in the T1D children (4.2% and 0.8% respectively) and about one quarter of T1D children had met the recommended intakes of Magnesium, Zinc, Vit B1, Vit C and Folate.

Correlations between macronutrients and anthropometry and biochemical variables in children T1D

The use of bivariate correlation analyses showed that calorie, protein, fat, and fiber intakes were positively correlated with weight, height, WC, sum of skinfolds and GO (BMI). In contrast, carbohydrate intake was negatively associated with these parameters (Table 4). On the other hand, CO (WHtR) showed a significantly negative correlation with calorie, protein, fat and fiber intake and a positive correlation with carbohydrate intake.

On the other hand, HbA1c and LDL were significantly and positively associated with fat and SFA intake and negatively associated with carbohydrate, MUFA, PUFA and fiber intake. Finally, HDL was positively associated with carbohydrate and PUFA intake and negatively with SFA intake.

Table 1. Socio-demographic, anthropometric, and biological characteristics by HbA_1c level

Variables (n=127)		Good HbA_1c (n=113)	Poor HbA_1c (n=240)	Total	P-value
Socio-demographic characteristics					
Sex	Male	64(55.7%)	51(44.3%)	115(100%)	0.415
	Female	63(50.4%)	62(49.6%)	125(100%)	
Age category	<= 4 years	32(56.1%)	25(43.9%)	57(100%)	≤ 0.001
	5-10 years	57(68.7%)	26(31.3%)	83(100%)	
	11-15 years	38(38%)	62(62%)	100(100%)	
Area of residence	Urban	84(58.7%)	59(41.3%)	143(100%)	0.028
	Rural	43(44.3%)	54(55.7%)	97(100%)	
Education attainment of the father	Never attended	76(47.2%)	85(52.8%)	161(100%)	0.087
	Primary school	11(57.9%	8(42.1%)	19(100%)	
	College school	14(66.7%)	7(33.3%)	21(100%)	
	Secondary school	7(53.8%)	6(46.2%)	13(100%)	
	University	19(73.1%)	7(26.9%)	26(100%)	
Education attainment of the mother	Never attended	81(46.0%)	95(54.0%)	176(100%)	0.005
	Primary school	23(65.7%)	12(34.3%)	35(100%)	
	College school	9(69.2%)	4(30.8%)	13(100%)	
	Secondary school	8(88.9%)	1(11.1%)	9(100%)	
	University	6(85.7%)	1(14.3%)	7(100%)	
Household income	Low	98(47.3%)	109(52.7%)	207(100%)	≤ 0.001
	Medium	22(84.6%)	4(15.4%)	26(100%)	
	High	7(100%)	0(0%)	7(100%)	
Characteristics of the disease					
Duration of diabetes (years)		2.66±1.80	3.89±2.78	3.24±2.39	≤ 0.001
History of diabetes	No previous history	102(82.9)	21(17.1)	123(100%)	≤ 0.001
	History of diabetes	25(21.4)	92(78.6)	117(100%)	
Number of injections / day	2 times/day	111(57.2%)	83(42.8%)	194(100%)	≤ 0.001
	3 times/day	11(26.8%)	30(73.2%)	41(100%)	
	4 times/day	5(100%)	0(0%)	5(100%)	
Self-monitoring of blood glucose	< 4times/day	98(46.9%)	111(53.1%)	209(100%)	≤ 0.001
	≥ 4 times/day	29(93.5%)	2(6.5%)	31(100%)	
Anthropometric characteristics					
Weight (kg)		25.56±12.29	33.76±16.20	29.41±14.81	≤ 0.001
Height (m)		1.21±0.21	1.31±0.23	1.25±0.23	0.143
WC (cm)		54.29±6.11	57.82±6.74	55.95±6.64	0.356
BMI (kg/m2)		18.29±4.32	20.9±5.59	19.51±5.12	≤ 0.001
WHtR (cm)		0.45±0.054	0.44±0.055	0.45±0.05	0.852
Sum of skinfolds (mm)		30.66±6.17	33.44±8.01	31.97±7.22	0.001
BMI Categories	Normal weight	98(59.4%)	67(40.6%)	165(100%)	≤ 0.001
	Overweight	8(21.1%)	30(78.9%)	38(100%)	
	Obese	2(33.3%)	4(66.7%)	6(100%)	
	Underweight	19(61.3%)	12(38.7%)	31(100%)	
Categories WHtR	No abdominal obesity	96(52.2%)	88(47.8%)	184(100%)	0.676
	Abdominal obesity	31(55.4%)	25(44.6%)	56(100%)	
Biological characteristics					
FBG (mg/dl)		2.6±0.08	2.94±0.06	2.76±0.05	0.033
PPG (mg/dl)		3.37±0.09	3.78±0.07	3.57±0.06	0.109

HbA_1c (%)		7.85±0.07	11.6±0.17	9.62±0.15	≤ 0.001
TC (mg/dl)		1.52±0.021	1.7±0.020	1.61±0.015	0.024
HDL (mg/dl)		0.65±0.01	0.47±0.01	0.56±0.01	0.001
LDL (mg/dl)		0.63±0.02	0.98±0.02	0.80±0.02	0.637
TG (mg/dl)		1.15±0.02	1.23±0.01	1.19±0.01	0.003
CRP (mg/l)		2.98±0.22	4.78±0.36	3.83±0.21	0.013

Abbreviations: Data are presented as mean ± standard deviation (SD) or number (%).
BMI: Body Mass Index; WHtR: Waist-to-Height ratio; FBG: fasting blood glucose; PPG: postprandial blood glucose; HbA_1c: Glycated hemoglobin; TC: Total cholesterol; HDL: High density lipoprotein cholesterol; LDL: Low density lipoprotein cholesterol; TG, Triglycerides; CRP: C-reactive protein.
The differences between socio-demographic, anthropometric and biological characteristics according to the level of HbA_1c were compared by the t test for continuous variables and by Chi2 test for categorical variables. The mean difference is significant at the 0.05 level.

Table 2. Association of dietary intake with GC

	Good HbA_1c (n=127)	Poor HbA_1c (n=113)	Total (n=240)	P-value
Calories and macronutrient intake				
Calories (kcal/d)	1480.41±530.31	1411.66±425.71	1448.04±484.12	0.012
Carbohydrates (%AET)	54.69±4.66	49.21±6.92	52.11±6.44	0.001
Protein (% AET)	14.09±2.19	14.14±2.94	14.11±2.57	0.01
Lipids (% AET)	31.21±4.08	36.66±5.68	33.78±5.59	0.007
AGS(%)	43.81±11.01	53.41±8.00	48.33±10.81	≤ 0.001
MUFA(%)	42.54±7.7	37.78±6.05	40.3±7.35	0.006
PUFA(%)	13.63±8.68	8.78±5.00	11.35±7.57	≤ 0.001
Micronutrient intake				
Fibers (g/d)	12.91±8.56	10.52±4.67	11.78±7.09	≤ 0.001
Cholesterol (mg/d)	105.01±85.46	89.02±78.68	97.48±82.56	0.368
Sodium (mg/d)	2364.23±1309.54	2450.44±1194.46	2404.82±1254.81	0.002
Magnesium (mg/d)	201.96±102.51	194.11±111.79	198.26±106.83	0.173
Calcium (mg/d)	714.8±386.06	445.09±286.88	587.81±367.89	≤ 0.001
Potassium (mg/d)	1576.63±676.08	1734.15±1016.38	1650.8±855.15	0.036
Zinc (mg/d)	5.58±3.07	4.65±2.11	5.14±2.7	≤ 0.001
Iron (mg/d)	6.31±2.35	5.81±2.72	6.08±2.54	0.028
Phosphorus (mg/d)	888.68±419.75	1044.62±463.11	962.1±446.63	0.049
Vit E (mg/d)	2.41±1.97	1.94±1.52	2.19±1.78	0.075
Vit B1 (mg/d)	0.54±0.22	0.52±0.2	0.53±0.21	0.885
Vit C (mg/d)	29.8±19.52	23.72±16.12	26.94±18.22	0.005
Folate (µg/d)	173.19±84.28	185.27±94.25	178.88±89.13	0.171
Food group intake (g/d)				
Cereals	416.74±186.59	336.19±116.76	378.81±162.38	≤ 0.001
Potatoes	59.46±28.66	73.63±39.77	66.13±34.99	≤ 0.001
Vegetables	167.58±65.19	123.69±45.86	146.92±60.89	0.003
Legumes	7.318±3.92	7.019±4.71	7.17±4.30	0.033
Fruits	109.17±37.9	83.33±39.79	97±40.82	0.626
Meat/poultry	36.86±14.99	49.06±24.43	42.60±20.87	0.028
Fish	22.01±14.78	17.40±9.05	13.90±8.76	≤ 0.001
Eggs	12.71±6.10	15.23±10.89	19.84±12.60	0.579
Dairy products	266.82±103.28	199.88±110.60	235.30±111.70	0.632
Oils/fats	16.42±8.41	21.25±11.84	18.7±10.43	≤ 0.001

Abbreviations: TEI: Total Energy Intake; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

Table 3. Daily macronutrient and micronutrient intake and proportion of participants meeting recommended targets

Nutrients	Average daily intake	n(%) meeting goals of ISPAD[a] or RDA[b]
Energy, calories	1448.04±484.12	-
Carbohydrates, % TE[a]	52.11±6.44	62(25.8%)
Proteins, % TE[a]	14.11±2.57	89(37.1%)
Lipids, % TE[a]	33.78±5.59	84(35%)
AGS, % TE[a]	48.33±10.81	0(0%)
Fibers (g/d) [a]	11.78±7.09	20(8.3%)
Sodium (mg/d) [b]	2404.82±1254.81	72(30%)
Magnesium (mg/d) [b]	198.26±106.83	55(22.9%)
Calcium (mg/d) [b]	587.81±367.89	27(11.3%)
Potassium (mg/d) [b]	1650.8±855.15	2(0.8%)
Zinc (mg/d) [b]	5.14±2.7	54(22.5%)
Iron (mg/d) [b]	6.08±2.54	43(17.9%)
Phosphorus (mg/d) [b]	962.1±446.63	66(27.5%)
Vit E (mg/d) [b]	2.19±1.78	10(4.2%)
Vit B1 (mg/d) [b]	0.53±0.21	56(23.3%)
Vit C (mg/d) [b]	26.94±18.22	55(22.9%)
Folate (µg/d) [b]	178.88±89.13	51(21.3%)

Abbreviations: Data are presented as mean ± standard deviation (SD). % TE: Percentage of total energy. ISPAD[a]: International Society for Pediatric and Adolescent Diabetes; RDA[b]: Recommended Dietary Allowance. Food and Nutrition Board. Institute of Medicine. National Academies. 2010.

[a] Target values recommended by ISPAD: **Carbohydrate**: 45-50% of TEI; **protein**: 15-20% of TEI; **Total Fat**:30-35% of TEI; Saturated Fat <10% of TEI; **Fiber:** 1 year or greater: 14 g/1000 kcal; > 2 years old: age (years) + 5.

[b] Target values recommended by RDA: [b] **Sodium**: Children 1-3y: 1g; Children 4-8y: 1.2g; Male or female 9-15y: 1.5g; [b] **Magnesium**: Children 1-3y: 80mg; Children 4-8y: 130mg; Male or female 9-13y: 240mg; Male 14-15y: 410mg; Female 14-15y: 360; [b] **Calcium**: Children 1-3y: 700mg; Children 4-8y: 1000mg; Male or female 9-15y: 1300mg; [b] **Potassium**: Children 1-3y: 3g; Children 4-8y: 3.8g; Male or female 9-13y: 4.5g; Male or female 14-15y: 4.7g; [b] **Zinc**: Children 1-3y: 3mg; Children 4-8y: 5mg; Male or female 9-13y: 8mg; Male 14-15y: 11mg; Female 14-15y: 9mg;[b] **Iron:** Children 1-3y: 7mg; Children 4-8y: 10mg; Male or female 9-13y: 8mg; Male 14-15y: 11mg; Female 14-15y: 15mg;[b]**Phosphorus:** Children 1-3y: 460mg; Children 4-8y: 500mg; Male or female 9-15y: 1250mg; [b] **Vit E**:Children 1-3y: 6; Children 4-8y: 7; Male or female 9-13y: 11; Male or female 14-15y: 15; [b] **Vit B1**:Children 1-3y: 0.5mg; Children 4-8y: 0.6mg; Male or female 9-13y: 0.9mg; Male 14-15y 1.2mg; Female 14-15y: 1mg; [b]**Vit C**: Children 1-3y: 15mg; Children 4-8y: 25mg; Male or female 9-13y: 45mg; Male 14-15y: 75mg; Female 14-15y: 65mg; [b] **Folates**: Children 1-3y: 150 µg; children 4-8y: 200 µg; Male or female 9-13y: 300 µg; Male or female 14-15y: 400 µg.

Table 4. Correlations between macronutrients and anthropometry, and biochemical variables in children T1D

	Calories (kcal/d)	Carbohydrates (%TEI)	Protein (%TEI)	Lipids (%TEI)	SFA (%)	MUFA (%)	PUFA (%)	Fibers (g/d)
Anthropometric characteristics								
Weight (kg)	0.491**	-0.406**	0.235**	0.363**	0.035	-0.008	-0.043	0.309**
Height(m)	0.533**	-0.377**	0.258**	0.318**	-0.013	0.026	-0.008	0.303**
WC (cm)	0.445**	-0.361**	0.246**	0.303**	0.044	0.023	-0.085	0.285**
BMI (kg/m^2)	0.492**	-0.372**	0.193**	0.344**	0.011	0.002	-0.018	0.335**
WHtR (cm)	-0.436**	0.241**	-0.152*	-0.210**	0.091	-0.036	-0.094	-0.238**
Sum of skinfolds	0.386**	-0.304**	0.179**	0.269**	0.034	0.039	-0.087	0.302**
Biological characteristics								
FBG (mg/dl)	0.023	-0.03	-0.078	0.069	0.021	-0.047	0.014	-0.056
PPG (mg/dl)	0.042	-0.048	-0.075	0.089	0.038	-0.075	0.018	-0.098
HbA_1c (%)	0.003	-0.375**	0.012	0.427**	0.415**	-0.323**	-0.279**	-0.258**
TC (mg/dl)	-0.084	-0.124	-0.023	0.156*	0.123	-0.117	-0.061	-0.142*

HDL (mg/dl)	0.082	0.150*	-0.108	-0.123	-0.340**	0.218**	0.273**	0.093
LDL (mg/dl)	-0.113	-0.174**	0.054	0.177**	0.289**	-0.209**	-0.208**	-0.159*
TG (mg/dl)	-0.036	-0.128*	-0.028	0.163*	0.157*	-0.145*	-0.084	-0.086
CRP	-0.021	-0.083	-0.011	0.114	0.09	-0.158*	0.025	-0.038

Abbreviations: BMI: Body Mass Index; WHtR: Waist-to-Height ratio; FBG: fasting blood glucose; PPG: Postprandial glycaemia. HbA_1c: Glycated hemoglobin; TC: Total cholesterol; HDL: High density lipoprotein cholesterol; LDL: Low density lipoprotein; TG, Triglycerides; CRP: C-reactive protein; ** significance level: <0.01; * significance level: <0.05.

DISCUSSION

The results of the present study show that the average dietary intake of Moroccan children with T1D was far from dietary recommendations. In this current study, daily intake and dietary quality were assessed in patients with T1DM at the Paediatric service to examine whether they adhered to the international dietary recommendations. The study revealed that SFA intake was almost five times the recommended maximum and fiber intake was inadequate in most young people. In addition, the present data also indicate an association of socio-demographic, anthropometric, biological characteristics, and dietary intake with GC in children and adolescents with T1D.

To our knowledge, few studies have focused on the assessment of nutritional status in children and adolescents with T1D. The prevalence of obesity is increasing in subjects with T1D [29]. Indeed, several factors associated with T1D may favor overweight, among them difficulty in managing GC and an unhealthy diet rich in animal fats [10]. In addition, the introduction of insulin treatment is associated with excess body weight in patients with T1D [7]. The results of the present study showed that the majority of children with T1D (68.8%) had normal nutritional status. However, about 16% of the participants were overweight and 2.5% were obese. This may be explained by the third phase of the nutritional transition that Morocco is going through, in addition to globalization, accompanied by considerable changes towards unhealthy lifestyles, including low physical activity and the adoption of Western eating habits with increasing consumption of fast food, rich in fat and sugar [17]. Previous data have also shown that overweight and GO are associated with poor GC. An association between HbA_1c and high fat accumulation in the abdominal region has been reported in the literature [30]. In contradiction with these studies, however, no significant difference was between CO and GC in the present study. On the other hand, a significant difference between TC, HDL, TG and HbA_1c was in the sample of children studied. Previous studies have also reported changes in lipid profile in patients with poor GC and long disease duration [31].

It is therefore clear that a healthy diet is essential for better GC and for the management of obesity and dyslipidemia, which contribute to CVD risk in diabetic subjects [32]. The children with T1DM in this study had a dietary intake far from the nutritional recommendations, particularly regarding to SFA and fiber intakes. These results agree with several studies that have reported poor adherence to dietary recommendations in children and adolescents with T1DM [33]. Furthermore, this poor adherence was associated with poor GC and thus risk of complications and CVD [34].

The results of this study agree with previous studies that indicated that high dietary carbohydrate intake was associated with low HbA_1c [35]. In contrast, another study showed that increased carbohydrate intake increased HbA_1c levels in young patients with T1D [36]. Other macronutrients that should be considered in the dietary recommendations include fat, protein, and fiber intake [37]. In addition, the American Heart Association has advocated moderate fat intake while reducing SFAs and replacing them with MUFAs and PUFAs [38]. In agreement with previous studies [39], the data reported in the present study show an association of fat and SFA with HbA_1c levels. However, this association is controversial in the literature. Some of studies have found no association between fat intake and GC [40], while on the contrary; other studies have reported that high fat intakes are associated with poor GC [41]. These different results could be explained by the replacement of carbohydrates by fats [42]. Protein intake was also associated with HbA_1c in the sample of participants in this study. In contrast, studies have found that low protein intake was associated with better GC [35].

The beneficial role of fiber intake in weight management, CVD prevention and digestive health is reported in the literature [43]. Mixed results regarding this role have been reported. Indeed, an association between low fiber intake and poor GC has been found by studies and confirmed by the present study [8]. In contrast, other studies have found no association between fiber and HbA_1c [41].

Furthermore, in this study, children, and adolescents with T1D of poor GC consumed fewer cereals and vegetables and more fat than youth with better GC. Our results are consistent with other studies that have found that adolescents with T1D with better optimal GC had low consumption of added sugars and high

consumption of fiber, fruits, and vegetables compared to those with less optimal GC [9].

Strengths and limitations of the study

This study has strengths and limitations. To our knowledge, this is the first study to assess daily dietary intake in Morocco in children and adolescents with T1D in relation to international recommendations. The strengths of the study include the use of three 24-hour recalls assessing dietary intake, which is one of the best methods for collecting dietary data, and the use of the food frequency questionnaire to more accurately determine the amount of food portions ingested.

Nevertheless, our study has some limitations that need to be considered. Firstly, the majority of participants are treated with two insulin injections and, therefore, the results may not be generalizable to adolescents with T1D on other types of diets. Secondly, it should be mentioned that the estimation of food intake is often misreported, and especially underreported, by children and adolescents with T1D. Thirdly, the number of subjects who participated in the study should be larger. This limitation is, however, offset by the accurate clinical measures that were collected. Finally, the study population may not be representative of the Moroccan population of children with diabetes. It would be wise to extend this study to a larger representative sample to generalize the results obtained.

CONCLUSION

In conclusion, the results of the present study indicate that the quality of the diet of children with T1D was poor and adherence to dietary recommendations was low with insufficient fiber intake and excess of SFA. Considering our results, we suggest continued nutrition education for children and parents by focusing on a healthy, balanced diet and limiting high-fat foods and increasing consumption of fiber-rich foods such as fruits and vegetables to optimize growth, maintain normal weight, reduce CVD risk, and improve GC in young diabetics.

Acknowledgements

The authors would like to thank the study participants (children, parents, or guardians of the participant), the Provincial Delegation of the Province of El Jadida, the Regional Health Directorate of Casablanca-Settat, and the medical and paramedical team for their cooperation. We would also like to thank the director of the Provincial Hospital Center and the staff of the biological analysis laboratory of this hospital for their cooperation. Special thanks are due to the staff of the pediatric unit of this hospital for allowing us to collect data. The study was supported by the Moroccan Ministry of Higher Education and Research.

Funding sources

This research has not received any specific grants from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

The authors declare that they have no competing interests.

REFERENCES

1. *International Diabetes Federation (IDF):* Diabetes in the young: a global perspective. In: IDF Diabetes Atlas. Ninth Edition. Brussels: International Diabetes Federation 2019. Available from: www.idf.org.
2. *Simmons K.M:* Type 1 Diabetes: A Predictable Disease. World J. Diabetes 2015; 6:380–390.
3. *Benjamin EJ, Blaha MJ, Chiuve SE, Cushman M, Das SR, DeFerranti SD, et al.* Heart Disease and Stroke Statistics Update: A Report from the American Heart Association. Circulation 2017;135:e146–e603.
4. *DiMeglio L.A., Acerini C.L., Codner E., Craig M.E., Hofer S.E., Pillay K., and al:* ISPAD Clinical Practice Consensus Guidelines: GC Targets and Glucose Monitoring for Children, Adolescents, and Young Adults with Diabetes.
5. Pediatric Diabetes 2018;19:105–114.
6. *American Diabetes Association*: Children and Adolescents: Standards of Medical Care in Diabetes—2021. Diabetes Care 2021.44 (Suppl. 1), S180–S199.
7. *Smart C., Aslander-van Vliet E., Waldron S:* Nutritional management in children and adolescents with diabetes. Pediatr Diabetes 2009; 10(suppl 12):100-117.
8. *Rovner AJ, Nansel TR:* Are children with type 1 diabetes consuming a healthy diet?: a review of the current evidence and strategies for dietary change. Diabetes Educ 2009;35:97–107.
9. *Katz ML, Mehta S, Nansel T, Quinn H, Lipsky LM, Laffel LM:* Associations of nutrient intake with GC in youth with T1D: differences by insulin regimen. Diabetes Technol Ther 2014;16(8):512–518.
10. *Overby NC, Margeirsdottir HD, Brunborg C, Andersen LF, Dahl-Jorgensen K:* The influence of dietary intake and meal pattern on blood glucose control in children and adolescents using intensive insulin treatment. Diabetology 2007;50:2044–51.
11. *Mayer-Davis E, Nichols M, Liese A et al :* Dietary intake among youth with diabetes: the SEARCH for Diabetes in Youth Study. J. Am. Diet 2006; Assoc 106(5), 689–697.
12. *Meissner T, Wolf J, Kersting M, Frohlich-Reiterer E, Flechtner-Mors M, Salgin B, and al:* Carbohydrate intake in relation to BMI, HbA1c and lipid profile in children and adolescents with type 1 diabetes. Clin Nutr 2014;33(1):75–8.

13. *Michaliszyn SF, Shaibi GQ, Quinn L, Fritschi C, Faulkner MS*: Physical fitness, dietary intake, and metabolic control in adolescents with type 1 diabetes. Pediatric Diabetes 2009;10:389–94.
14. *American Diabetes Association*: Nutrition recommendations and interventions for diabetes. A position statement of the American Diabetes Association. Diabetes Care 2006:29:2140–2157.
15. *Minges, KE; Whittemore, R.; Grey, M:* Overweight and obesity in youth with type 1 diabetes. Ann. Rev. Nurs. Res 2013;31:47–69.
16. *Van Vliet M., Van der Heyden J.C., Diamant M., et al:* Overweight is highly prevalent in children with type 1 diabetes and associates with cardiometabolic risk. J Pediatr 2010;156 (6):923-929.
17. *World Health Organization*: World diabetes report 2016. Available from:
18. https://apps.who.int/iris/bitstream/handle/10665/254648/9789242565256-eng.pdf.
19. *Belahsen R.* Nutrition transition and food sustainability. Proc Nutr Soc 2014;73:385–388.
20. *Snell-Bergeon J.K., West N.A., Mayer-Davis E.J., Liese A.D., Marcovina S.M., D'Agostino R.B., and al:* Inflammatory Markers Are Increased in Youth with Type 1 Diabetes: The SEARCH Case-Control Study. J. Clin. Endocrinol. Metab 2010;95:2868–2876.
21. *Purnell J.Q:* Definitions, Classification, and Epidemiology of Obesity 2000. [Updated 2018 Apr 12]. In: *Feingold KR, Anawalt B, Boyce A*, and al., editors. Endotext [Internet]. South Dartmouth (MA): MDText.com, Inc. Available from:https://www.ncbi.nlm.nih.gov/books/NBK279167.
22. *McCarthy H.D., Ashwell M:* A study of central fatness using waist-to-height ratios in UK children and adolescents over two decades supports the simple message—"keep your waist circumference to less than half your height". Int J Obes 2006; (London) 30:988–992.
23. WHO *Anthro* (version 1.0.4, January 2011) and macros [Internet] 2011: [cited 2012 May 5]. Available from: http://www.who.int/childgrowth/software/en/.
24. WHO. Child Growth Standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age. Methods and development 2006. Available from: https://www.who.int/childgrowth/standards/Technical_report.pdf?ua=1.
25. World Health Organization*:* WHO Child Growth Standards. Growth reference data for 5– 19 years. 2007. Available from: http://www.who.int/growthref/en/.
26. *Butte N.F., Garza C., de Onis M*: Evaluation of the feasibility of international growth standards for school-aged children and adolescents. J Nutr 2007;137:153–157.
27. *Rewers M., Pihoker C., Donaghue K* : Assessment and monitoring of GC in children and adolescents with diabetes. Pediatr Diabetes 2007;8:408–418.
28. *Donaghue K.C., Wadwa R.P., Dimeglio L.A:* ISPAD Clinical Practice Consensus Guidelines. Microvascular and macrovascular complications in children and adolescents. Pediatr Diabetes. 2014;15(Supplement 20):257–269.
29. *Thurnham D.I., Mccabe L.D., Haldar S., Wieringa F.T., Northrop-clewes C.A., Mccabe G.P:* Adjusting plasma ferritin concentrations to remove the effects of subclinical inflammation in the assessment of iron deficiency: 2018; (August):546–555.
30. *Elmoumni K:* Typical foods and preparations of the Moroccan population, Tool for estimating food consumption, Center for Information and Research on Food Intolerances and Hygiene (CIRIHA), 2008.
31. *DuBose S.N., Hermann J.M., Tamborlane W.V:* Obesity in youth with T1D in Germany, Austria, and the United States. J Pediatr 2015; 167(3):627–632.
32. *Valerio G., Iafusco D., Zucchini S., Maffeis C:* Study-Group on Diabetes of Italian Society of Pediatric Endocrinology and Diabetology [ISPED]. Abdominal adiposity and cardiovascular risk factors in adolescents with T1D. Diabetes Res Clin Pract 2012;97(1):99–104.
33. *Wysocka-Mincewicz M, Kołodziejczyk H, Wierzbicka E, et al*: Overweight, obesity and lipid abnormalities in adolescents with type 1 diabetes. Pediatr Endocrinol Diabetes Metab 2015;21(2):70–81.
34. *Evert A.B., Dennison M., Gardner C.D., Garvey W.T., Lau K.H.K., MacLeod J., Mitri J., et al*: Nutrition Therapy for Adults With Diabetes or Prediabetes: A Consensus Report. Diabetes Care 2019; 42:731–754.
35. *Mackey E.R., Rose M., Tully C., Monaghan M., Hamburger S., Herrera N., and al:* The Current State of Parent Feeding Behavior, Child Eating Behavior, and Nutrition Intake in Young Children with Type 1 Diabetes. Pediatric Diabetes 2020;21:841–845.
36. *Mackey E.R., O'Brecht L., Holmes CS, Jacobs M, Streisand R:* Teens with Type 1 Diabetes: How Does Their Nutrition Measure Up? J. Diabetes Res 2018 Sept.6;2018:5094569. Doi : 10.1155/2018/5094569. eCollection 2018.
37. *Nansel T.R, Lipsky L.M, Liu A:* Greater diet quality is associated with more optimal GC in a longitudinal study of youth with type 1 diabetes. Am J Clin Nutr 2016;104:81–87.
38. *Lamichhane A.P., Crandell J.L., Jaacks L.M., Couch S.C., Lawrence J.M., Mayer-Davis E.J:* Longitudinal associations of nutritional factors with glycated hemoglobin in youth with type 1 diabetes: the SEARCH Nutrition Ancillary Study. Am J Clin Nutr 2015;101:1278–1285.
39. *Smart C.E., Annan F., Higgins L.A., Jelleryd E., Lopez M., Acerini C.L*: ISPAD Clinical Practice Consensus Guidelines: Nutritional Management in Children and Adolescents with Diabetes. Pediatric Diabetes 2018;19:136–154.
40. *Sacks F., Lichtenstein A., Wu JHY et al*: Dietary Fats and Cardiovascular Disease: A Presidential Advisory from the American Heart Association 2017. Traffic.13 (3), e1–e23.
41. *Mehta SN, Volkening LK, Quinn N, Laffel LM:* Intensively managed young children with type 1 diabetes consume high-fat, low-fiber diets similar to age-matched controls. Nutr. Res 2014;34:428–435.
42. *Lamichhane A.P., Crandell J.L., Jacks L.M., Couch S.C., Lawrence J.M., Mayer-Davis E.J:* Longitudinal Associations of Nutritional Factors with Glycated

Hemoglobin in Youth with Type 1 Diabetes: The SEARCH Nutrition Ancillary Study. Am. J. Clin. Nutr 2015;101:1278–1285.
43. *Delahanty L.M., Nathan D.M., Lachin J.M., Hu F.B., Cleary P.A., Ziegler G.K., and al:* Association of diet with glycated hemoglobin during intensive treatment of type 1 diabetes in the Diabetes Control and Complications Trial. Am J Clin Nutr 2009;89:518–524.
44. *Soedamah-Muthu S.S., Chaturvedi N., Fuller J.H., Toeller MGroup EPCS:* Do European people with type 1 diabetes consume a high atherogenic diet? 7-year follow-up of the EURODIAB Prospective Complications Study. Eur J Nutr 2013;52:1701–1710.
45. *Dahl W., Stewart M:* Position of the Academy of Nutrition and Dietetics: Health Implications of Dietary Fiber. J. Acad. Nutr. Diet 2015;115(11):1861–1870.

Received: 27.03.2022
Accepted: 06.07.2022
Published online first: 02.09.2022