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The Role of Nutritional Status in Patients with Type 1 Diabetes Mellitus

Tip 1 Diyabetes Mellitus Hastalarında Beslenme Durumunun Rolü

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Abstract

Objective: To comprehensively evaluate nutritional status in adults with type 1 diabetes mellitus (T1DM) by assessing both the prognostic nutritional index (PNI) and the controlling nutritional status (CONUT) score and determining factors associated with malnutrition risk.

Methods: This retrospective cross-sectional study included 262 adults (132 T1DM and 130 healthy controls) who were followed at an internal medicine outpatient clinic. Demographic characteristics and routine laboratory measurements were retrieved from electronic medical records and patient files. PNI and CONUT were analyzed both as continuous and as categorical variables. Malnutrition risk, defined as CONUT ≥2, was explored using univariate and multivariate logistic regression adjusting for relevant metabolic and inflammatory parameters.

Results: Individuals with T1DM demonstrated significantly poorer nutritional profiles than controls, as reflected by lower PNI values and higher CONUT scores (both p<0.001). Severe nutritional impairment, based on PNI, was notably more frequent in T1DM, whereas optimal nutritional status was predominantly observed in controls (p<0.001). Similarly, malnutrition risk as assessed by CONUT was higher in patients with T1DM (p=0.003). In univariate analyses, both PNI and CONUT parameters were associated with compromised nutritional status. In the multivariate model, serum albumin, low-density lipoprotein cholesterol, and C-reactive protein remained independent correlates of malnutrition after adjustment.

Conclusion: Adults with T1DM exhibit substantial impairment in nutritional indices, as indicated by concordant abnormalities in both PNI and CONUT scores. Incorporating these complementary markers into routine clinical evaluations may facilitate early identification of biochemical malnutrition and support targeted nutritional and metabolic interventions.

Keywords: Type 1 diabetes mellitus, nutritional status, prognostic nutritional index

Öz

Amaç: Tip 1 diyabetes mellituslu (T1DM) erişkinlerde beslenme durumunu hem prognostik beslenme indeksi (PNI) hem de beslenme durumunu değerlendirme (CONUT) skoru üzerinden kapsamlı bir şekilde değerlendirmek ve malnütrisyon riski ile ilişkili faktörleri belirlemek.

Yöntem: Retrospektif ve kesitsel tasarıma sahip bu çalışmada, iç hastalıkları polikliniğinde izlenen 262 erişkin (132 T1DM, 130 sağlıklı kontrol) değerlendirildi. Demografik özellikler ile rutin laboratuvar ölçümleri elektronik tıbbi kayıtlar ve hasta dosyalarından elde edildi. PNI ve CONUT hem sürekli hem de kategorik değişkenler olarak analiz edildi. CONUT ≥2 ile tanımlanan malnütrisyon riski, ilgili metabolik ve inflamatuvar parametreler için yapılan uyarlamaları içeren tek değişkenli ve çok değişkenli lojistik regresyon modelleri ile incelendi.

Bulgular: T1DM'li bireylerde, kontrol grubuna kıyasla anlamlı derecede daha kötü beslenme profilleri saptandı; PNI değerleri daha düşük, CONUT skorları ise daha yüksekti (her ikisi için p<0,001). PNI'ya göre ciddi beslenme bozukluğu T1DM grubunda daha sık görülürken, optimal beslenme durumu çoğunlukla kontrol grubunda mevcuttu (p<0,001). Benzer şekilde, CONUT'a göre malnütrisyon riski T1DM'de daha yüksekti (p=0.003). Tek değişkenli analizlerde PNI ve

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Öz

CONUT parametrelerinin tümü bozulmuş beslenme durumuyla ilişkiliydi. Çok değişkenli modelde serum albümin, düşük yoğunluklu lipoprotein kolesterol ve C-reaktif protein, uyarlamalar sonrası malnütrisyonun bağımsız belirleyicileri olarak kaldı.

Sonuç: Erişkin T1DM hastalarında, hem PNI hem de CONUT skorlarındaki uyumlu bozukluklar beslenme indekslerinde belirgin bir kötüleşmeye işaret etmektedir. Bu tamamlayıcı beslenme belirteçlerinin rutin klinik değerlendirmelere entegre edilmesi, biyokimyasal malnütrisyonun erken tanımlanmasına yardımcı olabilir ve hedefe yönelik beslenme ile metabolik müdahaleleri destekleyebilir.

Anahtar Kelimeler: Tip 1 diyabetes mellitus, beslenme durumu, prognostik beslenme indeksi

Introduction

Type 1 diabetes mellitus (T1DM) is an autoimmune condition in which pancreatic β-cells are progressively destroyed by immune mechanisms, leading to a complete loss of endogenous insulin production and the need for lifelong insulin replacement. Although T1DM may occur at any age, it is most frequently diagnosed in childhood, adolescence, and early adulthood[1]. Globally, the incidence of T1DM has continued to rise over the past decade, with the most recent epidemiological reports indicating an annual increase of 3-4%, particularly in Europe and North America[1]. This rising trend highlights the increasing health burden posed by T1DM and underscores the need to improve understanding of its metabolic, inflammatory, and nutritional consequences.

Nutritional status plays a pivotal role in the clinical course and metabolic control of individuals with T1DM. Chronic hyperglycemia, increased catabolic activity, autoimmune comorbidities (e.g., celiac disease, autoimmune gastritis), dyslipidemia, and persistent low-grade inflammation may negatively influence protein synthesis, lipid regulation, intestinal absorption, and immune competence. These mechanisms can impair serum albumin concentrations, reduce lymphocyte counts, and alter cholesterol homeostasis-parameters that collectively reflect immunonutritional health[2]. Evaluating nutritional status in T1DM is therefore clinically advantageous, as early identification of biochemical malnutrition may enable individualized dietary interventions, optimization of glycemic control, reduction in susceptibility to infection, and prevention of long-term complications. Furthermore, nutritional assessment may serve as a risk-stratification tool, providing complementary prognostic information beyond traditional glycemic markers.

Conventional approaches to nutritional evaluation, including body mass index (BMI) and subjective screening tools, may overlook early biochemical deterioration. Consequently, objective laboratory-based indices such as the prognostic nutritional index (PNI) and the controlling nutritional status (CONUT) score have gained increasing prominence. PNI, which incorporates serum albumin and lymphocyte count, provides an integrated measure of protein reserves and immunologic competence. CONUT combines serum albumin, total cholesterol (TC), and total lymphocyte count, providing a broader assessment of metabolic and immune-nutritional status. Both indices are simple, reproducible, and cost-effective, relying on laboratory parameters routinely obtained in clinical practice, and are thus practical tools for screening malnutrition in metabolic diseases. Importantly, PNI and CONUT have been extensively validated across a wide range of chronic illnesses, including cardiovascular disease, chronic kidney disease, malignancies, cirrhosis, and heart failure, where they demonstrate strong associations with mortality, complications, hospitalization, and inflammation[3,4].

Despite their widespread application in chronic diseases, PNI and CONUT have been insufficiently studied in T1DM. Existing literature primarily focuses on type 2 diabetes mellitus (T2DM) or mixed diabetic cohorts, where poor PNI and elevated CONUT scores have been linked to suboptimal glycemic control, sarcopenia, microvascular complications, and increased mortality[5,6]. However, whether similar nutritional impairments occur in adults with T1DM-who often differ from T2DM patients in terms of age, body composition, autoimmune status, and metabolic profile-remains largely unexplored. To date, no study has comprehensively evaluated PNI and CONUT scores in a well-defined adult T1DM population compared with healthy controls. Thus, the lack of characterization of immunonutritional status in T1DM represents an important gap in current knowledge, with potential implications for early intervention, personalized dietary planning, and long-term risk mitigation.

Assessing PNI and CONUT in adults with T1DM may offer significant contributions to the literature for several reasons. First, identifying early biochemical malnutrition in this population-often young and without overt complications-may help anticipate future vulnerability to sarcopenia, frailty, and poor metabolic resilience. Second, given emerging evidence linking PNI and CONUT to diabetic retinopathy, nephropathy, cardiovascular disease, and mortality in broader diabetic cohorts[7,8], understanding their behavior in T1DM could inform individualized risk-stratification strategies. Determining whether albumin, cholesterol, inflammatory markers, or glycemic indicators predominantly drive nutritional impairment in T1DM could elucidate underlying pathophysiological mechanisms distinct from those in T2DM.

Therefore, the present study aimed to evaluate immunonutritional status in adults with T1DM by analyzing PNI and CONUT scores and comparing them with age-matched healthy controls. Additionally, we sought to determine the prevalence of biochemical malnutrition in T1DM, to identify laboratory predictors of CONUT-defined malnutrition risk, and to assess whether T1DM itself remains an independent determinant of nutritional impairment after adjustment for metabolic and inflammatory variables. By addressing these objectives, this study provides novel insight into the immunonutritional profile of adults with T1DM and contributes meaningful evidence to an underexplored area of diabetes research.

Materials and Methods

Study Design and Population

This retrospective cross-sectional study was conducted at the Internal Medicine outpatient clinics of University of Health Sciences Türkiye, Elazığ Fethi Sekin City Hospital between January 2023 and May 2025. A total of 262 individuals aged 18-75 years were included, comprising 132 patients diagnosed with T1DM and 130 age-matched healthy controls without any known chronic disease. The study was approved by the Non-Interventional Clinical Research Ethics Committee of University of Health Sciences Türkiye, Elazığ Fethi Sekin City Hospital (approval no: 2025/11-11, date: 12.06.2025).

Inclusion criteria: Patients aged 18-75 years with a confirmed diagnosis of T1DM based on the American Diabetes Association 2024 criteria (clinical symptoms of hyperglycemia, age <35 years at onset, random plasma glucose ≥200 mg/dL, fasting glucose ≥126 mg/dL, 2-hour oral glucose tolerance test ≥200 mg/dL, positive autoantibodies, C-peptide <0.6 ng/mL, and/or hemoglobin A1c (HbA1c) ≥6.5%)[9]. Healthy individuals aged 18-75 years with no chronic medical conditions.

Exclusion criteria: T2DM patients, gestational diabetes, acute or chronic inflammatory diseases, active infection, hematologic disorders, malignancy, use of medications affecting lipid metabolism, chronic liver or kidney disease.

Data Collection

As this was a retrospective study, no additional laboratory tests were performed. Demographic characteristics (age, sex) and laboratory data were retrieved from electronic medical records. The following parameters were recorded: leukocyte, neutrophil, lymphocyte, monocyte, and platelet counts; Hb, glucose, glycated HbA1c, urea, creatinine, aspartate aminotransferase, alanine aminotransferase (ALT), TC, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), C-reactive protein (CRP), and serum albumin.

Nutritional Indices

PNI was calculated as: PNI =albumin(g/L)+5×lymphocyte count (10^9/L)[7-8]. PNI was evaluated both as a continuous variable and in three categories: PNI <45=severe impairment, 45-49.9=moderate risk ≥50=good nutritional status[7,8].

The CONUT score was determined using serum albumin, TC, and total lymphocyte counts. Each parameter is assigned a specific score. A serum albumin level of ≥3.5 g/dL receives 0 points; levels between 3.0 and 3.4 g/dL receive 2 points; levels between 2.5 and 2.9 g/dL receive 4 points; and values below 2.5 g/dL are assigned 6 points. For TC, a level of ≥180 mg/dL is scored as 0 points; 140-179 mg/dL as 1 point; 100-139 mg/dL as 2 points; and <100 mg/dL as 3 points. For the total lymphocyte count, ≥1600 cells/µL corresponds to 0 points; 1200-1599 cells/µL to 1 point; 800-1199 cells/µL to 2 points; and <800 cells/µL to 3 points (Table 1)[7,8]. The sum of these three components provides an overall indication of nutritional status. Malnutrition risk was defined as CONUT ≥2[7,8].

Statistical Analysis

All statistical analyses were performed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as mean ± standard deviation and categorical variables as numbers and percentages. Normality of distribution was assessed using the Kolmogorov-Smirnov test. Group comparisons were conducted as follows: independent samples t-test: for normally distributed continuous variables, chi-square test: for categorical variables (e.g., PNI categories, CONUT ≥2).

Nutritional indices (PNI and CONUT) were compared between groups both as continuous and categorical variables.

Malnutrition risk (CONUT ≥2) was further evaluated using: univariate logistic regression to identify crude associations, multivariate logistic regression including variables significant in univariate analysis (T1DM status, albumin, LDL-C) odds ratios (ORs) and 95% confidence intervals were reported.

Results

A total of 262 participants were included in the study, comprising 132 individuals with T1DM and 130 healthy controls. Age and sex distributions were comparable between the groups (p>0.05) (Table 2).

Regarding hematologic parameters, including leukocyte, neutrophil, lymphocyte, platelet, and Hb values, no significant differences were observed between the groups (p>0.05). Glucose and HbA1c levels were markedly elevated in the T1DM group (both p<0.001). Urea levels were significantly higher among patients with T1DM (p=0.004), while creatinine

Table 1. CONUT score calculation

Variables	Undernutrition status			
	Normal	Light	Moderate	Severe
Albumin (g/dL)	≥3.5	3.0-3.49	2.5-2.9	<2.5
Points	0	2	4	6
Total lymphocyte count (/mm^3)	>1,600	1.200-1.599	800-1.199	<800
Points	0	1	2	3
Total cholesterol (mg/dL)	>180	140-180	100-139	<100
Points	0	1	2	3
Total CONUT score	0-1	2-4	5-8	9-12

CONUT: Controlling nutritional status

Table 2. Demographic, hematologic, and biochemical characteristics of the study population

Parameter	T1DM (n=132)	Control (n=130)	p-value
Age (years)	26.93±7.26	27.58±5.69	0.424
Male sex, n (%)	64 (48.5)	61 (46.9)	0.897
Leukocyte (10^3/μL)	7389.02±1820.30	7413.08±1592.10	0.909
Neutrophil (10^3/μL)	4360.76±1547.48	4390.08±1290.03	0.868
Lymphocyte (10^3/μL)	2287.58±710.50	2228.77±563.62	0.458
Platelet (10^3/μL)	284219.70±72220.43	268369.23±69260.90	0.071
Hemoglobin (g/dL)	13.86±1.84	14.08±1.54	0.297
Glucose (mg/dL)	231.44±120.70	87.45±8.70	**<0.001**
HbA1c (%)	9.28±2.12	5.23±0.25	**<0.001**
Urea (mg/dL)	27.64±16.90	23.09±6.51	**0.004**
Creatinine (mg/dL)	0.83±1.17	0.80±1.44	0.819
AST (U/L)	20.30±8.83	21.32±6.91	0.298
ALT (U/L)	18.53±11.13	23.54±17.38	**0.006**
Triglyceride (mg/dL)	135.81±112.51	110.02±66.27	**0.025**
LDL-C (mg/dL)	107.98±35.26	92.64±24.67	**<0.001**
HDL-C (mg/dL)	52.32±12.61	49.62±10.21	0.058
Total cholesterol (mg/dL)	184.37±44.93	164.49±30.64	**<0.001**
CRP (mg/L)	3.70±2.81	2.45±2.13	**<0.001**
Albumin (g/L)	37.58±6.85	42.00±3.55	**<0.001**

Continuous variables are presented as mean±standard deviation and were compared using the independent samples t-test. Categorical variables were compared using the chi-square test. A p-value <0.05 was considered statistically significant

T1DM: Type 1 diabetes mellitus, HbA1c: Hemoglobin A1c, AST: Aspartate aminotransferase, ALT: Alanine aminotransferase, LDL-C: Low-density lipoprotein cholesterol, HDL-C: High-density lipoprotein cholesterol, CRP: C-reactive protein levels did not differ between groups. ALT levels were significantly higher in the control group (p=0.006; Table 2).

In the lipid profile, TG levels, LDL-C levels, and TC levels were significantly higher in the T1DM group (p<0.05 for all), whereas HDL-C levels showed no significant difference (p=0.058). CRP levels were markedly elevated in the T1DM group (p<0.001). Albumin levels were lower in patients with T1DM than in controls (p<0.001) (Table 2).

Nutritional indices showed significant differences between the groups: PNI values were lower, and CONUT scores were higher in the T1DM group (both p<0.001) (Table 3). In categorical PNI analysis, severe nutritional impairment (PNI <45) was notably more common in T1DM patients (36.4%) compared with controls (5.4%), whereas optimal nutritional status (PNI ≥50) was more prevalent in controls (77.7%) (p<0.001) (Table 4, Figure 1).

Based on CONUT ≥2, malnutrition risk was significantly higher in the T1DM group (54.5%) than in controls (35.4%) (p=0.003) (Table 5, Figure 1).

Table 3. Comparison of nutritional indices between groups

Parameter	T1DM (n=132)	Control (n=130)	p-value
PNI	49.01±7.61	53.14±4.80	**<0.001**
CONUT	2.04±1.81	1.22±0.92	**<0.001**

Continuous variables are presented as mean±standard deviation. Groups were compared using the independent samples t-test
T1DM: Type 1 diabetes mellitus, PNI: Prognostic nutritional index, CONUT: Controlling nutritional status

Table 4. Distribution of PNI categories in T1DM and control groups

Group	PNI <45	PNI 45-49.9	PNI ≥50	p-value
Control	7 (5.4%)	22 (16.9%)	101 (77.7%)	
T1DM	48 (36.4%)	20 (15.2%)	64 (48.5%)	**<0.001**

Group comparisons were performed using the chi-square test. PNI<45=severe nutritional impairment; PNI 45-49.9=moderate nutritional risk, PNI≥50=good nutritional status, T1DM: Type 1 diabetes mellitus, PNI: Prognostic nutritional index

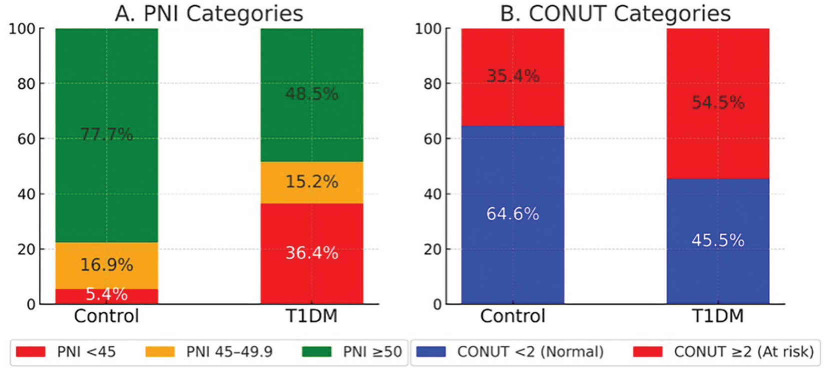

Figure 1. Distribution of nutritional status based on PNI and CONUT in adults with T1DM and controls

Panel A (PNI categories): stacked bar chart showing the distribution of PNI categories in the control and T1DM groups. Nutritional status is classified as PNI <45 (red; severe impairment), PNI 45-49.9 (orange; moderate impairment), and PNI ≥50 (green; optimal nutritional status). Controls predominantly exhibited optimal PNI values (77.7%), whereas individuals with T1DM showed markedly higher proportions of severe (36.4%) and moderate (15.2%) nutritional impairment. Panel B (CONUT categories): stacked bar chart illustrating CONUT categories. CONUT <2 (blue) indicates normal nutritional status, while CONUT ≥2 (red) reflects malnutrition risk. The T1DM group demonstrated a substantially higher prevalence of risk of malnutrition (54.5%) compared with controls (35.4%), whereas normal nutritional status was more common among controls (64.6%). Both panels highlight that adults with T1DM exhibit a significantly altered nutritional profile compared with healthy controls, consistent with group-level differences observed in PNI and CONUT scoring. Percentages displayed on each bar represent the proportion of participants within each category

PNI: Prognostic nutritional index, CONUT: Controlling nutritional status, T1DM: Type 1 diabetes mellitus

In univariate logistic regression analysis, T1DM status was significantly associated with malnutrition risk (OR=2.19; p=0.002). Albumin, LDL-C, and CRP were all significantly related to CONUT ≥2 in univariate analyses. In the multivariate model, albumin (adjusted OR=0.75; p<0.001), LDL-C (adjusted OR=0.96; p<0.001), and CRP (adjusted OR=1.05; p=0.026) remained independent predictors of malnutrition risk, whereas the association between T1DM and malnutrition risk became non-significant (p=0.139) (Table 6, Figure 2).

Table 5. Malnutrition risk based on CONUT ≥2

Group	CONUT <2 (normal)	CONUT ≥2 (at risk)	p-value
Control	84 (64.6%)	46 (35.4%)	
T1DM	60 (45.5%)	72 (54.5%)	**0.003**

OR=2.19, 95% CI: 1.33-3.60 interpretation: T1DM patients have approximately 2.2-fold higher odds of malnutrition compared with healthy controls. Group comparisons were made using the chi-square test.

CONUT <2=normal nutritional status; CONUT ≥2=at risk of malnutrition, T1DM: Type 1 diabetes mellitus, CONUT: Controlling nutritional status, OR: Odds ratio, CI: Confidence interval

Table 6. Logistic regression analysis for CONUT ≥2

Variable	Univariate OR (95% CI)	p-value	Multivariate OR (95% CI)	p-value
T1DM (vs. control)	2.19 (1.33-3.60)	0.002	1.67 (0.85-3.28)	0.139
LDL-C (per 1 mg/dL)	0.98 (0.97-0.99)	<0.001	0.96 (0.95-0.98)	**<0.001**
Albumin (per 1 g/L)	0.80 (0.75-0.85)	<0.001	0.75 (0.69-0.81)	**<0.001**
CRP (mg/L)	1.08 (1.03-1.14)	0.006	1.05 (1.01-1.11)	0.026

Univariate and multivariate logistic regression analysis for predictors of malnutrition risk (defined as CONUT ≥2). Odds ratios (ORs) with 95% confidence intervals (CIs) are reported. Variables with p<0.05 in univariate analysis were included in the multivariate model. OR <1 indicates an inverse association with malnutrition risk; OR >1 indicates increased odds of malnutrition risk. OR: Odds ratio, CI: Confidence interval, CONUT: Controlling nutritional status score, T1DM: Type 1 diabetes mellitus, LDL-C: Low-density lipoprotein cholesterol

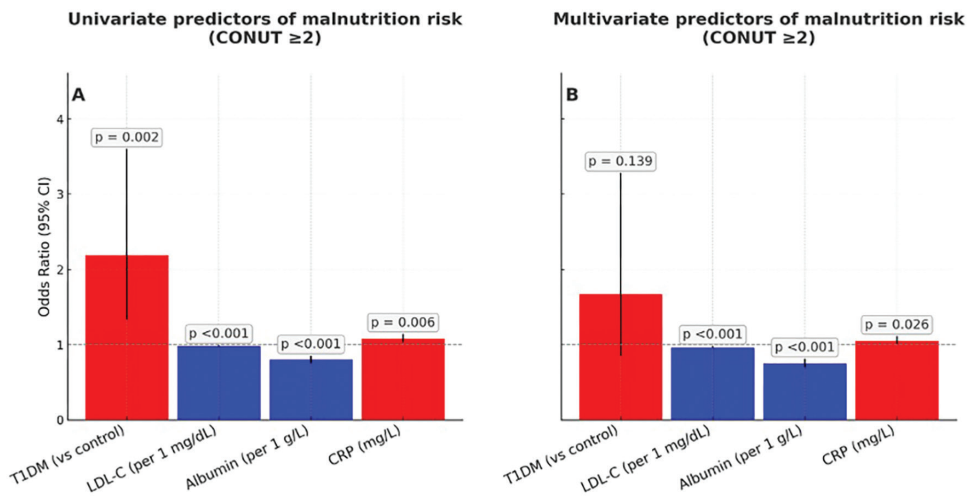

Figure 2. Univariate and multivariate logistic regression results for predictors of malnutrition risk (CONUT ≥2)

Panel A and Panel B display the univariate and multivariate logistic regression analyses evaluating predictors of malnutrition risk (defined as CONUT ≥2). Bars indicate odds ratios, and error bars represent 95% CIs; the dashed line denotes OR=1. Red and blue are used only to visually distinguish variables with ORs above or below 1. In the univariate model (Panel A), T1DM, lower LDL-C, lower albumin, and higher CRP were significantly associated with malnutrition risk. In the multivariate model (Panel B), albumin, LDL-C, and CRP remained independent predictors, whereas T1DM was no longer statistically significant

CONUT: Controlling nutritional status, OR: Odds ratio, CI: Confidence interval, T1DM: Type 1 diabetes mellitus, CRP: C-reactive protein

Discussion

In this retrospective case-control study, we evaluated objective immunonutritional indices (PNI and CONUT) in adults with T1DM and found that these adults exhibited significantly lower PNI and higher CONUT scores than age-matched healthy controls. These findings indicate that biochemical malnutrition is common, even among relatively young adults with T1DM. Our results complement growing evidence suggesting that nutritional disturbances-particularly those affecting albumin, lymphocyte count and lipid metabolism-are increasingly recognized as clinically relevant components of the metabolic and inflammatory milieu of T1DM.

Data on objective laboratory-based malnutrition indices in T1DM are sparse. Most recent work has focused either on dietary intake or on body-composition-derived measures, such as sarcopenia. A recent systematic review of older adults with T1DM reported that nutritional status and dietary intake are often suboptimal in this population, highlighting persistent nutrition-related challenges despite advances in diabetes care[10]. Similarly, a 2025 systematic review found that sarcopenia was associated with T1DM, with inflammation, poor glycemic control and reduced physical activity as major contributors[11]. Our observation that more than one-third of T1DM patients had PNI <45 and more than half had CONUT ≥2 is consistent with these reports and indicates that biochemical markers capture a substantial burden of malnutrition that may not be apparent from BMI alone.

Most studies using PNI and CONUT in diabetes have been conducted in T2DM or mixed diabetic cohorts. Piersa et al.[12] evaluated PNI and CONUT in adults with T2DM and showed that a substantial proportion of patients met malnutrition criteria, and that lower PNI and higher CONUT scores were significantly associated with poorer glycemic control and a higher burden of comorbidities. In a large cardiology cohort of patients with type 2 diabetes and angiographically confirmed coronary artery disease, malnutrition defined by the CONUT score was highly prevalent (over half of patients), and poorer nutritional status was independently associated with increased long-term all-cause mortality and adverse cardiovascular outcomes[13]. Our prevalence estimates in T1DM (54.5% with CONUT ≥2) are somewhat higher than those reported in T2DM and mixed diabetic populations[12,13]. This discrepancy may have several explanations: (I) our T1DM cohort being hospital-based and likely enriched for patients with suboptimal control; (II) autoimmune T1DM being frequently accompanied by concomitant autoimmune thyroid disease, celiac disease, or gastritis, which can negatively affect nutritional status; and (III) differences in age structure and duration of diabetes between studies. Nonetheless, the direction of effect-a shift towards poorer nutritional indices in diabetes compared with non-diabetic controls-is consistent across studies.

While our study identified albumin and LDL-C as key predictors of CONUT-defined malnutrition, other investigators have emphasized BMI, skeletal muscle mass and functional measures as predominant determinants of nutritional indices in diabetes[14]. We lacked body composition data or detailed dietary assessments, which may have limited our ability to identify sarcopenic or cachectic phenotypes. Consequently, our findings should be interpreted as primarily reflecting the biochemical rather than the functional dimension of malnutrition.

Recent narrative and systematic reviews have highlighted the tight interplay between diabetes, malnutrition and sarcopenia, emphasizing that chronic hyperglycemia, low-grade inflammation, and hormonal changes accelerate muscle catabolism and worsen functional outcomes[14,15]. Our finding of lower albumin and PNI in T1DM is in line with this concept of a "diabetes-malnutrition-sarcopenia" axis. Although we did not directly assess muscle mass or function, the presence of biochemical malnutrition in a relatively young cohort may herald subsequent sarcopenia and frailty if left unaddressed. Growing evidence indicates that PNI and CONUT are not only markers of nutritional status but also predictors of micro- and macrovascular complications in diabetes. In a large T2DM cohort, lower PNI independently predicted all-cause and cardiovascular mortality[16]. PNI has also been associated with diabetic nephropathy[17], diabetic peripheral neuropathy[18] and diabetic retinopathy[19]. Likewise, higher CONUT scores have been linked to diabetic retinopathy[20] and diabetic kidney disease, with some reports suggesting sex-specific differences, particularly stronger associations in women[20].

Our study did not specifically evaluate microvascular complications or long-term outcomes; however, the degree of PNI and CONUT impairment we observed in T1DM is similar to or worse than that reported in these complication-focused cohorts[21]. This suggests that even in the absence of overt complications, many adults with T1DM may already be on an unfavorable immunonutritional trajectory. From a pathophysiological perspective, the same composite deficits-hypoalbuminemia, lymphopenia, and dyslipidemia-that lower PNI or raise CONUT may also promote endothelial dysfunction, oxidative stress, and impaired tissue repair, thereby predisposing to microvascular injury.

The biological plausibility of our findings is supported by recent work linking PNI and CONUT with systemic inflammation. PNI integrates serum albumin with lymphocyte count; both components are influenced by chronic inflammatory activity. Large observational studies have shown that lower PNI predicts adverse outcomes in infectious conditions[22,23]. Similarly, the CONUT score is now recognized as a practical immunonutritional screening tool in hospitalized patients, with higher scores consistently associated with complication and mortality risk[24,25].

In our cohort, CRP levels were higher in T1DM than in controls, paralleling lower albumin and PNI and higher CONUT. This mirrors data from broader diabetic and cardiovascular populations where composite indices that combine nutritional parameters-such as the HbA1c or hybrid scores incorporating PNI-have been shown to outperform single markers in risk prediction[26]. While we did not test such composite indices, our data support the notion that immunonutritional derangements reflect the convergence of poor metabolic control, chronic inflammation, and catabolic stress in T1DM.

Notably, after adjustment, serum albumin and LDL-C-but not T1DM status per se-remained independent predictors of CONUT-defined malnutrition risk. This suggests that within a mixed diabetic/non-diabetic population, the biochemical expression of malnutrition is more strongly driven by direct nutritional and metabolic parameters than by the diagnostic label of diabetes itself.

Previous studies in heterogeneous diabetic cohorts have identified older age, low BMI, reduced energy and protein intake, longer diabetes duration, and comorbid conditions as key determinants of malnutrition[14]. Very few studies have specifically examined LDL-C as an independent covariate. In T2DM, some authors reported that higher CONUT scores coincide with lower TC and LDL-C, reflecting a catabolic or inflammatory state rather than classical atherogenic dyslipidemia[24,25]. Our finding of an inverse association between LDL-C and CONUT is consistent with these observations and highlights the dual role of cholesterol as both a cardiovascular risk factor and a surrogate marker of nutritional reserves. Aggressive statin use is less common in young adults with T1DM than in older adults with T2DM; therefore, lower LDL-C in the malnourished subgroup is unlikely to be driven solely by lipid-lowering therapy and may instead reflect reduced dietary intake, malabsorption, or chronic disease-related catabolism.

The loss of statistical significance for the "T1DM vs. control" variable in our multivariable model aligns with the growing evidence that the prognostic impact of diabetes is often mediated through deterioration in immunonutritional status, rather than acting as an entirely independent risk factor. Recent analyses in diabetic and prediabetic cardiovascular cohorts have demonstrated that low PNI strongly predicts all-cause and cardiovascular mortality, underscoring the central role of immunonutrition in shaping long-term outcomes[27]. Similarly, studies comparing T1DM and T2DM patients undergoing dialysis show that poorer nutritional profiles substantially modify clinical risk, further supporting the concept that diabetes-related adverse outcomes may, at least in part, reflect downstream nutritional and inflammatory disturbances rather than the binary presence of diabetes alone[28]. Accordingly, once key biochemical components of nutritional status, such as albumin and LDL-C, are included in our model, the incremental contribution of the diabetes label diminishes, without implying that T1DM itself lacks prognostic relevance.

Certain aspects of our results differ from some reports in the literature and merit discussion. While many T2DM studies have noted strong associations between higher CONUT scores and the presence or severity of specific complications-such as retinopathy, nephropathy or diabetic kidney disease[29,30]-we did not include complication data in our analysis. As a result, we cannot test whether similar relationships hold in T1DM. The absence of outcome data might give the impression that CONUT is less informative in T1DM; however, this is likely a limitation of our design rather than a true biological difference.

Mechanistic reviews have shown that lipid abnormalities in T1DM are shaped by complex interactions involving insulin deficiency, hepatic lipid handling, and inflammatory pathways, indicating that dyslipidemia in T1DM differs qualitatively from that observed in T2DM[31]. These discrepancies may stem from differences in statin use, diet, physical activity, regional dietary patterns, and healthcare access. Regional dietary habits, genetic background, and socioeconomic factors may influence albumin and cholesterol levels in Turkish adults with T1DM, warranting careful interpretation of PNI and CONUT thresholds. In our study, the T1DM group had higher TG, LDL-C, and TC levels than the controls. Our cohort represents routine clinical practice at a single center and may include patients with suboptimal adherence or limited access to lipid-lowering therapy, which could accentuate the association between dyslipidemia, malnutrition, and inflammation.

Clinical Implications and Future Directions

Despite these limitations, our study has several important clinical implications. First, it demonstrates that simple, routinely available laboratory parameters-albumin, lymphocyte count, and TC-can be combined into indices that detect a high burden of malnutrition in adults with T1DM, even when BMI may appear normal. Given emerging data linking PNI and CONUT with diabetic complications and mortality, early identification of at-risk individuals using these tools may allow timely nutritional interventions, optimization of glycemic control, and more intensive cardiovascular risk management.

Second, our results support the integration of immunonutritional screening into routine diabetes care and suggest that T1DM should not be viewed solely through the lens of glucose metrics. Comprehensive assessment of diet quality, protein intake, body composition, and functional status should accompany biochemical indices to provide a multidimensional picture of nutritional health. Interventional trials are now needed to test whether targeted nutritional support in patients with T1DM who have low PNI or high CONUT can reduce incident sarcopenia, improve quality of life, and mitigate microvascular or cardiovascular complications.

Finally, multicenter prospective cohorts with longer follow-up and detailed characterization of both T1DM and T2DM populations are required to clarify whether the prognostic thresholds for PNI and CONUT should differ by diabetes type, age, sex, or comorbidity profile. The development of composite indices that integrate nutritional markers may provide an additional avenue for refining risk-stratification in clinical practice.

Study Limitations

The strengths of our study include the focus on a relatively understudied population (adults with T1DM), the use of two complementary, widely validated nutritional indices (PNI and CONUT), and the inclusion of a contemporaneous healthy control group.

Nonetheless, several limitations must be acknowledged: a retrospective, single-center design; lack of detailed data on diabetes duration, insulin dose, BMI, body composition, and dietary intake (calorie and protein); and absence of information on microvascular complications (retinopathy, neuropathy, nephropathy) and macrovascular complications.

Additionally, urinary protein excretion (e.g., albuminuria or proteinuria) was not systematically recorded due to the retrospective design of the study. Although patients with clinically diagnosed chronic kidney disease were excluded, we cannot fully exclude the possibility that unrecognized proteinuria may have contributed to lower serum albumin levels in some individuals with T1DM. Therefore, albumin-based nutritional indices should be interpreted with this limitation in mind. Prospective studies incorporating quantitative measurements of proteinuria are warranted to further refine albumin-based nutritional assessment in T1DM.

Conclusion

In summary, our findings demonstrate that adults with T1DM exhibit significantly poorer immunonutritional profiles-reflected by lower PNI and higher CONUT scores-than healthy controls and have a high prevalence of biochemical malnutrition. These results align with and extend emerging evidence that malnutrition and inflammation are integral components of the diabetic phenotype and may contribute to adverse outcomes. Further prospective studies are warranted to determine whether routine screening and targeted correction of nutritional deficits in T1DM can improve long-term prognosis.

Ethics

Ethics Committee Approval: The study was approved by the Non-Interventional Clinical Research Ethics Committee of University of Health Sciences Türkiye, Elazığ Fethi Sekin City Hospital (approval no: 2025/11-11, date: 12.06.2025).

Informed Consent: Retrospective cross-sectional study.

Footnotes

Authorship Contributions

Surgical and Medical Practises: A.B., Concept: A.B., Design: A.B., T.T.Y., Data Collection or Processing: A.B., T.T.Y., Analysis or Interpretation: A.B., T.T.Y., Literature Search: A.B., T.T.Y., Writing: A.B.

Conflict of Interest: No conflict of interest was declared by the authors.

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