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Malnutrition and Metabolic Changes in Patients with Type 2 Diabetes

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ABSTRACT

Background/Aim: In patients with type 2 diabetes (T2D), malnutrition has been recognized as a serious health problem mainly in hospitalized conditions, but there is little data regarding malnutrition outside hospital settings. The aim of this study was to evaluate the risk of malnutrition and associated metabolic changes in ambulatory patients with T2D. **Material and methods:** This analysis used data collected from 161 patients with T2D enrolled in a larger cross-sectional study. Several anthropometric and metabolic parameters were obtained. Nutritional status was evaluated using the Controlling Nutritional Status (CONUT) score. Correlations between nutritional status and metabolic and anthropometric parameters of interest were examined. **Results:** Of all T2D patients, 29.8% had mild malnutrition (CONUT score 2–4). These patients presented lower triglyceride (124.8 ± 42.3 mg/dL vs. 165.7 ± 84.3 mg/dL, p <0.01) and LDL cholesterol concentrations (62.7 ± 20.0 mg/dL vs. 104.9 ± 30.6 mg/dL, p <0.0001), higher leptin levels (10.2 [1.6–44.9] ng/mL vs. 7.3 [0.9–49.8] ng/mL, p <0.05) and free leptin index (0.65 [0.04–2.88] vs. 0.36 [0.01–3.98], p <0.05) compared with patients with normal nutritional status. They also had higher total body adiposity. In patients with obesity, triglycerides levels were lower in those with mild malnutrition vs. those without malnutrition (mean difference: 27.26 mg/dL, p <0.05). Serum C peptide/leptin ratio was higher in T2D patients with normal nutritional status without obesity, the differences being significant vs. the two groups with obesity (with or without malnutrition, 0.71 ± 0.53, 0.42 ± 0.33, and 0.49 ± 0.68, respectively). HOMA-IR was lower in patients with normal nutritional status without obesity vs. those with obesity (mean difference: –0.7126, p <0.05), while in patients with mild malnutrition, HOMA-IR values were higher, but no differences were noted between the groups with or without obesity. **Conclusion:** In patients with T2D, malnutrition associated with lower triglycerides concentrations, even in the presence of obesity. Malnutrition and/or obesity associated with higher HOMA-IR, serum leptin levels and lower C peptide/leptin ratio.

Keywords: type 2 diabetes, malnutrition, metabolic parameters

BACKGROUND

Malnutrition has emerged as a serious health issue, mainly in hospitalized patients, because it is associated with a poorer overall prognosis.[1,2] It occurs as a result of an inadequate diet with improper quantities and/or quality of nutri-

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ents, malabsorption, or disease-related metabolic changes such as increased nutrient losses.[3] Malnutrition increases the risk of acute and chronic diseases, including osteoporosis or cardio-metabolic diseases, and alters the immune and muscular functions.[4] As a consequence, patients are at increased risk of infections or other complications such as impaired wound healing.[5] This might be particularly relevant for patients with type 2 diabetes (T2D), since they are already at increased risk of chronic complications due to hyperglycemia. In fact, both conditions can have serious health implications.

Some reports indicate that up to a third of T2D patients admitted to the hospital are malnourished, and this is associated with a longer hospitalization and a higher mortality risk.[3,6] On the other hand, diabetes has been identified as a risk factor for malnutrition in hospitalized patients.[7] However, there is little data regarding malnutrition in patients with T2D outside hospital facilities.

In this study we aimed to evaluate the risk of malnutrition and associated metabolic changes in ambulatory patients with T2D by using validated nutrition scores.

MATERIAL AND METHODS

Study population

This was an analysis of data obtained in a larger cross-sectional study that evaluated the role of leptin and leptin resistance in non-alcoholic fatty liver disease and in depression, in subjects with T2D. The study included adult patients with T2D, diagnosed according to the American Diabetes Association (ADA) criteria and older than 30 years of age.[8] Patients attended the Diabetes Outpatient Unit of the Emergency Clinical County Hospital of Tîrgu Mureş for regular checkups and were recruited in the study during 2017. Details regarding study participants, materials, and methods have been published previously.[9] The study was approved by the Ethics Committee of the University of Medicine and Pharmacy of Tîrgu Mureş, and all participants signed an informed consent before being enrolled.

Apart from demographic and clinical data (which included medical history, and measurement of blood pressure [BP] and pulse), several anthropometric parameters were also obtained by standard methods (weight, height, waist circumference, hip circumference, and four skinfolds that evaluated subcutaneous adipose tissue [subscapular, suprailiac, biceps, triceps]).

Several laboratory data were used in the analysis. Blood samples were collected after an overnight fast, in clot activator tubes (and aliquots stored at −80°C for subsequent analysis) and separately, on EDTA tubes for glycated hemoglobin (HbA1c) and complete blood count (CBC) analysis. The metabolic panel included blood glucose (measured by glucose-oxidase method), HbA1c (analyzed according to the DCCT-standardized and NGSP-certified [%] method, based on turbidimetric inhibition immunoassay), lipid profile (total cholesterol, high-density lipoprotein [HDL] cholesterol, triglycerides), C-peptide (measured by a competitive chemiluminescent enzyme immunoassay on Immulite 2000, Diagnostic Products Corporation, USA), serum leptin and soluble form of leptin receptor (sObR, measured by sandwich enzyme-linked immunosorbent assay [ELISA] on a DSX ELISA automated analyzer, Dynex Technologies, Inc. USA). Serum albumin was also measured on Cobas Integra 400 plus (Roche Diagnostic, Germany), together with HbA1c and lipids. The CBC was analyzed on a 5-differential hematology analyzer.

Calculations

Several metabolic and anthropometric parameters were calculated. Low-density lipoprotein (LDL) cholesterol concentrations were calculated with the Friedewald formula and the Free Leptin Index (FLI), basically an estimate of leptin resistance, by using the ratio of leptin and sObR values.[10] The Homeostasis Assessment Model (HOMA) calculator version 2.2.3 was used to estimate β-cell function (HOMA-B) and insulin resistance (HOMA-IR), by inputting fasting blood glucose and C-peptide values.[11] The waist-to-hip ratio (WHR), Σ4SF (the sum of 4 skinfolds), and the body mass index (BMI) were calculated. The percentage of body fat (BF) was estimated using the Durnin & Womersley and Siri equations.[12] The total body fat mass (TBFM) was calculated using the formula weight × %BF/100, and the non-fat mass (NFM) by the difference between weight and TBFM. The daily resting energy expenditure (REE) was estimated using the Harris-Benedict formula.[13]

The nutritional status was evaluated with the widely used and validated Controlling Nutritional Status (CONUT) score, which employs a scoring system based on serum albumin levels, total cholesterol concentrations, and total lymphocyte count.[14] A total CONUT score of 0–1 points indicates a normal nutritional status, 2–4 points indicate mild malnutrition, 5–8 points are indicative of moderate malnutrition, while 9–12 points indicate severe malnutrition.[14] In addition, the Prognostic Nutritional Index (PNI) was calculated using the formula: 10 × serum albumin (g/dL) + 0.005 × total lymphocyte (count/μL).[15] A score of 38 or more is indicative of normal nutritional status and below 35 of severe malnutrition.[15]

Statistical analysis

Descriptive statistics was calculated for all variables. They were expressed as mean ± SD or median (min-max) (continuous variables) or as frequency (%) (categorical variables). Student's t-test, Mann-Whitney, ANOVA, or Kruskal-Wallis tests were used to compare means or medians between groups, and the Dunn or the Bonferroni post-tests were employed to identify groups between which there were significant differences. Fisher's exact test was used for analysis of categorical variables. The correlations between variables were tested using Pearson's and Spearman's tests, respectively, and data are presented as r (95% confidence interval [CI]). The tests were two-tailed, and statistical significance was set at $p < 0.05$. GraphPad InStat3 was employed for analysis.

RESULTS

Data from 161 patients with T2D was analyzed and classified as having normal nutritional status (CONUT score 0–1 points) (70.2%) or mild malnutrition (CONUT score 2–4 points) (29.8%). No patient presented a CONUT score ≥5 points. There were no differences with regards to age (63.4 ± 8.0 years vs. 65.9 ± 6.6 years), gender distribution (66.4% vs. 72.9% females) and diabetes duration (6.0 [0.0–21.0] years vs. 5.5 [0.0–27.0] years) between the two groups (p: NS for all). Their BP values (129.7 ± 14.1/76.0 ± 9.7 mmHg vs. 128.7 ± 16.3/73.4 ± 9.5 mmHg) and their pulse (74.7 ± 11.5 b/min vs. 73.0 ± 10.1 b/min) were similar (p: NS for all). The group with mild malnutrition according to the CONUT score also had significantly lower PNI values (52.3 ± 4.5 vs. 55.0 ± 3.6, $p < 0.0001$).

Metabolic data

The CONUT score correlated negatively with LDL cholesterol concentrations (–0.78, 95%CI –0.84 to –0.71, $p < 0.0001$), triglycerides (–0.24, 95%CI –0.39 to –0.08, $p < 0.01$) (Figure 1A), HDL cholesterol (–0.23, 95%CI –0.37 to –0.07, $p < 0.01$), and C peptide/leptin ratio (–0.16, 95%CI –0.31 to 0.001, $p < 0.05$) and positively with leptin (0.21, 95%CI 0.05 to 0.36, $p < 0.01$), FLI (0.23, 95%CI 0.08 to 0.38, $p < 0.01$), HOMA-B (0.17, 95%CI 0.006 to 0.32, $p < 0.05$), and REE (0.18, 95%CI 0.02 to 0.33, $p < 0.05$).

The correlations of PNI with metabolic markers were additionally studied in order to verify the results. The PNI score correlated positively with triglycerides (0.28, 95%CI 0.12 to 0.42, $p < 0.001$) and negatively with leptin levels (–0.19, 95%CI –0.34 to –0.03, $p < 0.05$) and FLI (–0.17, 95%CI –0.32 to –0.01, $p < 0.05$).

TABLE 1. Metabolic parameters in patients with T2D with or without mild malnutrition

	CONUT score 0–1 (normal nutrition status) (n = 113)	CONUT score 2–4 (mild malnutrition) (n = 48)	p value
HbA1c (%)	6.4 (5.2–12.4)	6.5 (5.1–9.7)	NS
Fasting blood glucose (mg/dL)	138 (64–297)	136 (84–267)	NS
Total cholesterol (mg/dL)	175.7 (140.0–326.5)	128.1 (91.7–200.6)	<0.0001
HDL cholesterol (mg/dL)	46.9 ± 13.0 44.5 (24.0–81.7)	43.5 ± 9.7 41.6 (27.2–66.0)	NS
Triglycerides (mg/dL)	165.7 ± 84.3 143.6 (47.7–434.9)	124.8 ± 42.3 119.8 (56.7–234.3)	<0.01
LDL cholesterol (mg/dL)	104.9 ± 30.6 99.7 (53.3–217.7)	62.7 ± 20.0 61.0 (27.5 –12.1)	<0.0001
C-peptide (ng/mL)	2.89 ± 1.34 2.67 (0.33–6.52)	3.17 ± 1.71 2.96 (0.29–7.06)	NS
HOMA-B (%)	70.5 ± 31.1	83.3 ± 38.5	<0.05
HOMA-IR	2.52 ± 1.19 2.38 (0.45–5.92)	2.65 ± 1.42 2.4 (0.43–6.06)	NS
Leptin (ng/mL)	7.3 (0.9–49.8)	10.2 (1.6–44.9)	<0.05
FLI	0.36 (0.01–3.98)	0.65 (0.04–2.88)	<0.05
C-peptide/leptin ratio	2.91 (0.40–27.11)	3.40 (0.31–20.81)	NS
REE (kcal/day)	1,052.3 ± 198.1 1,080.2 (598.4–1,673.0)	1,121.9 ± 204.1 1,111.2 (592.6–1,821.8)	<0.05

FLI – free leptin index; REE – resting energy expenditure. Data are presented as mean ± SD and/or median (min-max).

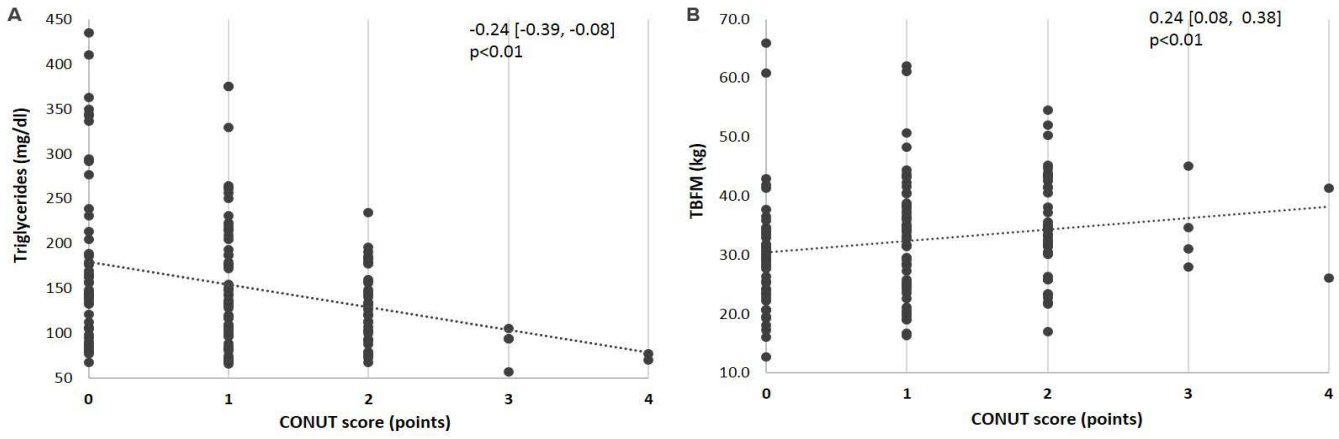

FIGURE 1. CONUT score correlations with serum triglyceride levels (**A**) and total body fat mass (TBFM) (**B**). Data is presented as r (95%CI).

There were no significant differences between the two CONUT groups with regards to fasting blood glucose, HbA1c, or HDL cholesterol levels, but triglycerides and LDL cholesterol concentrations were lower in the mild malnutrition group (124.8 ± 42.3 mg/dL vs. 165.7 ± 84.3 mg/dL, p <0.01 and 62.7 ± 20.0 mg/dL vs. 104.9 ± 30.6 mg/dL, p <0.0001, respectively) (Table 1, Figure 2A). Additionally, although there were no significant differences between C-peptide concentrations (2.89 ± 1.34 ng/mL vs. 3.17 ± 1.71 ng/mL, p: NS), patients with mild malnutrition had higher HOMA-B values, as well as higher leptin (Figure 2B) and FLI values, indicative of higher leptin resistance (Table 1). However, when C-peptide values were divided with leptin values, the difference was no longer significant (p: NS) (Table 1). The two groups presented similar insulin resistance (HOMA-IR).

Anthropometric data

The CONUT score correlated positively with weight (0.18, 95%CI 0.02 to 0.33, p <0.05), BMI (0.23, 95%CI 0.08 to 0.38, p <0.01), waist (0.26, 95%CI 0.11 to 0.41, p <0.001), hip circumference (0.23, 95%CI 0.07 to 0.37, p <0.01), %BF (0.16, 95%CI 0.004 to 0.31, p <0.05), TBFM (0.24, 95%CI 0.08 to 0.38, p <0.01) (Figure 1B), and Σ4SF (0.19, 95%CI 0.04 to 0.34, p <0.05). The PNI correlated negatively only with the hip circumference (-0.17, 95%CI –0.32 to –0.01, p <0.05).

Although the total body weight and NFM were similar between the two groups, contrary to our expectations, T2D patients with mild malnutrition had higher BMI values (34.1 ± 4.8 kg/m² vs. 32.2 ± 5.0 kg/m², p <0.01) (Figure 2C) and a higher proportion of them presented obesity

TABLE 2. Anthropometric parameters in patients with T2D with or without mild malnutrition

	CONUT score 0–1 (normal nutrition status) (n = 113)	CONUT score 2–4 (mild malnutrition) (n = 48)	p value
Weight (kg)	80.5 (55.5–136.5)	85.7 (62.0–157.0)	NS
BMI (kg/m²)	32.2 ± 5.0 31.8 (21.7–49.5)	34.2 ± 4.8 33.2 (25.8–49.6)	<0.01
Waist circumference (cm)	105.5 ± 11.1	109.8 ± 11.3	<0.05
Hip circumference (cm)	107.1 ± 9.0 106.0 (91.5–142.0)	110.4 ± 9.0 109.0 (97.0–142.0)	<0.05
WHR	0.98 ± 0.07	0.99 ± 0.06	NS
%BF	41.4 (14.1–51.6)	42.3 (22.3–47.8)	NS
TBFM (kg)	31.4 ± 9.8	34.8 ± 8.4	<0.05
NFM (kg)	47.3 (34.8–83.5)	49.5 (35.9–102.4)	NS
Σ4SF (mm)	97.1 ± 28.4	104.8 ± 22.7	NS

BMI – body mass index; WHR – waist-to-hip ratio; %BF – % body fat; TBFM – total body fat mass; NFM – non-fat mass, Σ4SF – sum of four skinfolds. Data are presented as mean ± SD and/or median (min-max).

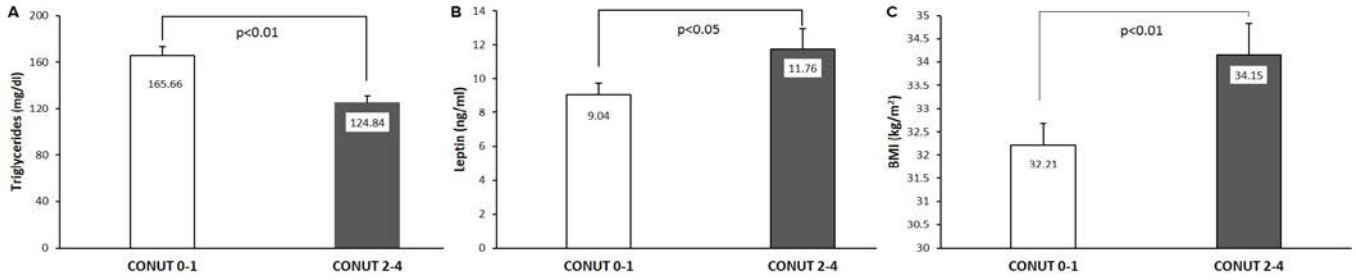

FIGURE 2. Serum triglyceride concentrations (**A**), serum leptin concentrations (**B**), and BMI (**C**) in patients with T2D with or without mild malnutrition. Data are presented as mean ± SE.

(87.5% vs. 60.2%, p <0.001). T2D patients with mild malnutrition had higher body adiposity (TBFM, waist and hip circumferences, p <0.05 for all) (Table 2).

The impact of malnutrition and obesity on metabolic and anthropometric parameters

In order to better discern the impact of obesity and malnutrition on metabolic changes, we have further divided the two CONUT groups according to the presence of obesity (BMI < or ≥30 kg/m²) and have delineated four subgroups: normal nutritional status without obesity (Group 1) or with obesity (Group 2), and mild malnutrition without obesity (Group 3) or with obesity (Group 4).

There was a significant difference in triglyceride values between the four groups (p <0.05, Table 3). Patients with obesity without malnutrition had significantly higher triglyceride concentrations than those with obesity

TABLE 3. Metabolic and anthropometric variables in T2D patients with/without obesity and with/without mild malnutrition, respectively

	Group 1 CONUT score 0–1 BMI <30 kg/m² (n = 45)	Group 2 CONUT score 0–1 BMI ≥30 kg/m² (n = 68)	Group 3 CONUT score 2–4 BMI <30 kg/m² (n = 6)	Group 4 CONUT score 2–4 BMI ≥30 kg/m² (n = 42)	p value
HbA1c (%)	6.3 (5.2–12.4)	6.5 (5.3–10.3)	6.0 (5.4–6.5)	6.5 (5.1–9.7)	NS
Fasting blood glucose (mg/dL)	138.0 (64.0–297.0)	138.5 (99.0–289.0)	128.5 (84.0–165.0)	136.0 (88.0–267.0)	NS
Triglycerides (mg/dL)	121.1 (47.7–434.8)	156.5 (65.1–375.5)*	98.4 (69.8–184.2)	120.4 (56.7–234.3)*	0.01
HDL cholesterol (mg/dL)	49.6 ± 14.4	45.1 ± 11.8	40.1 ± 7.9	44.0 ± 9.9	NS
LDL cholesterol (mg/dL)	109.4 ± 28.5$$	101.9 ± 31.8**	79.5 ± 24.8	60.5 ± 18.4$$**	<0.0001
Leptin (ng/ml)	5.1 ± 3.7 3.8 (0.9–18.4)¶¶$$	11.6 ± 7.9 10.9 (2.3–49.8)¶¶	9.2 ± 9.6 7.0 (1.6–27.5)	12.1 ± 7.9 10.4 (1.7–44.9)$$	<0.0001
FLI	0.24 ± 0.22 0.15 (0.01–1.18)¶¶$$	0.72 ± 0.6 0.58 (0.06–2.98)¶¶^	0.25 ± 0.25 0.17 (0.04–0.69)^#	0.78 ± 0.6 0.71 (0.09–2.88)$$##	<0.0001
C peptide (ng/ml)	2.39 ± 1.11¶	3.22 ± 1.39¶	3.01 ± 1.80	3.19 ± 1.73	<0.05
HOMA-B (%)	60.6 ± 26.0$$	77.0 ± 32.5	84.3 ± 21.6	83.2 ± 40.5$$	<0.01
HOMA-IR	2.08 ± 0.99¶	2.80 ± 1.23¶	2.55 ± 1.52	2.67 ± 1.43	<0.05
C peptide/leptin ratio	0.71 ± 0.53 0.60 (0.06–2.49)¶$	0.42 ± 0.33 0.28 (0.04–1.4)¶	0.53 ± 0.41 0.47 (0.09–1.21)	0.49 ± 0.68 0.29 (0.05–3.19)$	<0.01
REE (kcal/day)	913.5 ± 161.3¶¶$$	1,144.2 ± 164.4¶¶^^	895.9 ± 162.8^^##	1,154.2 ± 189.7$$##	<0.0001
Waist circumference (cm)	97.3 ± 7.0¶¶$$	110.9 ± 10.0¶¶^	97.8 ± 7.6^#	111.6 ± 10.8$$#	<0.0001
Hip circumference (cm)	100.5 ± 5.1¶¶$$	111.5 ± 8.3¶¶^	100.0 ± 3.2^#	111.9 ± 8.6$$#	<0.0001
TBFM (kg)	24.6 ± 6.2¶¶$$	35.9 ± 9.2¶¶^	25.1 ± 5.0^#	36.2 ± 7.9$$#	<0.0001
NFM (kg)	44.6 (34.8–68.2)¶	47.8 (40.2–83.5)¶	42.5 (35.9–66.6)	49.8 (39.5–102.4)	<0.01
%BF	37.9 (14.1–45.5)¶¶$$	43.1 (21.7–51.6)¶¶	40.8 (22.3–42.2)	42.6 (24.0–47.8)$$	<0.0001
Σ4SF (mm)	78.8 ± 20.6¶¶$$	109.2 ± 26.4¶¶^	82.8 ± 15.9^	107.9 ± 21.8$$	<0.0001

FLI – free leptin index; REE – resting energy expenditure; %BF – % body fat; TBFM – total body fat mass; NFM – non-fat mass; Σ4SF – sum of four skinfolds. Data are presented as mean ± SD and/or median (min-max).

* Group 2 vs. Group 4: p <0.05; ** Group 2 vs. Group 4: p <0.001; $$ Group 1 vs. Group 4: p <0.001; ¶¶ Group 1 vs. Group 2: p <0.001; ^ Group 2 vs. Group 3: p <0.05; # Group 3 vs. Group 4: p <0.05; ¶ Group 1 vs. Group 2: p <0.05; $ Group 1 vs. Group 4: p <0.01; ## Group 3 vs. Group 4: p <0.01; ^^ Group 2 vs. Group 3: p <0.01

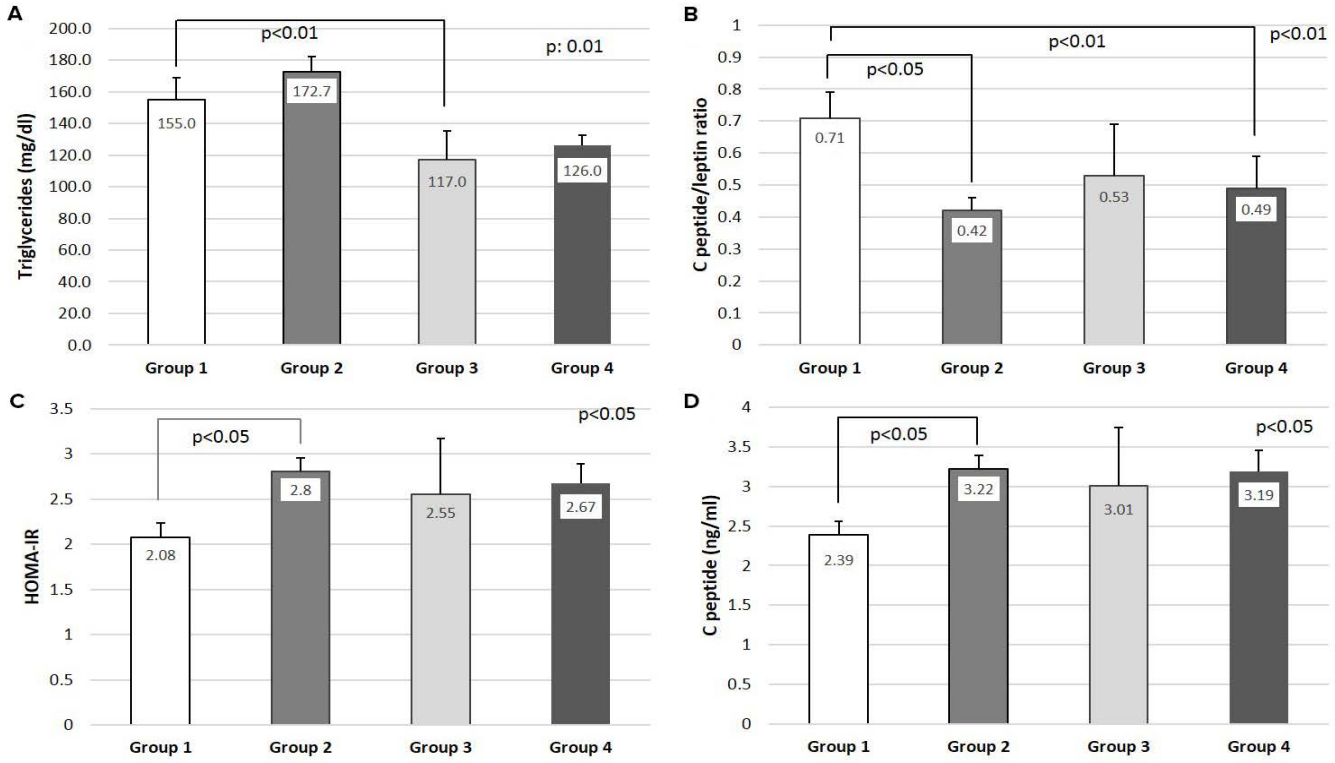

FIGURE 3. Differences in triglyceride concentrations (**A**), C-peptide/leptin ratio (**B**), HOMA-IR (**C**), and C-peptide (**D**) values in the four groups of patients with T2D: Group 1 – without malnutrition and without obesity; Group 2 – without malnutrition and with obesity; Group 3 – with mild malnutrition and without obesity; Group 4 – with mild malnutrition and with obesity. Data are presented as mean ± SE.

and mild malnutrition (mean difference: 27.26 mg/dL, p <0.05) (Figure 3A). There were also significant differences between the four groups with regards to FLI and several anthropometric parameters (Table 3), but this mostly reflected the presence of obesity. Serum leptin levels and HOMA-B were lower in T2D patients with normal nutritional status without obesity, while the C-peptide/leptin ratio was higher, the differences being significant vs. groups 2 and 4 (with obesity) (Table 3, Figure 3B). Serum C-peptide concentrations and HOMA-IR were lower in T2D patients with normal nutritional status without obesity vs. those with obesity (mean difference: –26.749 ng/mL and –0.7126, respectively, p <0.05 for both), indicating higher insulin resistance in this group (Group 2), while in patients with mild malnutrition, the respective values were higher, but no differences were noted between the groups with or without obesity (Group 3 vs. Group 4) (Table 3, Figure 3C and 3D).

DISCUSSION

This study evaluated the nutritional status of adult ambulatory patients with T2D by using the CONUT score, an index that reflects the immune function and nutritional status of the body and that has been mainly used in cardiovascular, hepatic, and oncologic diseases so far.

The first finding of this study was that about a third of outpatients with T2D have mild malnutrition. Other studies also indicated an increased prevalence of malnutrition and malnutrition risk in patients with T2D, mainly elderly inpatients.[3,16,17] The causes may be multiple. Advanced age or the presence of chronic complications, mainly diabetic nephropathy, have been shown to be associated with malnutrition.[17,18] T2D patients with diabetic nephropathy/chronic kidney disease (CKD) may follow a diet with decreased protein intake as part of their disease management and on the other hand, CKD associates with elevated protein catabolism and protein malnutrition.[19,20]

Another observation in this analysis was that malnutrition was present even in patients with obesity. Usually, malnutrition is associated with underweight/weight loss, but certain features of malnutrition can occur even in subjects with higher BMI. One of the studies mentioned above indicated that 15% of malnourished T2D patients were obese.[17] Although at first sight this might be surprising, in fact, obesity and malnutrition are not reciprocally exclu-

sive. A study in a large population of critically ill adults has demonstrated that obese patients with malnutrition had poorer outcomes than obese patients without malnutrition.[21] In fact, it has been recognized that poor diets may provide sufficient energy to meet or even exceed the needs, but may lack the quality required for an optimal health status, and may associate with subclinical nutrient deficiencies.[22] Actually, excessive body fat may hide sarcopenia and/or altered immune function and induce false clinical judgment. Moreover, obesity and diabetes may be associated with micronutrient deficiencies, such as thiamine, vitamin D, zinc, chromium etc., that play a role in glucose metabolism, insulin secretion, and signaling pathways.[23] Therefore, T2D patients with obesity should be evaluated for malnutrition as well.

We found that T2D patients with malnutrition had significantly lower triglycerides, even in the presence of obesity. Another study in elderly hypertensive subjects that used the CONUT scoring system to evaluate the nutritional status reported similar results: triglyceride concentrations decreased with malnutrition severity.[24] In both studies, patients with malnutrition also had lower LDL cholesterol levels.[24] It could be argued however, that since the CONUT score uses total cholesterol values as a parameter for scoring, the findings could be biased. In a different study that evaluated the nutritional status of patients with acute myocardial infarction by using the PNI, the authors similarly reported that patients with malnutrition had lower levels of serum triglycerides.[25] The causes are not entirely clear, but it is possible that in malnutrition there is an impairment in the body's ability to mobilize substrates, including triglycerides, and/or substrate malabsorption.

In addition, we found that patients with mild malnutrition had higher HOMA-B, serum leptin concentrations and leptin resistance, but this could be related to higher body adiposity observed in this group. In order to decipher the role of obesity, the data was further analyzed according to both malnutrition and obesity status. In T2D patients with normal nutritional status, obesity was associated with higher insulin resistance, serum C-peptide, and leptin levels, and lower C-peptide/leptin ratio. Patients with mild malnutrition had higher values of HOMA-IR, serum C-peptide, and leptin concentrations, and lower C peptide/leptin ratio, but there were no significant differences between those with and without obesity, suggesting that malnutrition per se may be associated with these changes. Animal data showed that chronic malnutrition is associated with insulin resistance, both through receptor and post-receptor defects.[26,27] There is limited data in humans in this regard.

The study had several limitations. First, it was a single center evaluation, with relatively low number of patients with mild malnutrition (mainly the subgroup without obesity). Moreover, no patient presented more severe degrees of malnutrition, which would have been helpful to better understand the metabolic changes associated with this condition. Second, it was a cross-sectional study, and the collection of prospective data would certainly add value. Third, perhaps different methods of nutritional assessment should be further employed in order to validate the results.

CONCLUSIONS

According to our results, in T2D patients, malnutrition is associated with lower triglyceride levels, even in the presence of obesity, and malnutrition and/or obesity is associated with higher HOMA-IR and serum leptin levels, and lower C peptide/leptin ratio.

CONFLICT OF INTEREST

Nothing to declare.

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