EVALUATION OF RED BLOOD CELL INDICES IN TYPE 2 DIABETES MELLITUS IN SULAYMANIYAH CITY, KURDISTAN REGION, IRAQ

Hisham Arif Alrawi [a]

Submitted: 25/8/2021; Accepted: 20/2/2022; Published: 21/6/2022

ABSTRACT

Background

Type 2 diabetes mellitus (T2DM) accounts for more than 90% of all diagnosed cases of diabetes. Earlier reports described an independent association of haematological indices, such as red blood cells (RBCs), haemoglobin (Hb), hematocrit (Hct), mean corpuscular haemoglobin (MCV), platelet count (Plt), and white blood cell count (WBC) with the risk of occurrence of T2DM.

Objectives

To evaluate the relationship between T2DM and red cell indices.

Patients and Methods

The current cross-sectional study recruited 400 patients with T2DM who were referred to the Diabetic Center in Sulaimani city, Northern Iraq, from November 2018 to March 2019 and 200 healthy blood donors who donated from March to April 2019 to the Sulaimani Blood Bank Center. The required data were collected from both groups, and relevant haematological tests and biochemical analyses were performed.

Results

Anemia was found in 8% of the patients giving higher rates among the females. Normocytic anaemia was observed in (82.8%) of the patients. Half of the patients had a high level of RBC counts, which correlates significantly with high HbA1c ($p=0.005$). The prevalence of pre-diabetic and diabetes was 15.5% among healthy blood donors. Patients with T2DM and donation experience showed lower HbA1c levels than those without blood donation ($p<0.05$).

Conclusion

Normocytic anaemia is the most common type in patients with T2DM. Patients with a high level of RBC count might be worth screening for T2DM. A high frequency of pre-diabetic and diabetic among asymptomatic healthy blood donors was observed.

Keywords: *Type 2 diabetes mellitus, Red blood cell indices, Red blood cell count, Glycosylated haemoglobin.*

---

[a] College of Medicine, University of Sulaimani, Kurdistan Region, Iraq

Correspondence: hisham.getta@univsul.edu.iq

https://doi.org/10.17656/jsmc.10361

INTRODUCTION

Type 2 diabetes mellitus (T2DM) or non-insulin-dependent diabetes mellitus constitutes around 90-95% of all diagnosed cases of diabetes [1]. It is a chronic disease caused by inherited or acquired insulin production deficiency or an insufficient response to secreted insulin by resistant body cells [2]. The crucial risk factors for T2DM are older age, obesity, family history, physical inactivity, and history of gestational diabetes. Instantly, uncontrolled hyperglycemia plays a significant role in developing cardiovascular disease and microvascular complications [3]. T2DM can be appropriately diagnosed using various techniques such as fasting blood sugar (FBS), random blood sugar (RBS), and glycosylated haemoglobin (HbA1c) level [4].

A high incidence of anaemia is observed in poorly controlled T2DM cases. The occurrence of haematological complications can be assessed by observing the haematological parameters through a complete blood count (CBC). For instance, the platelet count is related to HbA1c level and microvascular complications such as retinopathy [5, 6]. Furthermore, earlier studies reported higher mean platelet volume in the diabetic patients compared to the control group, particularly in patients with retinopathy compared to those without retinopathy [7, 8].

Moreover, epidemiological studies have indicated a close relationship between WBC count and components of metabolic syndrome. It was observed that the WBC is a reliable predictor of endothelial dysfunction and inflammation in T2DM [9, 10]. A recent study reported increased RBC aggregation and more significant vascular complications in T2DM [11].

The current study was designed to determine the relationship between T2DM and red blood cell indices in a cohort of patients with T2DM in Sulaimani city, northern Iraq.

PATIENTS AND METHODS

The present cross-sectional study was carried out from November 2018 to March 2019 in the Diabetic Center in Sulaimani, Northern Iraq. The study was conducted following the Sulaimani Directorate of Health (approval number 16/1). Informed consent was collected from all patients. Four hundred (200 males and females) T2DM patients aged 15-82 years were recruited. In contrast, the control group included 200 healthy male individuals aged 15-64 years with no history of T2DM. The control group were healthy voluntary blood donors collected from the Sulaimani Blood Bank Center from March to April 2019. A special questionnaire was prepared to collect data such as family history, age, gender, smoking status, the experience of a donation, and duration of the disease.

The blood samples were obtained by a well-trained phlebotomist under aseptic conditions using a standard technique.

Approximately 5 mL of venous blood from each participant was collected into K3 EDTA anticoagulant tubes, mixed thoroughly and used to determine the types of anaemia and measure the haematological parameters.

Such as haemoglobin (Hb), (Hct), (MCV), (MCH), (MCHC), (RBC), and red blood cell distribution width (RDW) using an electronic particle counter (Medtronic M-series, Sweden). Also, HbA1c was measured through Accent 200 HbA1c Cormany, Poland. Then, vacuum tubes containing clot activator were used to collect the serum to measure FBS, RBS, and creatinine using an automatic analyser (Cobas c311, Roche Diagnostics, Germany).

Statistical analysis

The collected data were expressed as mean ± standard deviation for all normally distributed continuous variables and median with interquartile range for abnormally distributed variables using the Statistical Package of the Social Sciences (SPSS version 25.0). The level of statistical significance was set at $p < 0.05$. Moreover, Pearson's correlation coefficient was utilised in normality to test univariate correlation with RBC. Finally, Spearman's correlation coefficient was employed to test the correlation between the abnormally distributed variables.

RESULTS

According to the data collected from the patients with T2DM, it was seen that their mean age was 55.8 ±10.8 years; most of them (75.5%) were adults aged 25-64 years, followed by the seniors aged ≥ 65 (23.5%) while only four patients (1.0%) were < 25 years. About their family history of diabetes, more than half of the patients (52.5%) had a positive history. Concerning the disease duration, the mean duration was 8.1 ± 5.9 years with a minimum of 5 years and a maximum of 30 years. Most of the diabetic patients (74%) had been suffering for ≤ 10 years, (24.5%) for 11-20 years, and (1.5%) for ≥ 21 years (Table 1).

Regarding the patients' biochemical analysis, the results revealed that their mean FBS was 192.8 ± 79.3 mg/dL with 82.5% of them having FBS ≥126 mg/dL (diabetes level) and 15.3% had 100-125 mg/dL (pre-diabetes level) while 2.2% of the patients had a normal FBS of <100 mg/dL (well-controlled diabetic patients). Their mean HbA1c was 9.04 ± 2.03%, with 95.3% of them having HbA1c level of ≥6.5% (diabetes level), (Table 2).

Our results showed that most of the patients, 83.2% had an average level of Hb. A high level of Hb was found in 8.8%, while only 8% had a low Hb level (anaemic). Further, it was shown that anaemia was significantly more prevalent among the females than the males (p=0.00). We observed that 85%, 13%, and 2% of the males and 81.5%, 4.5%, and 14% of the females had average, high, and low Hb levels, respectively, (Table 3).

Normocytic anaemia (MCV of 80 - 96 fl) was most frequently observed in our patients (82.8%), followed by microcytic (MCV< 80 fl) in 16% and macrocytic (MCV> 96 fl) in 1.3% of the patients.

Moreover, the serum creatinine was normal (0.4-1.2 mg/dL) in most of the cases (97.3%), while the remaining (2.7%) of the issues with high creatinine levels were not anaemic. Therefore, we excluded renal impairment as a cause of anaemia in our patients with T2DM.

In diabetic patients with a current or past history of smoking, our results revealed a significant difference in RBC counts between the males and females (p=0.00). However, there was no critical relationship between their smoking status and different RBC counts (Table 4). In addition, the results showed that 140 patients with T2DM had a history of blood donation (35%). The mean HbA1c was significantly lower in the diabetic patients who donated blood than those who did not contribute (p=0.02).

The present study showed that 203 (50.8%) patients had a high RBC count. These patients with high RBC count had a history of diabetes for ≤ 10 years. There was a significant relationship between the T2DM patients' HbA1c and different RBC counts. The HbA1c was significantly higher in patients with a high RBC count (p=0.005), (Table 5).

This finding became even more apparent when patients with low RBC count were included in the standard RBC count group (p<0.001) (Table 6). Furthermore, the results revealed a significant relationship between RBC count and FBS. Patients with a high RBC count had a higher level of FBS (p=0.00) (Table 7).

Concerning the data collected from the donors, it was observed that their mean age was 36.7 ±9.2 years (18 - 64 years). Most of the subjects (93%) were aged 25 to 64 years. Their HbA1c was normal in most cases (84.5%), with a mean of 5.23 ±1.06 % ranging from 2.1% to 11.5%. At the same time, 15.5% had high HbA1c.

Regarding the participant's haematological parameters, most of the subjects (81.5%) had normal Hb with a mean of 15.7 ±1.01. The Hct was standard in most subjects (72.5%) with a mean of 46.75 ±3.5. RBC count was also average (60.5%) with a mean of 5.66 ±3.53, (Table 8).

Finally, regarding the duration of donation in healthy subjects, it was seen that 48.5% of them had donated for 1-3 years, 32.5% for 4-6 years, 14% for ten years or more, and 5% for 7-9 years, with a mean of 4.6 ±3.7 years. Therefore, the results obtained from the healthy subjects indicated that 84.5% of them had normal HbA1c (≤5.6%), 8% had prediabetes levels of HbA1c (5.7-6.4%), and 7.5% had diabetes level of HbA1c (≥6.5%), (Table 8).

Moreover, there was no relationship between RBC count, Hct, and Hb with HbA1c in healthy individuals.

Table 1. Demographics of the patients with diabetes (n=400).

	Frequency	%
Age years:		
Youth (15-24 years)	4	1.0
Adults (25-64 years)	302	75.5
Senior (65 years and over)	94	23.5
Family History of T2DM:	210	52.5
Duration of Disease:(years)		
≤ 10	296	74.0
11-20	98	24.5
≥ 21	6	1.5
Total	**400**	**100**

Table 2. The diabetic patients' biochemical analysis (n=400).

		Frequency	%
FBS: Mean ± SD (192.8 ± 79.3), Range (87.0-504.0)			
Normal	< 100 mg/dL	9	2.2
Pre-diabetes	100-125 mg/dL	61	15.3
Diabetes	≥126 mg/dL	330	82.5
HbA1c: Mean ± SD (9.04 ± 2.03), Range (5.2-15.5)			
Normal	≤ 5.6 %	4	1.0
Prediabetes	5.7 - 6.4 %	15	3.7
Diabetes	≥ 6.5 %	381	95.3
Total		400	100

Table 3. Haemoglobin levels in the male and female T2DM patients.

Haemoglobin	Gender		Total	P-value
	Male	Female		
Low	4 (2.0)	28 (14.0)	32 (8.0)	0.00
Normal	170 (85.0)	163 (81.5)	333 (83.2)	
High	26 (13.0)	9 (4.5)	35 (8.8)	
Total	**200 (100)**	**200 (100)**	**400 (100)**	

According to WHO classification, Normal Hb for males: is 14-16.5 g/dl. Normal Hb for females: 12-16g/dl.

Table 4. The relationship between smoking and RBC count in T2DM patients.

RBC count			Gender		Total	P-value
			Male	Female		
Low	Smoking	Yes	1(100.0)	(0.0)	1(100.0)	0.00
		No	8(100.0)	(0.0)	8(100.0)	
		Quit	3(100.0)	(0.0)	3(100.0)	
	Total		12(100.0)	(0.0)	12(100.0)	
Normal	Smoking	Yes	23(92.0)	2(8.0)	25(100.0)	0.00
		No	49(37.7)	81(62.3)	130(100.0)	
		Quit	24(80.0)	6(20.0)	30(100.0)	
	Total		96(51.9)	89(48.1)	185(100.0)	
High	Smoking	Yes	27(90.0)	3(10.0)	30(100.0)	0.00
		No	42(30.7)	95(69.3)	137(100.0)	
		Quit	23(63.9)	13(36.1)	36(100.0)	
	Total		92(45.3)	111(54.7)	203(100.0)	
Total	Smoking	Yes	51(91.1)	5(8.9)	56(100.0)	0.00
		No	99(36.0)	176(64.0)	275(100.0)	
		Quit	50(72.5)	19(27.5)	69(100.0)	
	Total		200(50.0)	200(50.0)	400(100.0)	

According to WHO classification, the Normal RBC count for males: is 4.5-5.5 x 1012/L. Average RBC count for females: 3.8-4.8 x 1012/L.

Table 5. Relationship between RBC levels and HbA1c in T2DM.

		HbA1c				
RBC	**No.**	**Mean ± SD**	**(95% CI)**	**Minimum**	**Maximum**	**P-value**
Low	12	9.15±2.29	(7.6904 –10.6096)	5.80	12.90	0.005
Normal	185	8.68±1.91	(8.4103 – 8.9648)	5.20	14.70	
High	203	9.35±2.06	(9.0718 – 9.6447)	5.50	15.50	
Total	400	9.04±2.03	(8.8426 – 9.2411)	5.20	15.50	

Table 6. Relationship between normal, high RBC and HbA1c in T2DM.

	RBC	No.	Mean ± SD	P-value
HbA1c	Normal	197	8.71±1.93	**<0.001**
	High	203	9.36±2.06	

Table 7. Relationship between average, high RBC count and FBS in T2DM.

Group Statistics				
	RBC	**No.**	**Mean ± SD**	**P-value**
FBS	Normal	194	176.853±68.5414	**0.001**
	High	206	208.419±85.8923	

Table 8. The average healthy demographic and haematological parameters (n=200).

Parameter	Frequency	%
Age; Mean ± SD (36.7 ± 9.2), Minimum (18.0), Maximum (64.0)		
Youth (15-24 years)	14	7.0
Adults (25-64 years)	186	93.0
Total	200	100
HbA1c; Mean ± SD (5.23 ± 1.06), Minimum (2.1), Maximum (11.5)		
Normal ≤ 5.6 %	169	84.5
Prediabetes 5.7 - 6.4 %	16	8.0
Diabetes ≥6.5 %	15	7.5
Total	**200**	**100**
Hb; Mean ± SD (15.7 ± 1.01), Minimum (13.7), Maximum (18.4)		
Normal	163	81.5
High	37	18.5
Total	200	100
Hct; Mean ± SD (46.75 ± 3.5), Minimum (25.4), Maximum (56.4)		
Low	1	0.5
Normal	145	72.5
High	54	27.0
Total	200	100
RBC; Mean ± SD (5.66 ± 3.53), Minimum (4.46), Maximum (5.5)		
Normal	121	60.5
High	79	39.5
Total	200	100
Donation/years; Mean ± SD (4.6 ± 3.7), Minimum (1.0), Maximum (20.0)		
1 - 3	97	48.5
4 - 6	65	32.5
7 - 9	10	5.0
≥10	28	14.0
Total	200	100

*** According to WHO classification, Normal Hct for males: is 40-49%. Normal Hct for females: 36-46%.**

DISCUSSION

To determine the prevalence rate of anaemia in patients with T2DM and assess the red cell indices in such patients, 400 T2DM patients and 200 healthy blood donors were recruited. The required data, including demographics and haematological parameters, were obtained. The results revealed that most patients were adults aged 25-64 years. The control donor group was also populated mainly by this age group. In line with this finding, Nguyen et al. (2012) reported that most cases of T2DM are seen in middle-aged (25-64) individuals [12].

Our results revealed that family history is one of the significant risk factors for the development of T2DM. More than half of the T2DM patients had a positive family history. This finding agrees with a study conducted by Horrigan (2007), who reported family history as one of the risk factors for developing T2DM [13]. Analysis of the T2DM patients' haematological parameters and biochemical analysis concluded that FBS level was ≥126 mg/dl in most of the patients, which signals the presence of diabetes. This finding is in line with the reports of the WHO [14]. It was also observed that the average HbA1c was ≥ 6.5% in most of the patients, which indicates diabetes. This finding is in line with the review conducted by Florkowski (2013), who referred to HbA1c as a reliable diagnostic test for diabetes [15].

The prevalence rate of anaemia in T2DM patients was 8%, almost in agreement with the study by Bonakdaran et al. (2011). They studied the prevalence of anaemia in 1,962 patients with T2DM and reported that 19.6% of them had anaemia [16]. The higher rate of anaemia in the referred study can be related to the remarkable difference in sample size in the two investigations. In addition, the Hb level was average in most of the patients, which is in line with the results of the study conducted by Yang et al. (2017) [17].

Moreover, according to our results, the diabetic males and females differed significantly in their Hb level (low Hb level was observed in more females than men), revealing that anaemia was substantially more prevalent among the studied females than the males. This finding aligns with Bonakdaran et al. (2011), who reported that diabetic females had more anaemia than diabetic males. However, this difference was not significant in their study [16].

Normocytic anaemia (MCV of 80 - 96 fl) was the most frequent anaemia in our patients. This finding is consistent with the study carried out by Idris et al. (2018), who reported that normocytic anaemia accounted for 58.7% of the anaemia cases in the studied T2DM patients [18].

Serum creatinine was normal (0.4-1.2 mg/dl) in most of the patients; therefore, no relationship was found between serum creatinine and anaemia. Similarly, Harita et al. (2009) reported average levels of serum creatinine (0.6–1.1 mg/dl) in T2DM patients [19]. In the present study, the serum creatinine level did not have a significant relationship with low levels of Hb. This finding proves that the cause of anaemia is not the level of serum creatinine. Unlike this finding, Jurkovitz et al. (2003) reported a significant association between Hb concentration and serum creatinine at a p-value of 0.02 [20]. This difference can be attributed to the fact that Jurkovitz et al. (2003) studied the correlation between these two factors in patients with risk of coronary events, while the present study focused on T2DM patients.

Smoking history has been introduced as a risk factor for developing metabolic diseases such as T2DM [21]. However, our results showed that only 14% of the T2DM patients smoked. Furthermore, the association between smoking status and RBC count revealed that these variables were not significantly correlated. This finding is not in line with the study carried out by Malenica et al. (2017), who reported a rise of 10% in the RBC count of smokers [22].

According to the WHO, 2007, the average donation rate in the countries with 100% voluntary blood donation is 3.1% population [23]. However, compared to what WHO reported, a remarkable higher percentage of the patients with T2DM (35%) had experienced blood donation in our study. This finding can be justified because the dehydration rate is remarkably high in T2DM, leading to an increase in blood viscosity and RBC count, increasing the odds of diabetes development [24].

Comparing HbA1c in T2DM patients who experienced blood donation and those who did not donate blood showed that they had significantly different levels of HbA1c. Those who donated blood had an HbA1c level nearer to the normal range. This finding reveals that blood donation leads to a decrease in RBC count, resulting in increased plasma components in the whole blood, which finally prevents dehydration and decreases

blood viscosity, which in turn causes increased blood flow. Decreased blood hemodynamics has been known as one of the risk factors for the development of diabetes [25].

The results also indicated a significant relationship between high RBC count and HbA1c. Patients with high RBC count significantly demonstrate higher HbA1c levels (p=0.005). Similarly, patients with high RBC counts had significantly higher FBS (p=0.001). This finding agrees with Sheikhpour et al. (2013), who reported a significant relationship between HbA1c and RBC count in T2DM patients [26]. These findings are also in line with the study conducted by Jaman et al. (2018), who studied different haematological parameters in patients with T2DM [25].

This finding is again in line with a study conducted by Li et al. (2015), who concluded a significant direct relationship between HbA1c and RBC count in patients with T2DM. RBC rises with an increase in the values of HbA1c [24].

Moreover, a high level of RBC counts in the present study in (50.8%) of the patients can be a justification for their T2DM because, as reported by Tamariz et al. (2008), a high level of RBC count leads to an increased blood viscosity which is a risk factor for diabetes development [27].

To compensate for the lack of sensitivity and specificity in HbA1c, the RBC count was a good marker when combined with HbA1c. This finding suggests that haematological variables might be related to the underlying pathological changes associated with diabetes mellitus. This finding aligns with those reported by Milosevic and Panin (2019) [28].

Our study found that among the asymptomatic healthy blood donors, the prevalence of pre-diabetic and diabetic was 15.5%. This finding contrasts with earlier reports that demonstrated a 5-12% frequency of prediabetes and diabetes among healthy subjects [29, 30].

Furthermore, there was no relationship between RBC count, Hct, and Hb with HbA1c in healthy individuals. This finding is in line with the results reported by Huang et al. (2017), who revealed a non-significant relationship between RBC count and HbA1c in non-diabetic individuals [31]. Finally, the small sample size was an essential limitation of the study. Therefore, future studies are recommended to recruit larger study samples.

In conclusion, the prevalence of anaemia in our T2DM patients was 8%, with normocytic anaemia being the most common type, not related to renal insufficiency. Anaemia in female patients was more frequent than in males. In addition, we observed that high RBC counts significantly correlate with elevated HbA1c levels in our patients. Therefore, a high level of RBC count might be worth screening for T2DM. Finally, we notice a high frequency of pre-diabetic and diabetic among asymptomatic healthy blood donors.

Acknowledgements

The authors would like to thank Sulaimani Diabetic Center, Blood Bank Center, and the College of Medicine for their support, assistance, and facilities offered to accomplish this research.

Conflict of Interest

The authors declare no conflict of interest in this study.

REFERENCES

1. Antwi-Balfour S, Hammond S, Adjei JK, Kyeremeh R, Martin-Odoom A, Ekem I. A case-control study of the prevalence of anaemia among patients with type 2 diabetes. J Med Case Rep. 2016; 10 (1): 110.

2. Cho YI, M.P Mooney, DJ Cho. Hemorheological disorders in diabetes mellitus. J diabetes sci technol. 2008; 2(6):1130-1138.

3. Marini MA, Fiorentino TV, Andreozzi F, Mannino GC, Perticone M, Sciacqua A, et al. Elevated 1-h post-challenge plasma glucose levels in subjects with standard glucose tolerance or impaired glucose tolerance are associated with whole blood viscosity. Acta Diabetol. 2017; 54(8): 775-784.

4. Marini MA, Fiorentino TV, Andreozzi F, Mannino GC, Succurro E, Sciacqua A, et al. Hemorheological alterations in adults with prediabetes identified by haemoglobin A1c levels. Nutr Metab Cardiovasc Dis. 2017; 27(7): 601-608.

5. Lachin JM, Genuth S, Nathan DM, Zinman B, Rutledge BN; DCCT/EDIC Research Group. Effect of glycemic exposure on the risk of microvascular complications in the diabetes control and complications trial--revisited. Diabetes. 2008; 57(4): 995-1001.

6. Fadini GP, Morin M, Facco M, Bonamico S, Baesso I, Grego F, et al. Circulating endothelial progenitor cells are reduced in peripheral vascular complications of type 2 diabetes mellitus. J Am Coll Cardiol. 2005; 45(9): 1449-1457.

7. Wang ZS, Song ZC, Bai JH, Li F, Wu T, Qi J, et al. Red blood cell count as an indicator of microvascular complications in Chinese patients with type 2 diabetes mellitus. Vasc Health Risk Manag. 2013; 9: 237-43.

8. Milosevic D, Panin VL. Relationship between Hematological Parameters and Glycemic Control in Type 2 Diabetes Mellitus Patients. J Med Biochem. 2019; 38(2): 164-171.

9. Vozarova B, Weyer C, Lindsay RS, Pratley RE, Bogardus C, Tataranni PA. High white blood cell count is associated with a worsening of insulin sensitivity and predicts the development of type 2 diabetes. Diabetes. 2002; 51(2): 455-461.

10. Tong PC, Lee KF, So WY, Ng MH, Chan WB, Lo MK, et al. White blood cell count is associated with macro- and microvascular complications in Chinese patients with type 2 diabetes. Diabetes Care. 2004; 27(1): 216-222.

11. Deng Y, Papageorgiou DP, Li X, Perakakis N, Mantzoros CS, Dao M, et al. Quantifying Fibrinogen-Dependent Aggregation of Red Blood Cells in Type 2 Diabetes Mellitus. Biophys J. 2020; 119(5): 900-912.

12. Nguyen QM, Xu J-H, Chen W, Srinivasan SR, Berenson GS. Correlates of age onset of type 2 diabetes among relatively young black and white adults in a community. Diabetes Care. 2012; 35:1341-1346.

13. Harrigan N. Risk Factors for Type 2 Diabetes. US Pharm. 2007; 32(10): 61-63.

14. Akter S, Rahman MM, Krull Abe S, Sultana P. Prevalence of diabetes and prediabetes and their risk factors among Bangladeshi adults: a nationwide survey. Bulletin of the World Health Organization 2014; 92: 204-213A.

15. Florkowski C. HbA1c as a Diagnostic Test for Diabetes Mellitus - Reviewing the Evidence. ClinBiochem Rev. 2013; 34(2): 75-83.

16. Bonakdaran S, Gharebaghi M, Vahedian M. Prevalence of anaemia in type-2 diabetes and renal involvement. Saudi J Kidney Dis Transpl. 2011; 22: 286-290.

17. Yang J, Yan PJ, Wan Q, Li H. Association between haemoglobin levels and diabetic peripheral neuropathy in patients with type 2 diabetes: a cross-sectional study using electronic health records J. Diabetes Res. 2017; p. 2835981.

18. Idris I, Tohid H, Muhammad NA, A Rashid MR, Mohd Ahad A, Ali N, et al. Anaemia among primary care patients with type 2 diabetes mellitus (T2DM) and chronic kidney disease (CKD): a multicentred cross-sectional study. BMJ Open. 2018; 8(12): e025125.

19. Harita N, Hayashi T, Sato KK, Nakamura Y, Yoneda T, Endo G, et al. Lower serum creatinine is a new risk factor of type 2 diabetes: the Kansai healthcare study. Diabetes Care. 2009; 32(3): 424-426.

20. Jurkovitz CT, Abramson JL, Vaccarino LV, Weintraub WS, McClellan WM. Association of high serum creatinine and anaemia increases the risk of coronary events: results from the prospective community-based atherosclerosis risk in communities (ARIC) study. J Am Soc Nephrol. 2003; 14(11): 2919-2925.

21. Hu FB, Manson JE, Stampfer MJ, Colditz G, Liu S, Solomon CG, et al. Diet, lifestyle, and the risk of type 2 diabetes mellitus in women. N Engl J Med. 2001; 345(11): 790-797.

22. Malena M, Prnjavorac B, Bego T, Dujic T, Semiz S, Skrbo S, et al. Effect of Cigarette Smoking on Haematological Parameters in Healthy Population. Med. Arch. 2017; 71: 132-136.

23. WHO Blood Safety Indicators, 2007. Geneva: World Health Organization; 2009.

24. Li Q, Li L, Li Y. Enhanced RBC aggregation in type 2 diabetes patients. Journal of Clinical Laboratory Analysis. 2015; 29: 387–389.

25. Jaman S, Rahman S, Rubaiya SRR, Mahato J, Miah MM, Ayshasiddeka M, et al. Diabetes and red blood cell parameters. Ann Clin Endocrinol Metabol. 2018; 2:1-9.

26. Sheikhpour R, Sadeghian F, Rajabi S. Correlation between glycated haemoglobin, serum glucose and serum lipid levels in type 2 diabetes. Iranian Journal of Diabetes and Obesity. 2013; 5(1): 12-15.

27. Tamariz LJ, Young JH, Pankow JS, Yeh HC, Schmidt MI, Astor B, et al. Blood viscosity and hematocrit as risk factors for type 2 diabetes mellitus: the atherosclerosis risk in communities (ARIC) study. Am J Epidemiol. 2008; 168(10): 1153-1160.

28. Milosevic D, Panin VL. Relationship between Hematological Parameters and Glycemic Control in Type 2 Diabetes Mellitus Patients. J Med Biochem. 2019; 38(2):164-171.

29. Bigna JJ, Nansseu JR, Katte JC, Noubiap JJ. Prevalence of prediabetes and diabetes mellitus among adults residing in Cameroon: A systematic review and meta-analysis. Diabetes Res Clin Pract. 2018; 137: 109-118.

30. Mirahmadizadeh A, Fathalipour M, Mokhtari AM, Zeighami S, Hassanipour S, Heiran A. et al. The prevalence of undiagnosed type 2 diabetes and prediabetes in Eastern Mediterranean Region (EMRO): A systematic review and meta-analysis. Diabetes Res Clin Pract. 2020; 160: 107931.

31. Huang Z, Liu Y, Mao Y, Chen W, Xiao Z, Yu Y. Relationship between glycated haemoglobin concentration and erythrocyte survival in type 2 diabetes mellitus determined by a modified carbon monoxide breath test. J Breath Res. J Breath Res. 2017; 12(2): 026004.