Haematological Inflammatory Indices and Erythrocyte Sedimentation Rate among Patients with Type 2 Diabetes Mellitus Attending Rivers State University Teaching Hospital, Port Harcourt, Nigeria

ABSTRACT

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| --- |
| **Introduction:** Chronic inflammation plays a key role in the development and progression of diabetic complications. Haematological inflammatory indices have emerged as reliable markers of systemic inflammation in diabetes. **Aim/Objectives:** This study aimed to evaluate the neutrophil-to-lymphocyte ratio (NLR), platelet-to-neutrophil ratio (PNR), platelet-to-lymphocyte ratio (PLR), and erythrocyte sedimentation rate (ESR) derived from routine complete blood count (CBC) among individuals with type 2 diabetes mellitus (T2DM) attending the Rivers State University Teaching Hospital in Port Harcourt, Nigeria. The study compared the levels of NLR, PNR, PLR, and ESR between individuals with T2DM and non-diabetic controls, and examined the association between these haematological indices and glycaemic control, as indicated by glycated haemoglobin (HbA1c) levels.**Methodology:** This case-control study was conducted among 70 diabetic and 70 non-diabetic subjects comprising of 41 females and 29 males between the ages of 28-74. The NLR, PNR, and PLR were calculated from CBC results obtained using the Mindray BC-5150 haematology analyzer. ESR was measured using the Westergren method. Data obtained was analyzed using Graphpad Software version 8.0.2.**Results:** The NLR and ESR were significantly elevated in diabetic subjects compared to controls (NLR: *P*=0.0004; ESR: *P*<0.0001). In contrast, the PNR and PLR were significantly lower in the diabetic group (*P*<0.0001). Gender-based analysis revealed that male diabetic subjects had significantly higher NLR (*P*=0.0036) and ESR (*P*=0.0040), and lower PNR (*P*=0.0001) compared to male controls, with no significant difference in PLR. Among female subjects, diabetic subjects also had significantly higher NLR (*P*=0.0375) and ESR (*P* <0.0001), alongside lower PNR (*P*=0.0003) and PLR (*P*=0.0002). Although variations in these markers were observed with increasing duration of diabetes, the differences were not statistically significant. HbA1c was negatively correlated with PNR (*P*=0.0117) and PLR (*P*=0.0123), while NLR and ESR showed non-significant positive correlations.**Conclusion:** The findings highlight the relevance of haematological inflammatory indices as accessible tools for evaluating systemic inflammation in diabetes management. |

*Keywords: Diabetes Mellitus; Neutrophil-Lymphocyte Ratio; Platelet-Neutrophil Ratio; Platelet-Lymphocyte Ratio; Erythrocyte Sedimentation Rate*

1. INTRODUCTION

Diabetes is a chronic metabolic disorder marked by the body’s impaired ability to produce or respond to insulin, resulting in hyperglycaemia and often accompanied by dyslipidemia and insulin resistance (International Diabetes Federation, 2021). The two main types are type 1 and type 2 diabetes mellitus (T1DM and T2DM), with T2DM accounting for 90–95% of all cases (Chan *et al*., 2020). According to the Global Burden of Disease Study, diabetes is the eighth leading cause of death and disability globally (Vos *et al*., 2020). The increasing prevalence in Africa is attributed to rapid urbanization, aging populations, unhealthy diets, and the adoption of Western lifestyles (Mbanya *et al*., 2010). Research suggests that the prevalence of diabetes in Port Harcourt, the epicenter of the oil and gas industry in Southern Nigeria, is comparable to rates in Western countries. This upward trend is attributed to the "Westernization" of lifestyles in the region (Onu and Babatunde, 2018).

Diabetes mellitus leads to both microvascular and macrovascular complications, which are major contributors to the increased rates of morbidity and mortality associated with the disease (Goyal and Jialal, 2023). In the presence of prolonged hyperglycaemia, the red cells undergo alterations that impact hemorheology and microcirculation (Zhou *et al*., 2018). Consequently, the proportion of normal, biconcave disc erythrocytes decreases while deformed erythrocytes increase, heightening the risk of diabetic complications (Gyawali *et al*., 2012). These changes in erythrocyte characteristics are significant in the context of inflammation markers like the erythrocyte sedimentation rate (ESR). ESR measures how quickly red blood cells aggregate and settle at the bottom of a vertically placed tube containing anticoagulated blood, expressed in millimeters per hour (Kahar, 2022). In individuals with diabetes, ESR can be elevated even in the absence of infection due to the persistent low-grade inflammation associated with the disease (Music *et al*., 2010). Normal ESR values typically range from 2 to 20 mm/hour in adults (Bain, 2017), though they vary with age and gender (Alende-Castro *et al*., 2019). Markedly elevated ESR values (≥100 mm/hour) are often indicative of serious underlying conditions and warrant further clinical evaluation (Abbag and Qahtani, 2007).

In recent years, there has been a growing interest in exploring novel biomarkers that can provide insights into the pathogenesis and progression of diabetes. There has been an increase in studies reporting that many indices obtained from routine complete blood count (CBC) tests could provide rich and effective information to predict outcomes in pathological conditions (Paliogiannis *et al*., 2019; Özer *et al*., 2024). Among these are the neutrophil-to-lymphocyte ratio (NLR), platelet-to-neutrophil ratio (PNR), and platelet-to-lymphocyte ratio (PLR). By considering multiple immune cell populations, these indices offer a comprehensive perspective on systemic inflammation (Walzik *et al*., 2021) and on predicting inflammatory processes (Zahorec, 2021). Specifically, NLR reflects the balance between pro-inflammatory neutrophils and anti-inflammatory lymphocytes, serving as an indicator of immune system activation, while the ratios of platelets to white blood cell subtypes (PLR and PNR) reflect both pro-inflammatory and pro-coagulant status (Yun *et al*., 2021; Eissa *et al*., 2022). These novel biomarkers are increasingly recognized as reliable indicators of systemic inflammation and have the advantage of being easily integrated into routine clinical practice. Their clinical utility lies in their simplicity, speed, cost-effectiveness, and widespread availability across various healthcare services, making them valuable tools for monitoring diabetes mellitus, assessing glycaemic control, and forecasting diabetes-related vascular complications (Wang *et al*., 2020; Agnello *et al*., 2021).

The rising prevalence of T2DM is accompanied by severe complications, as well as high morbidity and mortality linked to prolonged hyperglycaemia. This underscores the urgent need for affordable and practical diagnostic strategies to assess the inflammatory status of individuals affected by the disease. This study, therefore, aims to assess the clinical relevance of ESR, NLR, PNR, and PLR in individuals with T2DM attending the Rivers State University Teaching Hospital in Port Harcourt, Nigeria. By investigating these inflammatory markers, the study seeks to enhance the understanding of the role of inflammation in diabetes and to explore their potential as predictive tools for early intervention and improved disease management within the local healthcare setting.

2. material and methods

**2.1 Study Design**

A case-control study design was employed to access the NLR, PNR, PLR and ESR in individuals with diabetes attending the Rivers State University Teaching Hospital in Port Harcourt, Nigeria

**2.2 Study Area**

The study was conducted in Port Harcourt, the capital city of Rivers State, Nigeria. Situated at latitude 4.750°N and longitude 7.000°E, the city lies along the Bonny River in the Niger Delta region. Port Harcourt hosts a diverse population comprising individuals from various ethnic, cultural, and socio-economic backgrounds. Diabetic participants for the study were recruited from the Family Medicine Department of the Rivers State University Teaching Hospital (RSUTH), located at 5–8 Harley Street, Old GRA, Port Harcourt.

**2.3 Study Population**

A total of one hundred and forty (140) age- and sex-matched participants were recruited for the study using the simple random sampling technique. Seventy (70) were diabetic patients, defined by glycated haemoglobin (HbA1c) levels greater than or equal to 6.5%, in accordance with the American Diabetes Association (2018) criteria, while 70 were non-diabetic healthy control subjects residing in Port Harcourt.

**2.4 Sample Size Determination**

The sample size was determined using Cochran’s formula for sample size estimation (Cochran, 1977). A prevalence rate of 3.7% was adopted based on the International Diabetes Federation’s 2021 report on the prevalence of T2DM in Nigeria (International Diabetes Federation, 2021). After adjusting for a 10% attrition rate, the final sample size was set at 140 participants, comprising 70 individuals with T2DM and 70 non-diabetic controls.

**2.5 Eligibility of Subjects**

Subjects were recruited based on specific eligibility criteria. Eligible diabetic participants were required to be at least 18 years of age, non-pregnant, attending RSUTH, and willing to provide informed consent. Individuals diagnosed with known haematological malignancies, or inflammatory disorders were excluded from the study. Structured, interviewer-administered questionnaires were used to collect demographic and other relevant data from the participants.

**2.6 Sample Collection**

Five (5) milliliters of venous blood were collected into K₃EDTA (tripotassium ethylenediaminetetraacetic acid) anticoagulant vacutainer tubes for the analysis of HbA1c, CBC and ESR, while 3 milliliters were collected into fluoride oxalate tubes for fasting blood glucose (FBG) estimation. All samples were collected using standard venepuncture techniques as described by Cheesebrough (2006).

**2.7 Laboratory Analysis**

All reagents used in the study were commercially obtained, and the manufacturers’ standard operating procedures were strictly followed. Fasting blood glucose (FBG) was determined using the glucose oxidase method as described by Barham and Trinder (1972), following the protocol of ELITech Clinical Systems, France. Glycated haemoglobin was measured using the fluorescence immunoassay method (Hicks, 1984), as specified by Finecare™, China. Complete blood count was performed using the Mindray BC-5150 haematology analyzer (Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China). The NLR was calculated by dividing the absolute neutrophil count by the absolute lymphocyte count; the PLR by dividing the platelet count by the absolute lymphocyte count; and the PNR by dividing the platelet count by the absolute neutrophil count. The ESR was determined by the Westergren method as described by Westergren (International Council for Standardization in Haematology [ICSH], 1993) using Skytec pipette with prefilled and capped filling tube.

**2.8 Statistical Analysis**

The data obtained was analyzed using Graphpad prism software version 8.0.2 produced by Graphpad Software Inc. USA. Independent student’s t-test and analysis of variance (ANOVA) were done where necessary. Pearson’s correlation was also used to correlate parameters. Results were considered significant at a 95%confidence interval (P ≤ 0.05), and are expressed as mean ± standard deviation (SD).

3. results and discussion

**3.1 Results**

**3.1.1 Characteristics of Study Participants**

The diabetic and control groups comprised 41 females (58.6%) and 29 males (41.4%). Among the study participants the ages ranged from 28 to 74 years. The mean age of participants in the diabetic group was 55.01 ± 11.80 years, while that of the control group was 52.33 ± 11.79 years. Based on the duration of diabetes, 44.3% (n = 31) of the patients had been diagnosed for 1–5 years, 22.9% (n = 16) for 6–10 years, and 32.9% (n = 23) for more than 10 years.

**3.1.2 Comparison of Glycaemic Parameters, White Blood Cell Count, and Platelet Count between Diabetic and Non-diabetic Subjects**

The differences in HbA1c and FBG between the diabetic and control groups were statistically significant (*P*<0.0001). Diabetic subjects had significantly higher total WBC and neutrophil counts compared to the controls, while lymphocyte counts were similar in both groups. In contrast, platelet counts were significantly lower in the diabetic group (Table 1).

**Table 1. Comparison of Glycaemic Parameters, White Blood Cell Parameters, and Platelet Count between Diabetic and Non-diabetic Subjects**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Groups/Parameters | Diabetics(n= 70) | Non-diabetic Control (n= 70) | P value | Inference |
| **Mean ± SD** | **Mean ± SD** |
| FBG (mmol/L) | 7.513 ± 3.475 | 4.493 ± 0.5787 | <0.0001 | S |
| HBA1c (%) | 8.576 ± 1.777 | 5.329 ± 0.3773 | <0.0001 | S |
| WBC (×109/L) | 5.800 ± 1.900 | 4.740 ± 0.9011 | <0.0001 | S |
| Neut (×109/L) | 2.977 ± 1.510 | 2.115 ± 0.6401 | <0.0001 | S |
| Lym (×109/L) | 2.381 ± 0.5900 | 2.260 ± 0.5747 | 0.2208 | NS |
| PLT (×109/L) | 266.3 ± 79.98 | 319.8 ± 80.72 | 0.0001 | S |

**Key:** S**-** Significant, NS**-** NotSignificant, FBG- Fasting blood glucose, HbA1c- Glycated haemoglobin,WBC-White blood cell, Neut- Neutrophil, Lym-Lymphocyte, PLT- Platelet

**3.1.3 Comparison of Neutrophil-Lymphocyte Ratio, Platelet–Neutrophil Ratio, Platelet–Lymphocyte Ratio and Erythrocyte Sedimentation Rate of Diabetic and Non-diabetic Subjects**

The mean NLR was significantly higher in diabetic subjects compared to non-diabetic controls (*P*=0.004). In contrast, both the PNR and PLR were significantly lower in the diabetic group (*P*=0.0001). Also, ESR was significantly elevated in diabetic subjects compared to controls (*P*<0.0001) (Table 2).

**Table 2. Comparison of Neutrophil-Lymphocyte Ratio, Platelet–Neutrophil Ratio, Platelet–Lymphocyte Ratio and Erythrocyte Sedimentation Rate of Diabetic and Non-diabetic Subjects**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Groups/Parameters | Diabetics(n= 70) | Non-diabetic Control (n= 70) | P value | Inference |
| **Mean ± SD** | **Mean ± SD** |
| NLR | 1.289 ± 0.5267 | 0.9982 ± 0.4079 | 0.0004 | S |
| PNR | 99.75 ± 38.29 | 163.7 ± 65.38 | <0.0001 | S |
| PLR | 116.9 ± 40.47 | 151.1 ± 57.91 | <0.0001 | S |
| ESR | 32.09 ±29.20 | 14.10 ± 16.23 | <0.0001 | S |

**Key:** S**-** Significant, NLR-Neutrophil-lymphocyte ratio, PNR-Platelet-neutrophil ratio, PLR-Platelet-lymphocyte ratio, ESR – Erythrocyte sedimentation rate

**3.1.4 Comparison of Neutrophil-Lymphocyte Ratio, Platelet–Neutrophil Ratio, Platelet–Lymphocyte Ratio and Erythrocyte Sedimentation Rate in Male/Female Diabetics with Male/Female Healthy Controls**

Sex-based comparison of NLR, PNR, PLR and ESR revealed that among male participants, the mean NLR was significantly higher in diabetics compared to non-diabetics (*P*=0.0036). Similarly, PNR was significantly lower in diabetic males than in non-diabetic males (*P*= 0.0001). Although PLR was lower in male diabetics compared to controls, the difference was not statistically significant (*P*=0.0741). ESR, however, was significantly elevated in male diabetic subjects compared to non-diabetic controls (*P*=0.0040). In the female subjects, diabetic subjects showed a significantly higher NLR than the non-diabetic controls (*P*= 0.0375). Both PNR and PLR were significantly lower in diabetic females compared to non-diabetic females (*P*<0.0001 and *P*=0.0003, respectively). ESR was also significantly higher in diabetic females compared to non-diabetic controls (*P*=0.0002) (Table 3).

**Table 3. Comparison of Neutrophil-Lymphocyte Ratio, Platelet–Neutrophil Ratio, Platelet–Lymphocyte Ratio and Erythrocyte Sedimentation Rate in Male/Female Diabetics with Male/Female Healthy Controls**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable name | Male (Mean ± SD) | P value | Female (Mean ± SD) | P value |
| **Diabetic (n=29)** | **Non-diabetic (n=29)** | **Diabetic** **(n=41)** | **Non-diabetic (n=41)** |
| NLR | 1.380 ± 0.6359 | 0.9586 ± 0.3713 | 0.0036\* | 1.225 ± 0.4305 | 1.025 ± 0.4329 | 0.0375\* |
| PNR | 92.85 ± 43.79 | 145.8 ± 52.27 | 0.0001\* | 104.6 ± 33.59 | 176.4 ± 71.14 | <0.0001\* |
| PLR | 109.4 ± 34.44 | 126.8 ± 38.19 | 0.0741 | 122.2 ± 43.88 | 168.2 ± 63.52 | 0.0003\* |
| ESR | 20.45 ± 18.20 | 9.571 ±6.137 | 0.0040\* | 40.32 ± 32.73 | 17.12 ±19.88 | 0.0002\* |

**Key:** \***-** Significant, NLR-Neutrophil-lymphocyte ratio, PNR-Platelet-neutrophil ratio, PLR-Platelet-lymphocyte ratio, ESR – Erythrocyte sedimentation rate

**3.1.5 Effects of Duration of Diabetes on Neutrophil-Lymphocyte Ratio, Platelet–Neutrophil Ratio, Platelet–Lymphocyte Ratio and Erythrocyte Sedimentation Rate**

The comparison of NLR, PNR, PLR, and ESR across different durations of diabetes among the diabetic subjects revealed that the observed differences were not statistically significant (Table 4).

**Table 4. Effects of Duration of Diabetes on Neutrophil-Lymphocyte Ratio, Platelet–Neutrophil Ratio, Platelet–Lymphocyte Ratio and Erythrocyte Sedimentation Rate**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parameters/Duration | 1-5 (Yrs)(n=31) | 6-10 (Yrs)(n=16) | >10 (Yrs) (n=23) | F value | P value | Inference |
| **Mean ± SD** | **Mean ± SD** | **Mean ± SD** |
| NLR | 1.150 ± 0.4674 | 1.386 ±0.5184 | 1.410 ± 0.5827 | 2.024 | 0.1402 | NS |
| PNR | 107.1 ± 36.91 | 98.05 ± 45.67 | 91.04 ± 34.08 | 1.187 | 0.3116 | NS |
| PLR | 114.2 ± 40.84 | 125.3 ± 51.79 | 114.8 ± 31.10 | 0.4424 | 0.6443 | NS |
| ESR | 24.65 ± 22.64 | 41.31 ± 36.61 | 35.70 ± 30.14 | 2.040 | 0.1380 | NS |

**Key:** NS-Not Significant, NLR-Neutrophil-lymphocyte ratio, PNR-Platelet-neutrophil ratio, PLR-Platelet-lymphocyte ratio, ESR-Erythrocyte sedimentation rate

**3.1.6 Correlation between HbA1c levels and Neutrophil-Lymphocyte Ratio, Platelet–Neutrophil Ratio, Platelet–Lymphocyte Ratio and Erythrocyte Sedimentation Rate**

The correlation analysis revealed a statistically significant negative correlation between HbA1c levels and both PNR (*P*=0.0117) and PLR (*P*=0.0123). However, no significant correlation was observed between HbA1c and NLR or ESR (Table 5).

**Table 5. Correlation between HbA1c levels and Neutrophil-Lymphocyte Ratio, Platelet–Neutrophil Ratio, Platelet–Lymphocyte Ratio and Erythrocyte Sedimentation Rate**

|  |  |  |
| --- | --- | --- |
| Variables | HbA1c |  |
| **r-value** | **p-value** | **Inference** |
| NLR | 0.08546 | 0.4818 | NS |
| PNR | -0.2998 | 0.0117 | S |
| PLR | -0.2978 | 0.0123 | S |
| ESR | 0.02146 | 0.8600 | NS |

**Key:** r- correlation coefficient, NLR-Neutrophil-lymphocyte ratio, PNR-Platelet-neutrophil ratio, PLR-Platelet-lymphocyte ratio, ESR-Erythrocyte sedimentation rate, NS- Not significant

**3.2 Discussion**

Chronic inflammation is increasingly acknowledged as a significant contributor to the development of diabetic complications and the progression of the disease itself (Pop-Busui *et al*., 2016; Mertoglu and Gunay, 2017). Hyperglycaemia has been reported to influence both the number and function of circulating neutrophils, with elevated neutrophil counts commonly observed in patients with T2DM (Giovenzana *et al*., 2022). This increase may be attributed to hyperglycaemia-induced myelopoiesis (Nagareddy *et al*., 2013). In this study, we see this effect in the higher NLR, which is a known sign of overall inflammation in different health issues. An elevated NLR results from elevated neutrophils—a hallmark indicator of systemic inflammation. A more pronounced imbalance between neutrophil and lymphocyte counts corresponds to a heightened inflammatory response (Anastasakis *et al*., 2024). The findings in the present study are consistent with the report from Klisić *et al*. (2022), who observed that NLR was elevated in T2DM patients compared to prediabetic and healthy individuals. Several other studies have also documented increased NLR levels in diabetics compared to healthy controls (Mertoglu and Gunay, 2017; Nagabhushan and Geetha, 2019; Dik, 2020; Chen *et al*., 2024).

Numerous studies have demonstrated the predictive value of NLR in diabetes-related complications. NLR has been shown to be a stronger predictor of adverse outcomes (Shiny *et al*., 2014). According to Moursy *et al*. (2015), its predictive power is comparable to established inflammatory markers such as C-reactive protein (CRP), IL-1, IL-6, and TNF-α in identifying subclinical inflammation and endothelial dysfunction. Liu *et al*. (2018) reported that elevated NLR levels in T2DM patients are associated with a higher risk of developing diabetic peripheral neuropathy, while Li *et al*. (2024) identified NLR as a potential marker for assessing the risk of diabetic kidney disease. Additionally, Li *et al*. (2024) highlighted its diagnostic relevance in diabetic retinopathy. Mertoglu and Gunay (2017) also reported that higher NLR values are associated with increased insulin resistance.

In this study, diabetic subjects showed a lower PNR compared to healthy controls, possibly indicating an imbalance characterized by increased neutrophil-driven inflammation and reduced platelet-mediated haemostatic function. This observation aligns with the findings of Sun *et al*. (2025), who reported that a decrease in platelet count combined with an increase in neutrophils can lead to reduced PNR levels. Although research on PNR in individuals with diabetes remains limited, it is gaining attention as a valuable marker. PNR provides a broader reflection of the interplay between thrombotic and inflammatory processes (Sun *et al*., 2025). While chronic hyperglycaemia promotes neutrophil activation and recruitment, several factors may contribute to reduced platelet counts in diabetes. The prothrombotic state commonly seen in diabetes, driven by abnormal platelet activity and coagulation pathway activation, can lead to higher platelet consumption during thrombus formation. Additionally, inflammatory cytokines and oxidative stress in diabetes may damage platelets, accelerating their removal from circulation (Liao *et al*., 2025). The findings of this study are consistent with those of Klisic *et al*. (2022), who reported significantly lower PNR values in individuals with T2DM compared to those with prediabetes or healthy controls. The study by Essawi *et al*. (2023) also reported reduced PNR in individuals with diabetes. Sun *et al*. (2025) also demonstrated that diabetic retinopathy patients with lower PNR were more likely to develop diabetic macular edema. Beyond diabetes, reduced PNR has also been associated with disease severity in other conditions. Jin *et al*. (2019) found that a lower PNR at admission was associated with poor 90-day outcomes in patients with acute ischemic stroke.

The PLR has also recently gained attention as a marker of systemic inflammation in chronic diseases, including diabetes-related complications (Kim *et al*., 2016; Mertoglu and Gunay, 2017; Serban *et al*., 2024). Several studies have demonstrated a strong association between PLR and diabetes, suggesting its potential utility in assessing disease progression (Atak *et al*., 2019), predicting diabetes-related lower limb vascular disease (Liu *et al*., 2019), and evaluating atherosclerosis and diabetic foot ulcers (Mineoka *et al*., 2019). In the present study, we observed a reduced PLR in diabetic subjects compared to non-diabetic controls. This decrease may reflect increased platelet activation and aggregation commonly seen in individuals with T2DM, consistent with findings reported by Mendes *et al*. (2019). Although Klisic *et al*. (2022) also observed lower PLR values in T2DM patients compared to those with prediabetes and healthy controls, the difference was not statistically significant. Mertoglu and Gunnay (2017) reported a biphasic pattern in PLR dynamics, with lower values in prediabetes and early-stage diabetes and higher levels in advanced diabetes. However, findings on PLR remain mixed. While some studies, such as those by Dik (2020) and Yazar *et al*. (2015), found no significant differences in PLR between diabetic and healthy individuals, others have reported elevated PLR in T2DM patients (Atak *et al*., 2019; Wang *et al*., 2020). Given these inconsistencies, longitudinal studies are needed to track PLR changes over time and across different stages of diabetes, as well as under varying clinical conditions, to better determine its diagnostic and prognostic relevance.

Diabetic patients in the present study exhibited significantly higher ESR compared to healthy controls, indicating that hyperglycaemia may also impact RBC morphology and function. Erythrocytes are the primary glucose-consuming cells in the bloodstream, and in hyperglycaemic conditions, excess glucose binds to haemoglobin within RBCs, forming HbA1c, which is stable and does not easily degrade (Zhou *et al*., 2018; Wang *et al*., 2021). This glycation process extends to the erythrocyte membrane, resulting in membrane stiffening and reduced cell deformability (Lee *et al*., 2015; Loyola-Leyva *et al*., 2018). Structural changes in erythrocytes under high-glucose conditions have been well documented. For example, Babu and Singh (2004) reported that hyperglycaemia leads to a proportional increase in the perimeter of erythrocytes, a reduction in surface area, and greater irregularities in membrane structure. Consequently, as the internal environment becomes increasingly hyperglycaemic, the proportion of normal biconcave erythrocytes declines, while the number of deformed cells rises (Wang *et al*., 2021). These morphological changes promote rouleaux formation, which is a key driver of elevated ESR. Beyond morphological changes, the elevated ESR observed may also reflect an increase in acute-phase reactants commonly associated with diabetes. Mahajan *et al*. (2023) found that levels of these inflammatory proteins were significantly higher in diabetic patients and increased with disease duration. Additionally, the chronic low-grade inflammation characteristic of diabetes likely contributes to the production of acute-phase proteins, which causes a further rise in ESR. These findings are consistent with previous studies that also reported significantly higher ESR values in diabetic individuals compared to control groups (Mungamuri *et al*., 2018; Al-Nimer and Ratha, 2022; Abbas *et al*., 2023).

Gender-based comparison also revealed significantly elevated NLR and reduced PNR in both male and female diabetic subjects compared to their healthy control counterparts. While PLR remained comparable between the diabetic and non-diabetic males, there was a significantly lower PLR among the diabetic female subjects when compared to the healthy female controls. The ESR was also high among both male and female diabetic patients compared to their healthy control counterparts. This supports the notion that inflammation is a central feature of diabetes, irrespective of gender. When comparing the trend in ESR, female diabetic patients exhibited higher values than their male counterparts. This observation is consistent with the findings of Alende-Castro *et al*. (2019), who reported that ESR varies with both age and gender but is generally higher in females.

Although the duration of diabetes did not have a statistically significant effect on the NLR, PNR, PLR, and ESR, certain trends were observed. NLR exhibited an upward trend with increasing disease duration, while PNR showed a gradual decline. This may reflect the progressive nature of chronic inflammation in diabetes, as prolonged hyperglycaemia is known to enhance neutrophil activity and contribute to systemic inflammation (Kizilgul *et al*., 2018; Giovenzana *et al*., 2022), potentially explaining the rise in NLR. Conversely, the decline in PNR might suggest reduced platelet-neutrophil interaction over time. Unlike the present study, other research has reported significantly higher PLR levels in patients with longer durations of T2DM and in those with complications (Mertoglu and Gunay, 2017; Chen *et al*., 2021; Atli *et al*., 2022), highlighting the variability in inflammatory responses among diabetic populations. Similarly, while ESR tended to increase with longer disease duration, likely reflecting the cumulative effect of chronic low-grade inflammation, this trend also did not reach statistical significance, possibly due to inter-individual differences in inflammatory status.

This study assessed the correlation between HbA1c and NLR, PNR, PLR, and ESR among diabetic subjects. Glycated haemoglobin is a well-established indicator of long-term glycaemic control in diabetic patients and a key predictor of microvascular complications (Amaeshi *et al*., 2024). The findings of this study indicate that NLR and ESR are not associated with HbA1c levels. However, several studies have reported a positive association between the NLR and HbA1c levels, suggesting NLR could be useful for assessing glycemic control (Mousry *et al*., 2015; Hussain *et al*., 2017; Mahajan *et al*., 2023). These discrepancies may reflect variations in study populations, sample sizes, or disease severity. The PNR and PLR were negatively correlated with HbA1c. The observed association between PLR and PNR with HbA1c in this study reflects the effects of increasing hyperglycaemia on neutrophil, lymphocyte, and platelet counts. These changes are characteristic of chronic inflammation and support the notion that poor glycemic control, as indicated by higher HbA1c levels, is associated with heightened systemic inflammation, increased platelet activation, and a pro-thrombotic state. This is further accompanied by altered immune cell profiles, marked by neutrophil predominance and lymphocyte suppression. Such dysregulated haematological indices may contribute to the development of diabetes-related complications, including atherosclerosis, insulin resistance, and microvascular damage.

4. Conclusion

The findings from this study revealed significantly elevated NLR and ESR, alongside reduced PNR and PLR in diabetic individuals compared to non-diabetic controls, indicating a state of chronic low-grade inflammation in T2DM. These alterations were observed irrespective of gender; however, they remained unaffected by disease duration. Negative correlations between HbA1c and both PLR and PNR underscore the potential of these indices as markers of poor glycemic control. These results support the use of haematological inflammatory markers as accessible tools for assessing systemic inflammation in diabetes management. The study of these haematologic ratios remains relevant in Nigeria, where T2DM is prevalent and imposes a high healthcare and economic burden. Importantly, these markers are low-cost and readily accessible, making them valuable tools in resource-limited settings. Hence, it is recommended that studies involving larger, multi-center cohorts with a more diverse T2DM population, including newly diagnosed individuals and those with existing complications, should be conducted, as this would provide more insights into the impact of hyperglycaemia on these biomarkers. Also, long-term follow-up could also help determine whether baseline or dynamic changes in PNR and PLR predict specific complications, supporting their use as prognostic biomarkers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author(s) hereby declares that this manuscript is solely the result of the author’s original research. No generative AI technologies such as large language models (ChatGPT, Copilot, etc.) and text-to-image generators have been used during writing of this manuscript.

Consent

As per international standards or university standards, patient(s) written consent has been collected and preserved by the author(s).

Ethical approval

Ethical approval for this study was obtained from the Research Ethics Committee of the Rivers State University Teaching Hospital, Port-Harcourt, Rivers State, Nigeria (Reference Number: RSUTH/REC/2024/577).

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