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Clinical and Biological Characterization of Type 2 Diabetic Patients Followed at the National Center for Diabetology and Arterial Hypertension of the Central Hospital of Yaoundé, Cameroon

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Abstract

Introduction: Diabetes remains a real public health problem today, due to its associated morbidity and mortality. It induces numerous metabolic, biochemical, hematological, and immunological changes, responsible for multiple complications. The objective of this study was to characterize clinically and biologically type 2 diabetic patients followed at the National Center for Diabetology and Arterial Hypertension of the Central Hospital of Yaoundé. **Method:** This prospective, cross-sectional, and analytical study took place from April 5 to July 31, 2023 (4 months) on 100 diabetic patients of both sexes (61 women and 39 men), aged from 31 to 88 years. Body Mass Index, systolic and diastolic blood pressure, and cardiac frequency were measured on each of the patients. Subsequently, blood was collected from the patients for the determination of the complete blood count, HBA1c, lipid profile, serum albumin, TNF-α, and IL-6 levels. The data were analyzed using SPSS 17.0 software. **Results:** The age average of our population was 56.99 ± 11.51 years, the population was primarily female (61%) and primarily between the ages of 55 and 88. 67% of respondents were married. 59% went to secondary school. 73% of

them lived in urban areas. 30% were obese and 40% were overweight, with an average BMI of 28.75 kg/m^2. 76% of patients took oral antidiabetic medications. HbA1c level average was 8.65%, with 60% having readings above 6.5%. Low hemoglobin and hypochromia were among the abnormalities of red blood cells observed. Lipid profiles revealed low HDL-cholesterol and high triglycerides and cholesterol. Elevated levels of TNF-α and IL-6 indicated inflammation and cardiovascular risk. **Conclusion:** These results indicate the necessity of focused diabetic care and management for diabetic patients attending the central hospital of Yaoundé, Cameroon.

Keywords

Clinical, Biological, Characterization, Type 2 Diabetic Patients, Central Hospital of Yaoundé

1. Introduction

Diabetes Mellitus (DM) is a chronic, metabolic disease characterized by elevated levels of blood glucose, which leads over time to serious damage to the heart, blood vessels, eyes, kidneys and nerves. The most common is type 2 diabetes, usually in adults, which occurs when the body becomes resistant to insulin or doesn't produce enough insulin [1].

80% of type 2 diabetics are obese or overweight. Weight loss or gain is closely correlated with variations in insulin sensitivity, which constitutes a strong argument in favor of a cause-and-effect relationship between obesity and insulin resistance [2] [3]. Type 2 diabetes exposes one to numerous complications which arise from complex mechanisms combining hyperglycemia, insulin resistance, low-grade inflammation and accelerated atherogenesis [4]. Insulin resistance is associated with abnormalities in carbohydrate and lipid metabolism in a context of excess visceral fat [5]. Diabetes is associated with a high incidence of dyslipidemia with quantitative and qualitative abnormalities of lipoproteins constituting a factor aggravating the risk of atheroma in this population.

In 2021 worldwide, 537 million adults (20 - 79 years) were living with diabetes, or 1 in 10. This number is expected to reach 643 million by 2030 and 783 million by 2045. Diabetes was responsible for 6.7 million deaths in 2021 or 1 dead every 5 seconds [6].

The prevalence of diabetes in Africa is the lowest (4.2%) compared to other continents, but the prevalence and the burden of this disease are rising quickly in Africa [7] [8]. Uncontrolled urbanization and major changes in lifestyle seemed to drive this burden [9] [10]. In Cameroon, diabetes prevalence was estimated at around 6% in 2018 [11]. There is a regional disparity between rural and urban areas, with a rural prevalence of diabetes lower than the urban one but rising with time [12]-[14]. Diabetes prevalence also seems to be increased in particular groups: patients with stroke (12.8%) and patients with end-stage renal disease

(15.9%) [15] [16].

Several hematological changes affecting the red blood cells (RBCs), white blood cells (WBCs), and the coagulation factors are shown to be directly associated with DM [17]. Alamri *et al.* [18] showed that hyperglycemia increases the red blood cells count, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). Red blood cell distribution width (RDW) was negatively correlated with poor glycemic control. Concurrently, the presence of micro and macroangiopathies with hyperglycemia shortens the lifespan of RBCs [18].

Abdominal obesity (central or android) is strongly linked to type 2 diabetes [19]. Obesity is defined as an "excessive increase in body fat in such a proportion that it can have an influence on the state of health" [20]. The current international reference measurement is the body mass index (BMI) or Quételet index equal to the ratio of weight (kg) to the square of height (meter) ($BMI = P/T^2$ in kg/m^2).

In epidemiology, excess mass fat defining obesity is most often estimated using anthropometric criteria [21]. Body Mass Index seeks to convert weight into a value that is independent of height, a BMI greater than 25 kg/m^2 is the threshold value currently used to define overweight in adults [22].

The association between diabetes and high blood pressure is common. It increases cardiovascular risk and accelerates the occurrence of degenerative complications of diabetes. In type 1 diabetes, hypertension is rather the consequence of kidney damage, in type 2 diabetes, high blood pressure precedes diabetes and accelerates kidney damage. In diabetes, blood pressure must be below 130/80 mmHg [23]. Hypertension associated with type 2 diabetes concerns a particular population of patients characterized by a state of insulin resistance where the atherogenic dyslipidemia triad is also found (hypertriglyceridemia, low HDL-cholesterol, excess LDL-cholesterol), as well as the existence of android obesity [24]. Hypertension is associated with type 2 diabetes (T2D), in 80% of cases; it contributes to the high risk of cardiovascular diseases associated with type 2 diabetes [25]. Chronic low-grade inflammation occupies an important place among the links connecting all organs involved in the pathogenesis of type 2 diabetes and insulin resistance, thus contributing to chronic hyperglycemia [26].

The visceral adipose tissue of type 2 diabetes produces significant quantities of pro-inflammatory adipokines secreted by different cell types [27]. The main pro-inflammatory cytokines are TNFα, IL-1β, IL-6 and MCP-1 (Monocyte Chemoattractant Protein-1). Chronic inflammation leads to insulin resistance by different mechanisms: involvement of cytokines and chemokines, signaling pathways linked to the action of insulin, the inflammasome, and macrophage infiltration [28] [29].

The lipid abnormalities usually observed in type 2 diabetic are: hypertriglyceridemia, Hypo-HDL cholesterolemia and qualitative abnormalities of LDL cholesterol [30].

The hemato-biochemical profile of type 2 diabetic patients has been extensively studied all over the world, with a number of research examining its link with anthropometric and physical markers. Shehri [31] investigated the relationship

between some biochemical and hematological changes in type 2 diabetes patients in Saudi Arabia, and found an increase in the values of SGPT, alkaline phosphatase, urea, serum creatinine, total cholesterol, triglycerides, and LDL in the T2DM group compared to the control. Diabetes had a significantly lower HDL than the control group, as well as values of hemoglobin, RBC, MCV, MCHC, and MCH.

In Iraq, Al-Ali [32] discovered that diabetic patients had significantly greater levels of WBC, serum glucose, AST, ALT, and uric acid than the control group. Additionally, they had considerably lower total protein, and albumin values had dropped than healthy controls.

Milosevic and Panin [33] explored the relationship between complete blood count parameters (CBC) and glycemic control, as well as other risk factors (hypertension, hyperlipidemia, obesity, disease duration) in T2DM patients in Serbia, and discovered that PCT was correlated with leukocytes, neutrophils, and monocytes; MPM was significantly associated with MPV; MPC, PDW, GLU0, HDL-C; and PMDW was significantly correlated with HbA1c%, GLU0, HDL-C, and BW in all patients.

Several other authors have also discussed the impact of type 2 diabetes on the hematological profile in Africa. In a study on hematological parameters conducted at a comprehensive specialized hospital in Dessie, Ethiopia, Ebrahim *et al.* [34] discovered a significant difference in the total blood count between T2DM patients and the healthy control group. According to Ebrahim *et al.* [34], the prevalence of anemia was found in T2DM patients to be 25.8% overall, with a greater prevalence in female patients (16.7%).

Al Salhen and Mahmoud [35] found that diabetic patients of El-Beida, Libya had higher total WBC counts, MCHC concentrations, MCH, lymphocytes, and neutrophil counts, and significantly lower HCT values, hemoglobin content, RBC count, and MCV concentration than the controls.

In Cameroon, to our knowledge, there are no studies that have focused on the hemato-biochemical profile of type 2 diabetes, nor even on the anthropometric and physical profile, therefore the aim of this work was to characterize clinically and biologically type 2 diabetic patients followed at the Central Hospital of Yaoundé, Cameroon.

2. Methods and Materials

This prospective observational study was carried out from April 5 to July 31, 2023, with participants who attended the National Center for Diabetology and Hypertension in the central hospital of Yaoundé, Cameroon.

2.1. Study Design and Period

A prospective cross-sectional study was conducted from April 5 to July 31, 2023 (4 months).

2.2. Study Area

This study was conducted at the Central Hospital of Yaoundé. The hospital is

located in Yaoundé town in the Centre region, Cameroon. The hospital serves the people of Yaoundé and the neighboring areas. Located approximately 250 km from the coast of the Atlantic Ocean and on the edge of the great southern forest, it is part of the Mfoundi basin over an area of approximately 256 km^2.

2.3. Population

All patients with T2DM (type 2 diabetes) who were registered in the National Center for Diabetology and Hypertension were used as the source population. Patients with T2DM who had a registration list with each follow-up date in their medical records at the National Center for Diabetology and Hypertension at the time of data collection and who fulfilled the inclusion criteria were the study population.

The data were collected on the basis of a specially designed questionnaire for this research, which included demographic data, age, gender, smoking status, duration of diabetes, presence of associated illnesses (hypertension, coronary artery disease, dyslipidemia, stroke), type of medication (oral antidiabetic or insulin). The questionnaire was filled in by patients in cooperation with medical students.

2.3.1. Eligibility Criteria

- Inclusion criteria

The study included all medical records of patients with T2DM (HbA1c ≥ 6%) above the age of 30 for at least 3 months prior to the data collection and who had regular follow-up and comprehensive data.

- Non inclusion criteria

Patients with T2DM who had received a blood transfusion in the previous 3 months, pregnant women, patients with T2D who have not complied with the guidelines for fasting blood glucose tests and patients under 30 years old were non included.

The exclusion criteria from the study were endocrinological diseases affecting the metabolism of glucose and lipids, hematological diseases, systemic diseases, pregnancy, acute diseases, degenerative diseases of the nervous system and malignancy.

2.3.2. Sample Size Determination and Sampling Technique

The sample size calculation was done according to the Lorentz formula, on the basis of 6% (the prevalence of type 2 diabetes in Cameroon) [11]. This study included a total of 100 diabetic patients who had follow-up data for at least 3 months prior to the data collection period and had complete information for key factors.

2.3.3. Data Collection Tools

The data sources were the patient admission form, follow-up card, and DM registration book. The data extraction sheet consists of sex, age, body mass index (BMI), duration of DM, glycated hemoglobin (HbA1c), type of medication, and hematological parameters. Hematological parameters including RBC, Hgb, hematocrit (HCT), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin

concentration (MCHC), mean cell volume (MCV), WBC, WBC differential count, and platelet count were collected. Diastolic and systolic blood pressure, heart rate, IL-1, TNF alpha and lipid profile were also assessed.

2.3.4. Operational Definitions

According to the WHO, underweight is defined as a BMI of <18.5 kg/m^2, normal weight is defined as a BMI of between 18.5 and 24.9 kg/m^2, overweight is defined as a BMI of 25 and 29.9 kg/m^2, and obesity is defined as a BMI of ≥30 kg/m^2.

2.3.5. Anthropometric Measurement

Anthropometric indicators were taken in the morning while subjects minimally clothed without shoes. Weight was measured using Camry® mechanical personal scale and height was measured using a portable stadiometer. The body mass index (BMI) was then calculated as follows: BMI (kg/m^2) = weight (kg)/height^2 (m^2). Blood pressure (diastolic and systolic) and heart frequency were measured for all subjects in the study using a standardized mercury sphygmomanometer in the right arm in a sitting posture.

2.3.6. Biochemical Parameters

About 10 mL of blood was obtained from each diabetic patient. The blood was allowed to sit at 37˚C and then centrifuged at 3000 rpm for 15 min with a Mini laboratory centrifuge from Hunan Michael Laboratory Instrument Co., Ltd. Serum was then separated and stored at −20˚C until analysis. An automated hematological count was performed using the GENRUI KT-6300®.

HbA1c was analyzed using a Finecare™ FIA System. Serum samples were collected and Interleukin 6 (IL-6), Tumor Necrosis Factor-alpha (TNF-α) were determined by ELISA using Elabscience kits using the ALTA ELISA Plate Reader. Albumin was determined by a colorimetric method with bromocresol green (Biolabo, France). Serum concentrations of total cholesterol (TC), triglyceride (TG) and high-density lipoprotein cholesterol (HDL-C) were measured using kit enzymatic method (Biolabo Company). Indirect serum concentration of low-density lipoprotein cholesterol (LDL-C) was calculated via the Friedewald formula (total cholesterol (TC)-HDL-C -TG/5) [36]. Biochemical parameters were determined using a UV-VIS Single Beam Spectrophotometer LBUV400.

2.4. Ethical Consideration

The study was carried out after the Ethical Review Committee of the University of Douala (Cameroon) gave ethical clearance. A letter of approval was also provided by the General Director of the Central Hospital. Consent of participants in the study was required because it was a prospective study from medical records. To maintain confidentiality, the data collected from the participants was coded.

2.5. Statistical Analysis

SPSS (Statistical Package for Social Science) software version 17.0 for Windows was used for the statistical analysis of the results. Qualitative results were

estimated using proportion and/or percentage. Data was estimated as mean ± standard deviation. The data were analysed by descriptive statistics and the values were compared to the reference.

3. Results

3.1. Socio-Demographic Characteristics of Type 2 Diabetics Attending the National Center for Diabetology and Hypertension in the Central Hospital of Yaoundé, Cameroon

Our study population consisted of 100 type 2 diabetic patients of both sexes aged 31 to 88 years, with a mean age of 56.99 ± 11.51, with a predominance of women (61%) (Table 1). The majority of diabetes in the study population resided in urban areas (73%). The mean BMI value was 28.75 ± 6.60 kg/m^2, meaning that the majority of diabetic patients were overweight. The average duration of diabetes was 7.56 years (approximately 7 years and 6 months). 59% of the study population had a secondary level, 24 had a primary level and 17% had a higher education level. 76% of patients were treated with oral antidiabetics, 14% with oral antidiabetics and insulin, while 7% used insulin only. 3% of patients were not taking any therapy (Table 1).

Table 1. Sociodemographic and clinical characteristics of T2DM patients attending the National Center for Diabetology and Hypertension in the central hospital of Yaoundé, Cameroon.

Parameters	Sub-Parameters	Number	Moyenne ± SD
Age		100	56.99 ± 11.51
Sex	Male	39	
	Female	61	
Residence	Semi-urban	27	
	Urban	73	
BMI (Body Mass Index)	Normal	40	28.75 ± 6.60
	Overweight	30	
	Obese	30	
Duration of DM diagnosis (Years)	Between 1 and 5 years	52	7.56 ± 6.73
	Between 6 and 11 years	26	
	Between 12 and 17 years	10	
	Between 18 and 26 years	12	
Educational status	Primary school	24	
	Secondary school	59	
	Diploma and above	17	
Type of Medications	Without medication	3	
	Oral Diabetes Medications	76	
	Insulin	7	
	Oral Diabetes Medications + Insulin	14	

3.2. Distribution of the Population According to Hematological Parameters

The hematological analysis carried out in the 100 diabetic patients revealed that the average white blood cell value was 4.14± 1.5 G/L. The average value of red blood cells was 13.96 ± 66.83 Tera per liter (T/L). That of hemoglobin was 10.94 ± 1.95 g/dL. The average hematocrit value was 10.95% ± 4.86%. The mean value of mean corpuscular volume (MCV) was 81.96 ± 5.25 fl. The mean value of MCH (mean corpuscular hemoglobin) was 24 ± 2.31 pg. The mean value of MCHC (mean corpuscular hemoglobin concentration) was 29.98 ± 1.21 g/dL. The average platelet value was 193.55 ± 54.81 giga/liter (G/L). The mean platelet volume (MPV) was 11.04 ± 1.06. The average PCT value was 0.20% ± 0.05% (Table 2).

Table 2. Hematological parameters of T2DM patients attending the National Center for Diabetology and Hypertension in the central hospital of Yaoundé, Cameroon.

Parameters	Number	Mean ± SD	Normal range
WBC ($\times 10^9$/L)	100	4.14 ± 1.54	4 - 10
LYM ($\times 10^9$/L)	100	1.61 ± 0.60	0.6 - 4.1
MID ($\times 10^9$/L)	100	0.31 ± 0.22	0.1 - 0.8
NEUT ($\times 10^9$/L)	100	2.50 ± 2.87	2 - 7.8
RBC ($\times 10^{12}$/L)	100	13.96 ± 66.83	3.5 - 5.5
HGB (g/dL)	100	10.94 ± 1.95	11 - 15
HCT (%)	100	36.61 ± 4.86	40 -54
MCV (fL)	100	81.96 ± 5.25	80 - 99
MCH (pg)	100	24.55 ± 2.31	26 - 32
MCHC (g/dL)	100	29.98 ± 1.21	32 -36
PLT ($\times 10^9$/L)	100	193.55 ± 54.81	100 - 300
MPV (fL)	100	11.04 ± 1.06	7.4 - 10.4

SD: Standard Déviation. **WBC:** White blood cells. **LYM:** Lymphocytes. **MID**: MID cells. **NEUT:** Neutrophil. **RBC:** Red Blood Cell. **HGB:** hemoglobin concentration. **HCT:** hematocrit. **MCV:** mean corpuscular volume. **MCH:** mean corpuscular hemoglobin content. **MCHC**: mean cell hemoglobin concentration. **PLT:** platelets number. **MPV:** mean platelet volume.

3.3. Physical Parameters of Adults with T2DM Attending the National Center for Diabetology and Hypertension in the Central Hospital of Yaoundé, Cameroon

Mean diastolic pressure was 86.26 ± 17.02, about 6-7 mmHg higher. Mean systolic pressure was 137.11 ± 25.68 also high. When compared to normal range, mean heart rate was 78.31 ± 12.28 (Table 3).

3.4. Biochemical Parameters

The mean HbA1c value in the study population was 8.65% ± 2.45%. This value

reflects hyperglycemia of the order of 200 mg/dL. The TNF alpha concentration was 82.88 ± 13.49 pg/dL (very high compared to the normal of 0.24 pg/dL). The IL-6 value was normal. The mean total cholesterol value (202.48 ± 59.82 mg/dL) was higher than the normal. HDL-C was low (15.61 ± 6.21) compared to the normal 40 mg/dL. The triglyceride level was high (245.13 ± 92.15) compared to the normal of 150 mg/dL, while that of LDL was normal (148.43 ± 60.65 ≤ 160 mg/dL) (Table 4).

Table 3. Physical parameters of adults with T2DM attending the National Center for Diabetology and Hypertension in the central hospital of Yaoundé, Cameroon.

Parameters	Values	Normal range
Diastolic Pressure (mmHg)	86.26 ± 17.02	≤80
Systolic Pressure (mmHg)	137.11 ± 25.68	≤120
Cardiac frequency (BPM)	78.31 ± 12.28	60 to 100

Table 4. Biochemical parameters of adults with T2DM attending the National Center for Diabetology and Hypertension in the central hospital of Yaoundé, Cameroon.

Parameters	Values	Normal range
HbA1c (%)	8.65 ± 2.45	4% - 5.6%
TNF alpha (pg/dL)	82.88 ± 13.49	0.24 pg/dL
IL-6 (pg/mL)	4.08 ± 0.85	≤5 pg/mL
Lipid profile		
CT (mg/dL)	202.48 ± 59.82	≤2g/L (200 mg/dL)
HDL-C (mg/dL)	15.61 ± 6.21	≥0.4 g/L (40 mg/dL)
TG (mg/dL)	245.13 ± 92.15	≤1.5 g/L (150 mg/dL)
LDLc (mg/dL)	148.43 ± 60.65	≤1.6 g/L (160 mg/dL)
Albumin (g/dL)	7.33 ± 0.54	3.4 to 5.4 g/dL

HbA1c: glycated hemoglobin. **TNF alpha:** Tumor Necrosis Factor. **IL-6:** Interleukin 6. **CT:** Total Cholesterol. **HDL-C:** High Density Cholesterol. **TG:** Triglycerides. **LDLc:** Low Density Lipoprotein

4. Discussion

The objective of this study was to characterize type 2 diabetics attending the National Diabetology and Hypertension Center of the Yaounde Central Hospital. It involved 100 type 2 diabetic patients and took place over a period of 4 months. In this population, there were 61% of type 2 diabetic women compared to 39% of diabetic men. This result corroborates that of Biadgo *et al.* [37] of patients in Gondar; Northwest Ethiopia which showed that the female population was the most affected by type 2 diabetes (respectively 48% and 58.6%). This result can be explained by the sedentary lifestyle and the influence linked to sex hormones in women especially after menopause. The age group most represented in our study is that of 55 to 88 years. It represents 68% of the population and the average age

is 56.99 ± 11.51 years with the extremes ranging from 31 to 88 years. These results are higher than those of Diallo [38] who found 37.7% for an age group of 50 to 60 years. We note that the risk of developing diabetes increases with age.

The number of diabetes is inversely proportional to the duration of diabetes: this could be explained by the emergence of complications over time resulting in their mortality hence shortening the duration of diabetes and reducing the number of patients who survive the condition.

The majority of patients live in urban areas, who relies on limiting physical activity and eating a food high in energy index.

The educational level was mainly that of secondary school: education is a strong indication of the possession of knowledge and better care.

In our study, the majority of our patients were married (67%). This preponderance could be attributed to the influence of family difficulties, responsibilities and stress on the onset of diabetes.

The body mass index (BMI) of diabetics in our population was 28.75 ± 6.60 kg/m^2, only 30% of the study population had a normal BMI. 40% were overweight and 30% of them were obese. Our results are higher than those of Fagot *et al.* [39]. who found that only 20% of diabetics had a normal weight and 39% were overweight. This may be due to the lack of regular physical activity observed in our patients or to the increasingly high carbohydrate and lipid diet.

In our study, Oral Antidiabetic Drugs (OADs) were the most common treatment with a percentage of 76%. This result indicates that OADs represent the most used treatment in the majority of cases to treat type 2 diabetes in our patients.

HbA1c is a long-term glycemic marker. It is commonly used to assess the adequacy of glycemic control for 3 months in diabetic patients. In our study population, the mean value of glycated hemoglobin (HbA1c) was 8.65% ± 2.45% and approximately 60% of patients had HbA1c levels ≥ 6.5%, suggesting poor glycemic control over the previous 3 months. The longer hyperglycemia persists, the greater the possibility of glycation of proteins such as hemoglobin. This prevalence may be related to that of Nnakenyi *et al.* [40]. who found poor glycemic control in 60% of their Nigerian patients. These high HbA1c levels could be explained by non-compliance with hygiene and dietary rules and lack of regular physical activities.

It has been documented that qualitative and quantitative changes in the blood count are common in type 2 diabetics and an important cause of premature death in these patients [41] [42]. In the present study, several changes were observed in the red blood cell parameters of diabetic patients. The mean red blood cell count was high (13.96 ± 66.83). This can be explained by the effect of insulin resistance which is associated with the stimulation of erythroid progenitors increasing the red blood cell count. We also observed that hemoglobin, an index of anemia was low in outpatients. This result is consistent with the findings of studies conducted in Libya [35], which reported significantly lower hemoglobin levels in patients with type 2 diabetes. The possible explanation is that the decrease in hemoglobin levels could be due to hyperglycemia which causes increased production of

reactive oxygen species (ROS) and non-enzymatic glycosylation of hemoglobin. The mean values of MCHC and MCH were low in our patients). Adane *et al.* [43] reported these same results in Gondar patients in Ethiopia. This may be explained by the persistent hyperglycemia observed in diabetes mellitus. Long-term hyperglycemia causes structural and functional alterations to erythrocytes, including hypochromia. Hypochromia is indicated by a decrease in MCHC which is a constant finding of anemia in type 2 diabetics. In view of all these changes induced by diabetes, erythrocyte-related indicators could provide clinical data and could be used to monitor the development of diabetes and reduce complications induced by type 2 diabetes.

In the general population and in people with diabetes, a blood pressure reading of less than 120/80 mmHg is considered normal. The study revealed that many diabetes patients had high systolic blood pressure [44]. According to the ADA, the combination of high blood pressure and type 2 diabetes is particularly lethal and can significantly raise the risk of having a heart attack or stroke. Having type 2 diabetes and high blood pressure also increases chances of developing other diabetes-related diseases such as kidney disease and retinopathy [45].

It is known for type 2 diabetes that the concentrations of many proteins of the acute phase of inflammation such as TNF-α are increased and that this increase is one of the characteristics associated with this condition (insulin deficiency, insulin resistance). In our study, all mean TNF-α concentration values were elevated and our results are in agreement with those of Phosat *et al.* [46] who found elevated TNF-α levels in their study population.

The mean concentration of IL-6 was 4.08 ± 0.85 pg/mL. Interleukin-6 (IL-6) is a protein molecule produced by various cell types' particularly immunocompetent cells in response to tissue injury. The normal range for IL-6 levels in healthy adults is less than 5 pg/mL. The mean value obtained for our study population is higher than normal, knowing that all our subjects are on medication. Excessive concentrations of interleukin-6 in the blood are predictive of cardiovascular disease and diabetes.

In this study, the albumin level was higher than normal. A high albumin level usually reflects dehydration, diarrhea or other pathologies. According to the work of Jun *et al.* [47] increase in serum albumin concentration might protect against early glycemic deterioration and progression to type 2 diabetes even in subjects without metabolic syndrome. Elevated albumin levels are indicators of several chronic kidney diseases and a common complication of type 1 and type 2 diabetes [48].

Patients with type 2 diabetes often have an atherogenic lipid profile (hypertriglyceridemia, hypercholesterolemia, hyper-LDL cholesterolemia, Hypo-HDL cholesterolemia, and increased free fatty acids) which promotes their risk of cardiovascular diseases through the process of atherosclerosis [49]. Our patients' blood lipid analysis showed elevated levels of total cholesterol (202.48 ± 59.82 mg/dL) and triglycerides (245.12 ± 192.15 mg/dL), and low HDL cholesterol concentration

(15.61 ± 16.21 mg/dL). These results are similar to those of Jayakumari *et al.* [50], who found low HDL-c and high TG, LDL-c and TC. This may be explained by the fact that our study population consisted mainly of obese and overweight patients.

Multi-regression analyses revealed many positive correlations between hematological and some lipid profile parameters. A positive and high relationship observed between white blood cells and lymphocytes in this study was noted. Type 2 diabetes is associated with a chronic low-grade inflammatory state. This constant inflammation stresses the immune system. The TNF-alpha in this study was elevated; this can lead to an increase in the number of certain types of white blood cells, including lymphocytes. This correlation observed in this study would be due either to oxidative stress linked to hyperglycemia which damages cells, causing inflammation, or to insulin resistance, a key symptom in type 2 diabetes or to changes in the intestinal microbiota which can influence the immune system and also the level of white blood cells. Kheradmand *et al.* [51] in their study on the "association between white blood cell count and diabetes mellitus in Tabari Cohort Study" found that increased levels of WBC count, neutrophils and lymphocytes are all predictors for incidence of type 2 diabetes. This can be linked with our study since lymphocytes are a sub-population of white blood cells.

The correlation between hemoglobin and hematocrit levels can be influenced by the anemia observed in many diabetics, by a decrease in the number of red blood cells or the amount of hemoglobin. This can be either a micronutrient deficiency, diabetes can impair the absorption of some nutrients required for the production of red blood cells, such as iron and vitamin B12, or kidney disease or cardiovascular disease can lead to anemia, as well as some oral antidiabetic drugs can induce anemia. Diabetics are more prone to dehydration, which can also lead to an apparent increase in hematocrit (because there is less plasma in the blood). In a study in Peru, authors found that hemoglobin is a predictor of hematocrit according to age and sex in a population [52], this is consistent with our results which reveal a strong positive correlation between hemoglobin and hematocrit.

The correlation test also revealed a direct and significant relationship between LDL-cholesterol and total cholesterol. Indeed, LDL cholesterol represents a significant part of total cholesterol. Thus, an increase in LDL-cholesterol generally leads to an increase in total cholesterol. High levels of LDL-cholesterol and total cholesterol are the expression of atherogenic dyslipidemia in type 2 diabetics, in the presence of high levels of triglycerides and/or low levels of HDL-cholesterol in our study. A study made in China showed that there was no significant age or sex influence on the degree of correlation between serum total cholesterol and LDL-cholesterol [53]. Our study reveals the same trend.

Increased MCH and MCHC: a positive correlation between MCH and MCHC in our type 2 diabetics may suggest macrocytosis and contain more hemoglobin. This could be due to various factors, including iron deficiency, vitamin B12 deficiency, or folate deficiency.

Preview study among T2DM patients, treatment with metformin and concomitant use of PPI/H2-antagonists are associated with a higher chance of developing B12 deficiency than among non-diabetics [54]. This can be verified also in our study since most of them were treated by oral antidiabetic. A positive correlation between MCH and Hbg in type 2 diabetes may suggest that red blood cells are larger than normal (macrocytosis) and contain more hemoglobin. This could be due to various factors, including iron deficiency, vitamin B12 deficiency, or folate deficiency, but also linked to oral antidiabetic medications as previously mentioned.

5. Conclusion

A study of 100 type 2 diabetic patients in Cameroon found a female, urban, overweight population with poor glycaemic control (HbA1c: 8.65% ± 2.45%). Elevated TNF-alpha levels and dyslipidaemia were also found. Haematological values were mostly within normal limits. The findings underscore the importance of improved diabetes care and cardiovascular risk factor control in this group, particularly in urban areas, in order to prevent the risk of complications and comorbidities.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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