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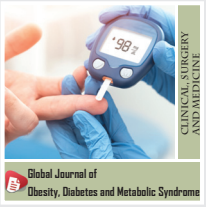

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Research Article

Neutrophil-to-Lymphocyte Ratio and Selected Hematological Parameters in Adults with Diabetes Mellitus: A Case-Control Study in Gezira State, Sudan

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Keywords: Diabetes mellitus; Neutrophil-to-lymphocyte ratio; NLR; Absolute neutrophil count; Inflammation; Complete blood count; Sudan

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Abstract

Background: Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia and a low-grade inflammatory state. The Neutrophil-to-Lymphocyte Ratio (NLR), calculated from routine complete blood count parameters, is an inexpensive and readily available inflammatory index that has been investigated as a marker of disease severity and complications.

Objective: To compare NLR and selected hematological parameters between adults with diabetes mellitus and healthy controls, and to examine the relationship of NLR with demographic characteristics, metabolic parameters, and hematological indices in Gezira State, Sudan.

Methods: A case–control study was conducted at Abo Aglaa Diabetic Center, Gezira State, Sudan, from April to September 2025. One hundred adults were enrolled, including 50 patients with diabetes mellitus (cases) and 50 apparently healthy controls. Three milliliters of venous blood were collected into EDTA tubes and analyzed for complete blood count using a Sysmex XP-300 automated hematology analyzer. Absolute Neutrophil Count (ANC), Absolute Lymphocyte Count (ALC), and NLR were obtained, and demographic and clinical information was collected using a structured questionnaire. All variables were analyzed as continuous measurements (age was recorded in categories and analyzed as an ordinal variable). Normality was assessed with the Shapiro–Wilk test; because at least one study group showed evidence of non-normality for each analyzed variable, non-parametric methods were used, and groups were compared using the Mann–Whitney U test (two groups) or the Kruskal–Wallis test (more than two groups), and associations were assessed using Spearman correlation. A two-sided $p<0.05$ was considered significant.

Results: Median ANC (3.74 vs 2.66 $\times 10^3/\mu L$, $p=0.003$) and ALC (2.84 vs 2.24 $\times 10^3/\mu L$, $p=0.009$) were higher in diabetic patients than in controls; however, these differences were confined to the 11 patients with type 1 diabetes and were not present when type 2 patients (n=39) were compared with controls ($p=0.194$ and $p=0.406$). NLR did not differ between diabetic patients and controls (median 1.15 [IQR 0.90–1.48] vs 1.12 [0.90–1.68]; U=1274.0, $p=0.871$). NLR was higher in participants with reported obesity than in those without (median 1.30 vs 1.10, $p=0.015$) but was not associated with age group ($p=0.445$), sex ($p=0.487$), education level ($p=0.639$), or chronic disease status ($p=0.909$). NLR was not correlated with fasting blood glucose, random blood sugar, or HbA1c in the total sample or in diabetic patients (all $p>0.05$). NLR correlated positively with ANC in the total sample ($\rho=0.487$, $p<0.001$) and in diabetic patients ($\rho=0.464$, $p<0.001$) and negatively with ALC in the total sample ($\rho=-0.456$, $p<0.001$).

Conclusion: NLR did not differ significantly between adults with diabetes and healthy controls, and it was not correlated with glycemic indices. Higher ANC and ALC in diabetic patients appeared to be driven by the small type 1 subgroup (n=11), whose values require verification. NLR may therefore be considered a supportive inflammatory marker rather than a standalone indicator of diabetes status or glycemic control in clinically stable patients. Larger studies including patients with different stages of disease and complications are warranted.

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Abbreviations

ALC: Absolute Lymphocyte Count; ANC: Absolute Neutrophil Count; CBC: Complete Blood Count; DM: Diabetes Mellitus; FBG: Fasting Blood Glucose; HbA1c: Glycated Hemoglobin; IQR: Interquartile Range; NLR: Neutrophil-to-Lymphocyte Ratio; RBS: Random Blood Sugar; SD: Standard Deviation; SPSS: Statistical Package for the Social Sciences; WBC: White Blood Cell Count

Introduction

Diabetes Mellitus (DM) is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from impaired insulin secretion, impaired insulin action, or both. Type 1 and type 2 diabetes are the major clinical forms, with type 2 diabetes accounting for most cases. Chronic hyperglycemia is associated with progressive dysfunction and damage involving multiple organs and contributes to both microvascular and macrovascular complications [1-3].

The pathophysiology of diabetes involves complex interactions between insulin resistance, β-cell dysfunction, metabolic abnormalities, obesity, and inflammatory processes. In type 2 diabetes, insulin resistance and β-cell dysfunction contribute to persistent hyperglycemia, while obesity is an important metabolic risk factor [2,3]. Diabetes and its cardiovascular comorbidities are also a recognized health burden in Sudan [4,5].

Diagnosis and monitoring of diabetes rely on established biochemical measurements, including fasting plasma glucose, oral glucose tolerance testing, and glycated hemoglobin (HbA1c) [6]. Although these tests are central to metabolic assessment, hematological indices may provide additional information about systemic inflammatory activity.

Inflammation is an important component of diabetes and its complications. White blood cell count and its differential components are accessible laboratory parameters that may reflect inflammatory activity. The Neutrophil-to-Lymphocyte Ratio (NLR), calculated by dividing the absolute neutrophil count by the absolute lymphocyte count, integrates two components of the immune response and has been investigated in several inflammatory and metabolic conditions, including gestational diabetes [7-9].

Previous studies have reported associations between increased NLR and diabetic complications, including peripheral neuropathy, cardiovascular disease, diabetic kidney disease, and other adverse clinical outcomes [7,10-13]. However, findings have not been uniform, and NLR may vary according to disease duration, metabolic control, complications, age, obesity, and other population characteristics [10,11]. Data from Sudanese populations are scarce. This study therefore compared NLR and selected hematological parameters between adults with diabetes and healthy controls in Gezira State and examined the relationship of NLR with demographic characteristics, metabolic parameters, and leukocyte indices.

Materials and methods

Study design

A case–control study was conducted to determine NLR and selected hematological parameters in patients with diabetes mellitus compared with apparently healthy controls.

Study area and duration

The study was conducted at Abo Aglaa Diabetic Center, Wad Medani, Gezira State, Sudan, from April to September 2025.

Study population

The study included adults of both genders. The case group consisted of patients previously diagnosed with diabetes mellitus. The control group consisted of apparently healthy adults attending the study center who met the following criteria: age ≥18 years, no prior diagnosis of diabetes mellitus, normal fasting blood glucose and/or HbA1c according to local laboratory reference ranges, no significant chronic diseases (such as cardiovascular, renal, hepatic, immune, or malignant disorders), no acute infection or active inflammation within the previous two weeks, and no use of medications known to affect complete blood count (including systemic corticosteroids, chemotherapy, or immunosuppressive agents) within the previous month. All controls provided written informed consent.

Inclusion criteria

Inclusion criteria for both cases and controls were age ≥18 years, either gender, and provision of written informed consent. For the case group, inclusion additionally required a confirmed diagnosis of diabetes mellitus (type 1 or type 2) and regular follow-up at the diabetes centre.

Exclusion criteria

Exclusion criteria for both groups were: age <18 years, active infection or inflammation at the time of sampling, receiving antibiotic therapy at the time of sampling, known hematological disorders (such as hemolytic anemia, leukemia, bone marrow disorders, thalassemia major), systemic corticosteroid use within the previous month, chemotherapy or radiotherapy within the previous six months, active autoimmune diseases, active malignancy, advanced renal or hepatic failure, pregnancy or lactation, gestational diabetes only, and refusal to participate.

Individuals were additionally excluded from the control group if they had a prior diagnosis of diabetes or elevated FBG/HbA1c, or recent use of medications affecting CBC.

Sample size and sampling

A total of 100 participants were included: 50 diabetic patients (cases) and 50 apparently healthy controls.

Data collection

Demographic and clinical information was collected using a structured questionnaire. The questionnaire included age

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(recorded in age categories), gender, education level, reported obesity status (yes/no), chronic disease history, diabetes-related information, treatment and follow-up, current clinical manifestations, infection/inflammation, complications, and relevant laboratory parameters. Body mass index was not recorded. Obesity was recorded as a yes/no questionnaire item without BMI, measured weight and height, or an operational definition; it is therefore referred to as "reported obesity status" throughout.

Specimen collection and preparation

Under standard laboratory safety and quality-control procedures, 3 mL of venous blood was collected by venipuncture into an EDTA anticoagulant tube. The tube was gently inverted three times to ensure adequate mixing and was appropriately labeled. Samples were analyzed within two hours of collection [14].

Hematological analysis

Complete blood count analysis was performed using a calibrated Sysmex XP-300 automated hematology analyzer after commercial quality-control materials had been run according to the manufacturer's instructions. Samples were inspected for visible clots, and clotted samples were excluded. The analyzer uses the DC resistance principle for hematological measurement [15].

Calculation of hematological indices

Absolute Neutrophil Count (ANC) was calculated as WBC × relative neutrophil count ÷ 100. Absolute Lymphocyte Count (ALC) was calculated as WBC × relative lymphocyte count ÷ 100. NLR was calculated as ANC ÷ ALC. The NLR values recorded in the study database were used for analysis; recalculation as ANC ÷ ALC was performed as a sensitivity analysis. One implausible ALC value (131 $\times 10^3/\mu L$) was considered a probable data-entry or recording error; this participant was retained in all analyses not involving ALC and excluded only from ALC-related analyses.

Quality control

Commercial quality-control materials were run daily, proper mixing of blood samples was ensured, and routine analyzer maintenance and calibration were performed according to standard laboratory procedures.

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS), version 20, and cross-checked using Python (SciPy). All continuous variables (ANC, ALC, NLR, fasting blood glucose, random blood sugar, and HbA1c) were analyzed as continuous measurements and were not divided into intervals. Age was recorded only in categories (<30, 30–45, 45–60, and ≥60 years) and was therefore analyzed as an ordinal variable (coded 1–4). The distribution of each variable was assessed separately in each group using the Shapiro–Wilk test, supplemented by inspection of histograms and Q–Q plots; $p<0.05$ indicated non-normal distribution. Variables are presented as mean ± standard deviation when normally distributed and as median (interquartile range, IQR) otherwise. An exploratory descriptive threshold of NLR >2.0 was also examined.

Comparisons between two independent groups (diabetic patients vs controls, sex, and reported obesity status) used the independent-samples t-test for normally distributed data or the Mann–Whitney U test otherwise. Comparisons across more than two groups (education level, chronic disease status, and age group) used one-way ANOVA or, when normality was not satisfied, the Kruskal–Wallis test. Education was analyzed in three groups (basic, secondary, university/postgraduate; the single postgraduate participant was merged with the university group) and chronic disease in three groups (none, hypertension, other). Correlations of NLR with age group, hematological indices, and glycemic parameters used Pearson's coefficient only when both variables were normally distributed and Spearman's rank coefficient otherwise. Baseline categorical characteristics were compared with the chi-square or Fisher's exact test, and the reference-range categories of ANC and ALC (supplementary descriptive analysis) were compared using the chi-square test with the Fisher–Freeman–Halton exact p-value (Monte Carlo estimation, 10,000 permutations). A sensitivity analysis compared controls with the subgroup of patients with type 2 diabetes. A two-sided p-value <0.05 was considered statistically significant; no adjustment for multiple comparisons was applied.

Ethical considerations

Ethical approval was obtained from the Research Directorate, General Directorate of Planning and Development, Ministry of Health, Gezira State, Sudan, under approval No. 13. The study was approved for implementation at Abo Aglaa Diabetic Center, Wad Medani, Gezira State, Sudan. Written informed consent was obtained from all participants before sample collection. Participant information and laboratory data were handled confidentially and used only for the purposes of the study.

Results

Participant characteristics

The study included 100 participants, comprising 50 diabetic patients and 50 controls. Overall, 60 participants were female and 40 were male. By age group, 44 participants were aged 45–60 years, 32 were aged 30–45 years, 18 were younger than 30 years and 6 were aged ≥60 years. Education levels included basic education (20), secondary education (56), university education (23), and postgraduate education (1). Thirty-nine participants were reported as obese. Seventy-four participants reported no chronic disease, while hypertension was reported in 22 participants and other chronic conditions in 4. Diabetic patients were older, more often female, less educated, and more often hypertensive than controls (Table 1).

Among the 50 diabetic patients, 39 (78.0%) had type 2 and 11 (22.0%) had type 1 diabetes; 34 (68.0%) had at least one diabetic complication (Table 2).

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Table 1: Baseline characteristics of the study participants, n (%).

Characteristic	Controls (n=50)	Cases (n=50)	Total (N=100)	p-value*
Sex				0.024
Female	24 (48.0)	36 (72.0)	60 (60.0)	
Male	26 (52.0)	14 (28.0)	40 (40.0)	
Age group				0.010
<30 years	11 (22.0)	7 (14.0)	18 (18.0)	
30–45 years	22 (44.0)	10 (20.0)	32 (32.0)	
45–60 years	16 (32.0)	28 (56.0)	44 (44.0)	
≥60 years	1 (2.0)	5 (10.0)	6 (6.0)	
Education				0.043
Basic	5 (10.0)	15 (30.0)	20 (20.0)	
Secondary	31 (62.0)	25 (50.0)	56 (56.0)	
University/ postgraduate	14 (28.0)	10 (20.0)	24 (24.0)	
Reported obesity				0.218
Yes	16 (32.0)	23 (46.0)	39 (39.0)	
No	34 (68.0)	27 (54.0)	61 (61.0)	
Chronic disease				<0.001
None	50 (100.0)	24 (48.0)	74 (74.0)	
Hypertension	0 (0.0)	22 (44.0)	22 (22.0)	
Other	0 (0.0)	4 (8.0)	4 (4.0)	

*Chi-square or Fisher's exact test.

Table 2: Clinical characteristics of diabetic patients (n=50).

Characteristic	Category	n	%
Type of diabetes	Type 1	11	22.0
	Type 2	39	78.0
Current clinical manifestation	No	50	100.0
Diabetes complications	None	16	32.0
	Neuropathy	18	36.0
	Cardiac problem	9	18.0
	Retinopathy/neuropathy	4	8.0
	Nephropathy	3	6.0

Normality assessment of continuous variables

The distribution of continuous variables was assessed using the Shapiro–Wilk test before choosing the statistical test (Table 3). All variables departed significantly from normality in at least one group ($p<0.05$) and were therefore analyzed using non-parametric tests (Mann–Whitney U, Kruskal–Wallis, and Spearman correlation). Body mass index was not available.

Comparison of NLR and hematological parameters between groups

Compared as continuous variables, median ANC (3.74 vs 2.66 $\times10^3$/µL; U=817.5, p=0.003) and ALC (2.84 vs 2.24 $\times10^3$/µL; U=851.0, p=0.009) were higher in diabetic patients than in controls, whereas NLR did not differ (median 1.15 vs 1.12; U=1274.0, p=0.871) (Tables 4,5). Recalculating NLR as ANC ÷ ALC gave the same conclusion (p=0.761). Using an exploratory threshold of NLR >2.0 as a secondary descriptive analysis, NLR >2.0 was found in 3 of 50 participants (6.0%) in each group (Fisher's exact test, p=1.000). As expected, fasting blood glucose, random blood sugar, and HbA1c were significantly higher in diabetic patients (all $p<0.001$).

The higher ANC and ALC were confined to patients with type 1 diabetes (n=11; median ANC 9.10 and ALC 7.90 $\times10^3$/µL). When patients with type 2 diabetes (n=39) were compared with controls, neither ANC (p=0.194) nor ALC (p=0.406) differed, and NLR remained similar (p=0.712) (Table 4, last column).

Associations between NLR and demographic/clinical factors

NLR (continuous) was significantly higher in participants with reported obesity than in those without (median 1.30 vs 1.10; U=1532.5, p=0.015). The association was also present among diabetic patients (1.30 vs 1.10, p=0.035) and showed the same direction among controls (1.40 vs 1.10, p=0.128). NLR was not significantly associated with age group (Spearman $\rho=-0.078$, p=0.445; Kruskal–Wallis p=0.062), sex (p=0.487), education level (p=0.639), or chronic disease status (p=0.909) (Table 6).

Correlation of NLR with metabolic parameters

Because all variables were non-normally distributed, Spearman's coefficient was used. NLR was not significantly correlated with fasting blood glucose, random blood sugar, or HbA1c, either in the total sample or in diabetic patients (Table 7).

Correlation of NLR with hematological parameters

In the total sample, NLR correlated positively with ANC ($\rho=0.487$, $p<0.001$) and negatively with ALC ($\rho=-0.456$, $p<0.001$). Among diabetic patients, NLR correlated positively with ANC ($\rho=0.464$, $p<0.001$), whereas the negative correlation with ALC was not significant ($\rho=-0.236$, p=0.102). In type 2 patients, correlations were $\rho=0.637$ (ANC) and $\rho=-0.411$ (ALC) (Table 8).

Discussion

This case–control study evaluated NLR and selected hematological parameters among diabetic patients and non-diabetic controls attending Abo Aglaa Diabetic Center, Gezira State, Sudan. When analyzed as continuous variables, NLR did not differ between diabetic patients and controls, and it was not correlated with glycemic indices. ANC and ALC were higher in the diabetic group overall, but this difference was confined to the small type 1 subgroup.

Table 3: Normality assessment (Shapiro–Wilk W, p-value) of continuous variables.

Variable	Controls (n=50)	Cases (n=50)	Distribution
ANC ($\times10^3$/µL)	0.942, 0.017	0.847, <0.001	Non-normal
ALC ($\times10^3$/µL)	0.941, 0.015	0.795, <0.001	Non-normal
NLR	0.951, 0.038	0.871, <0.001	Non-normal
FBG (mg/dL)	0.955, 0.055	0.898, <0.001	Non-normal
RBS (mg/dL)	0.957, 0.068	0.938, 0.011	Non-normal
HbA1c (%)	0.965, 0.148	0.928, 0.005	Non-normal

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Table 4: Comparison of hematological and glycemic parameters between controls and diabetic patients (Mann–Whitney U test).

Parameter	Controls (n=50) median (IQR)	All cases (n=50) median (IQR)	U	p-value	Type 2 cases only (n=39) median (IQR)	p-value†
ANC (×10³/μL)	2.66 (2.29–3.19)	3.74 (2.35–4.88)	817.5	0.003	3.14 (2.09–3.80)	0.194
ALC (×10³/μL)	2.24 (1.80–2.69)	2.84 (1.90–3.91)	851.0	0.009	2.33 (1.73–3.04)	0.406
NLR	1.12 (0.90–1.68)	1.15 (0.90–1.48)	1274.0	0.871	1.10 (0.90–1.55)	0.712
FBG (mg/dL)	107.50 (94.25–115.00)	140.00 (115.50–187.50)	407.5	<0.001	140.00 (112.50–190.00)	<0.001
RBS (mg/dL)	112.50 (106.00–123.75)	158.50 (130.25–201.00)	306.5	<0.001	156.00 (128.00–210.50)	<0.001
HbA1c (%)	3.65 (3.32–4.10)	6.45 (6.00–7.75)	0.0	<0.001	6.00 (5.70–7.60)	<0.001

ANC and ALC: all cases n=50 and n=49 (ALC), type 2 cases n=39 and n=38, respectively. †Controls vs type 2 cases. NLR, neutrophil-to-lymphocyte ratio; IQR, interquartile range.

Table 5: Supplementary: ANC and ALC by reference-range category, n (%).

Category (×10³/μL)	Controls (n=50)	Cases (n=50 for ANC; n=49 for ALC)	χ^2	p (χ^2)	p (exact)
ANC low (<2.0)	3 (6.0)	9 (18.0)	17.753	<0.001	<0.001
ANC normal (2.0–7.5)	47 (94.0)	30 (60.0)			
ANC high (>7.5)	0 (0.0)	11 (22.0)			
ALC low (<1.0)	1 (2.0)	0 (0.0)	13.382	0.001	<0.001
ALC normal (1.0–4.8)	49 (98.0)	38 (77.6)			
ALC high (>4.8)	0 (0.0)	11 (22.4)			

Descriptive only; categorization of continuous data was not used for inference. ALC categories: controls n=50, cases n=49. The χ^2 values (computed without continuity correction) are shown descriptively; because some expected cell counts were <5 for ALC, inference rests on the Fisher–Freeman–Halton exact p-value (Monte Carlo estimation).

Table 6: Association of NLR (continuous) with demographic and clinical factors, total sample.

Factor	Test applied (per normality)	Statistic	p-value
Age group (ordinal; n=100)	Spearman ρ	ρ = -0.078	0.445
Age group (4 categories; n=100)	Kruskal–Wallis	H = 7.325	0.062
Sex (male vs female)	Mann–Whitney U	U = 1101.0; medians 1.10 vs 1.20	0.487
Reported obesity (yes vs no)	Mann–Whitney U	U = 1532.5; medians 1.30 vs 1.10	0.015
Education level (3 groups)	Kruskal–Wallis	H = 0.896	0.639
Chronic disease status (3 groups)	Kruskal–Wallis	H = 0.192	0.909

Table 7: Spearman correlation between NLR and metabolic parameters.

Variable pair	Total sample n	ρ	p-value	Cases n	ρ	p-value
NLR vs FBG	100	-0.052	0.604	50	-0.057	0.692
NLR vs RBS	100	-0.084	0.408	50	-0.050	0.728
NLR vs HbA1c	100	-0.063	0.532	50	-0.080	0.581

Table 8: Spearman correlation between NLR and hematological parameters.

Variable pair	Total n	ρ	p	Cases n	ρ	p	Type 2 n	ρ	p
NLR vs ANC	100	0.487	<0.001	50	0.464	<0.001	39	0.637	<0.001
NLR vs ALC	99	-0.456	<0.001	49	-0.236	0.102	38	-0.411	0.010

Median ANC and ALC were higher in diabetic patients than in controls. This is directionally compatible with previous work describing increased neutrophil activity in diabetes and in patients with diabetic complications [10,11]. However, the sensitivity analysis showed that the difference was not present when patients with type 2 diabetes were compared with controls, and the 11 patients with type 1 diabetes had markedly higher counts (median ANC 9.10 and ALC 7.90 ×10³/μL) than all other participants. Such values lie well above usual adult reference ranges in clinically stable individuals without infection and may reflect characteristics of this small subgroup or measurement- or recording-related factors; they should be interpreted cautiously and verified in larger, type-stratified samples. Patients with active infection or inflammation, those receiving antibiotics, and those using systemic corticosteroids within the previous month were excluded by design, which reduces, but does not eliminate, the likelihood that these factors explain the values. Clinical details that could account for them (e.g., recent ketoacidosis or hospitalization) and verification of recorded units or decimal placement were not available in the analyzed dataset. The present data therefore do not allow the conclusion that diabetes per se is associated with higher neutrophil or lymphocyte counts.

NLR itself did not differ between diabetic patients and controls (median 1.15 vs 1.12; p=0.871), and the result was unchanged when NLR was recalculated from ANC and ALC, when an exploratory NLR threshold of 2.0 was applied (6.0% in each group), and when only type 2 patients were analyzed. Because numerator and denominator rose together in the type 1 subgroup, their ratio likely remained stable. Previous studies have reported higher NLR values in diabetes and associations with diabetic complications [10-13]. Differences between studies may relate to sample size, disease duration, clinical stability, complication burden, metabolic status, and population characteristics. In the present study, the absence of acute infection and the relatively stable clinical status of participants may have contributed to the lack of a between-group difference.

NLR was higher in participants with reported obesity, both overall and among diabetic patients, which is compatible with the recognized relationship between adiposity and low-grade inflammation [3,13]. Reported obesity status was recorded only as a yes/no variable and BMI was not available, so the strength of this association could not be explored, and, because

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multiple comparisons were not adjusted for and obesity status was reported rather than measured, this finding should be considered hypothesis-generating and interpreted cautiously. The previously suggested association of NLR with age was not confirmed when age (as an ordered category) was analyzed with an appropriate rank-based test, and NLR was likewise not associated with education level; the age-group comparison approached but did not reach significance (p=0.062), and a modest age effect cannot be excluded in this sample. NLR was not associated with sex or chronic disease status; the latter should be interpreted cautiously because chronic disease categories other than hypertension contained very few participants and all controls were free of chronic disease by design. Moreover, cases and controls differed in age, sex, education, and hypertension (Table 1), and these imbalances were not adjusted for.

No significant correlation was observed between NLR and fasting blood glucose, random blood sugar, or HbA1c in the total sample or among diabetic patients. This is consistent with the observation in previous work that NLR may relate more closely to inflammatory burden and complications than to glycemic indices alone [11]. A single NLR measurement should therefore not be interpreted as a direct surrogate for glycemic control.

The relationship between NLR and its components was clearer. NLR correlated positively with ANC and, in the total sample, negatively with ALC (but not significantly among all diabetic patients). These findings are expected mathematically and biologically because NLR is determined directly by the balance between neutrophils and lymphocytes; they support the use of NLR as a composite indicator of leukocyte balance rather than as an isolated disease-specific test.

NLR is inexpensive and can be obtained from a routine CBC, making it potentially useful as a supportive inflammatory measure where additional biomarkers are not readily available. However, the absence of a significant difference between diabetic patients and controls in this sample indicates that NLR should not be used alone to diagnose diabetes or to determine disease severity. Its interpretation should remain integrated with clinical assessment, metabolic parameters, and other laboratory findings [7,8].

Study limitations

- The sample size was relatively small (100 participants), which may have limited statistical power, particularly for subgroup analyses (type 1 diabetes, n=11).
- The study was conducted at a single center in Gezira State, limiting generalizability to other Sudanese populations.
- The study population was clinically stable and excluded patients receiving antibiotic therapy; the findings may therefore not represent patients with acute infection or severe inflammatory complications.
- The case–control and cross-sectional nature of the study does not establish temporal or causal relationships.
- Cases and controls differed in age, sex, education, and hypertension, and no multivariable adjustment was performed; multiple comparisons were not adjusted for.
- Body mass index was not recorded (reported obesity status was a yes/no variable without an operational definition), and total WBC count was not available in the analyzed dataset; only ANC, ALC, and NLR were therefore analyzed.
- The counts observed in patients with type 1 diabetes were markedly higher than in other participants and require confirmation; clinical details that could explain them (e.g., recent ketoacidosis or hospitalization) were not analyzed; one ALC value was implausible and was excluded only from ALC-related analyses.
- Several chronic disease subgroups contained very few participants, limiting reliable subgroup inference.

Conclusion

- Median ANC and ALC were higher in diabetic patients than in controls, but this difference was confined to the small group of patients with type 1 diabetes (n=11), whose values require verification, and was not observed in type 2 patients.
- NLR did not differ significantly between diabetic patients and controls (median 1.15 vs 1.12; p=0.871); 6.0% of each group had NLR >2.0.
- NLR was higher in participants with reported obesity, but was not significantly associated with age group, sex, education level, or chronic disease status.
- NLR was not significantly correlated with fasting blood glucose, random blood sugar, or HbA1c.
- NLR correlated positively with ANC (total sample and diabetic patients) and negatively with ALC (total sample).
- Overall, NLR may be considered a supportive inflammatory marker, but it should not be used as a standalone indicator of diabetes status, glycemic control, or disease severity.

Recommendations

The observed association between reported obesity status and NLR should be considered hypothesis-generating and requires confirmation using measured BMI and adjusted analyses. Larger multicenter studies are recommended, with adjustment for confounders and stratified analyses by diabetes type, disease duration, and complications, to determine the clinical value of NLR in Sudanese patients with diabetes. The markedly high ANC and ALC values observed in the type 1 subgroup should be verified against source records, and longitudinal studies should evaluate NLR in relation to glycemic control and the development or progression of complications.

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Ethical approval

Ethical approval was obtained from the Research Directorate, General Directorate of Planning and Development, Ministry of Health, Gezira State, Sudan, under approval No. 13. The study was approved for implementation at Abo Aglaa Diabetic Center, Wad Medani, Gezira State, Sudan. Written informed consent was obtained from all participants before sample collection. Participant information and laboratory data were handled confidentially and used only for the purposes of the study.

Consent for participation

All participants provided informed consent before sample collection.

Data confidentiality

Participant information and laboratory data were handled confidentially and used exclusively for the purposes of the study.

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Conflict of interest

The authors declare that they have no conflict of interest.

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