Journal of ENVIRONMENTAL Treatment Techniques

J. Environ. Treat. Tech.
ISSN: 2309-1185

Journal web link: http://www.jett.dormaj.com

Evaluation of Biochemical Parameters in Type 1 and Type 2 Diabetics in Rabat District of Morocco

Miloudi Hilali[1]*, Asmae Tantane[2], Mohamed Rhajaoui[2], Hanae El Monfalouti[1] and Badr Eddine Kartah[1]

[1]Laboratory of Plant Chemistry and Organic and Bioorganic Synthesis, Faculty of Science, University Mohamed-V, Av Ibn Battouta, BP 1014 Agdal-Rabat, Morocco
[2]Laboratory biochemistry national institute of hygiene of Rabat, Morocco

Received: 25/03/2020 Accepted: 29/06/2020 Published: 20/09/2020

Abstract

Diabetes represents a major public health problem and exposes to serious complications such as cardiovascular, renal, ocular, neurological diseases and sometimes wounds which are difficult to heal leading in the most extreme cases to amputation. The objective of this work is therefore to carry out an evaluation of certain biological parameters (fasting blood sugar, urea, total cholesterol, HDL, creatinine, uric acid), and hematological (white blood cells, red blood cells, platelets) in diabetic patients. the rabat-sale region and to find out which type of diabetic is the most distributed in this region so that in the end we will raise awareness among the entire population to make periodic analyzes in order to draw lessons and offer recommendations. The study of this work focused on 40 diabetic patients, including 8 type 1 diabetic patients and 32 type 2 diabetic patients. After that we took blood samples for biological analyzes. According to the study, we found that the number of type 2 diabetics (80%) is higher than that of type 1 diabetics (20%), the number of women is greater than the number of men and the majority diabetic patients in our population are hypertensive (70%). Our results also show that in type 2 diabetics the average rates of all parameters (fasting blood sugar, urea, creatinine and uric acid) are lower than those recorded in type 1 diabetics. Total cholesterol and HDL in type 2 diabetics are higher than those recorded in type 1 diabetics. This study shows that our patients do not have a problem of bacterial infection or rheumatism because almost all the values of creatinine, urea, uric acid, total cholesterol and the level of white blood cells are normal and also shows, the absence of cardiovascular and renal complications. But our study also showed that total cholesterol, urea and creatinine increase with age, and people between the ages of 60 and 75 are more at risk than others. The study of this work shows that the number of women who have diabetes is greater than the number of men and most of these people have chronic diseases, so to avoid serious complication on a health scale, we must therefore to sensitize and educate the populations to make periodic analyzes, to make sport activities and food rigime to finally reduce the rate of diabetic diseases.

Keywords: Diabetes, Complications, Biochemical, Fasting glucose, Urea, Total cholesterol, HDL, Creatinine, Uric acid

1 Introduction

Diabetes is a chronic disease that cannot be cured, but can be treated and controlled. It is caused by a lack or lack of use of a hormone called insulin. When there is a lack of insulin, or when it does not perform its function effectively, as is the case in a person with diabetes, glucose cannot be used as a fuel for cells. It then accumulates in the blood and causes an increase in sugar level (hyperglycemia). In the long run, high blood sugar causes complications, including eye, kidney, nerve, heart and blood vessel complications [1, 2].

There are different types of diabetes: prediabetes, type 1 diabetes, type 2 diabetes, gestational diabetes and other rarer types; Type 1 diabetes, accounts for 10 to 15% of diabetes cases [3]. It occurs most often in a non-obese subject before the age of 30 [4]. Diabetes type 2 known as fatty or mature diabetes, noninsulin-dependent diabetes mellitus (NIDDM) is a metabolic disorder characterized by chronic excess of blood sugar (hyperglycemia) [5]. The peripheral use of sugar in the cells: insulin, a hormone made by the pancreas, allows cells to collect and use glucose. Gestational Diabetes affects 3 to 20% of pregnant women [6]. It manifests itself as an increase in blood glucose towards the end of the 2nd and 3rd trimesters of pregnancy. In the majority of cases, it disappears after delivery. Diabetes is recognized today, supported by figures like a global epidemic and a tsunami whose human, social and economic consequences are devastating. In Morocco, the latest national figures exceed 10% for people over the age of 20 years. And if we consider the age groups beyond 50 years, the prevalence exceeds 14%. Thus, today around two million people suffer from diabetes in our country [7]. diabetes is one of the worst health calamities in Morocco which costs millions of dirhams at the state coffers, each year, 500,000 people at risk in primary health care establishments including people with a history 1st degree family (father or mother) with diabetes. Worse, almost 50% of all diabetics are unaware of their disease.

Main objective of the study is concerned with three goals: (a) to determine the distribution of diabetic patients by type of diabetes, sex, age and presence or absence of hypertension; (b) a comparison of different biochemical parameters (fasting glucose, urea, total cholesterol, HDL, creatinine, uric acid) between type 1 diabetics and type 2 diabetics; (c) a comparison of the different cellular elements of blood which are white blood cells, red blood cells and platelets between type 1 diabetics and type 2 diabetics; and (d) do a lot of

Corresponding author: Miloudi Hilali, Laboratory of Plant Chemistry and Organic and Bioorganic Synthesis, Faculty of Science, University Mohamed-V, Av Ibn Battouta, BP 1014 Agdal-Rabat, Morocco. Email address: hilali400@yahoo.com.

analyzes in Moroccan populations to detect people decay before the complication of health.

2 Materials and methods

2.1 Sampling

This is a comparative study of some biochemical parameters in diabetic patients during a period of two months (June and August) of the year 2019 in the biochemistry department of the National Institute of Hygiene of Rabat (INH). The study has undertaken includes 40 diabetic patients from the Rabat region in Morocco. The selection of patients is based on a questionnaire on their gender, age, medical history and quality of life.

2.2 Blood sampling

Blood samples are taken after at least 12 hours of fasting. Samples are made in two tubes: first, a dry tube to determine: Blood glucose, creatinine, uric acid, ASTL, total cholesterol and HDL and second tube containing an EDTA anticoagulant for hematological analyzes. The dry tube is centrifuged in a centrifuge at 4000 rpm for 10 minutes in order to obtain serum, the assay of all the parameters will be performed.

2.3 Methods of determination biochemical parameters

2.3.1 Fasting blood glucose

Enzyme reference method for hexokinase. Glucose is phosphorylated to glucose-6-phosphate by the action of ATP and hexokinase (HK). Then, a second enzyme, glucose-6-phosphate dehydrogenase (G6PDH) catalyzes the oxidation of glucose-6-phosphate by $NADP^+$ to form NADPH [8].

$$\text{Glucose} + \text{ATP} \xrightarrow{HK} \text{glucose-6-phosphate} + \text{ADP}$$

$$\text{Glucose-6-phosphate} + \text{NADP} \xrightarrow{+G-6-PDH} \text{6-phosphogluconate} + \text{NADPH} + \text{H}^+$$

The concentration of NADPH formed is directly proportional to the glucose concentration. It is measured by increasing the absorbance at 340 nm. Reference interval: (0.65 - 1.10) (g / l)

2.3.2 Total cholesterol

Total cholesterol find out via using colorimetric enzymatic method. Cholesterol esterase (CE) [9].

$$\text{Esters of cholesterol} + H_2O \xrightarrow{CE} \text{cholesterol} + \text{RCOOH}$$

$$\text{Cholesterol} + O_2 \xrightarrow{CHOD} \text{Chlestene-4-en-3-one} + H_2O_2$$

$$2H_2O_2 + \text{amino-4phenazone} + \text{phenol} \xrightarrow{POD} \text{red colored derivative (quinone-imine)} + 4H_2O$$

The intensity of the staining developed is directly proportional to the cholesterol concentration. It is determined by the increase of the absorbance at 512 nm. Reference interval: (1.25 - 2.00) (g / l)

2.3.3 HDL cholesterol

Enzymatic colorimetric assay was in homogeneous phase. In the presence of magnesium sulphate, dextran sulphate forms complex hydrosoluble with LDL, VLDL and chylomicrons [10].

$$\text{HDL} + H_2O \xrightarrow{\text{cholesterol ester cholesterol esterasemodified with PEG}} \text{cholesterol HDL} + \text{ROOH}$$

$$\text{HDP} + O_2 \text{ Cholesterol Oxidase Cholesterol Oxidase Modified by PEG } \Delta 4\text{-Cholestenone} + H_2O_2$$

$$2\ H_2O_2 + \text{4-amino-antipyrine} + \text{HSDA} * + H^+ \xrightarrow{\text{peroxidase}} \text{derivative colored blue-violet} + 5H_2O$$

The intensity of the developed coloration is directly proportional to the HDL cholesterol concentration. It is determined by the increase of the absorbance at 583 nm. Reference interval: (0.35 - 0.80) (g / l). * HSDA: sodium N-(2-hydroxy-3-sulfo-propyl) -3,5-dimethoxy aniline.

2.3.4 Creatinine

In Jaffé's reaction an alkaline solution, creatinine reacts with the picrate to form a yellow-red product.

$$\text{Creatinine} + \text{picric acid} \xrightarrow{\text{pH alkaline}} \text{complex young orange}$$

The amount of dye formed (intensity of color) is directly proportional to the creatinine concentration of the sample. It is measured by the increase of the absorbance at 512 nm. Serum and plasma samples contain proteins that react nonspecifically in the Jaffé method [11]. Reference Interval: (5.0 - 12.0) (mg / l)

2.3.5 Uric acid

Enzymatic colorimetric assay performed via using uricase and 4-amino phenazone. In a first step, uric acid is oxidized in a reaction catalyzed by uricase. The hydrogen peroxide formed reacts with [N-ethyl- (3-methylanilino)] (sodium 2-hydroxypropyl-3-sulfonate) (TOOS) and 4-amino phenazone in the presence of peroxidase (POD) to form a colored derivative quinoneimine [12].

$$\text{Uric acid} + 2\ H_2O + O_2 \xrightarrow{\text{Uricase}} \text{allantoin} + CO_2 + H_2O_2$$

$$2\ H_2O_2 + H^+ + \text{TOOS} + \text{4-aminophosphonazone} \xrightarrow{\text{Peroxidase}} \text{derivative quinone-diimine} + 4H_2O$$

The color intensity of the quinone-diimine formed is directly proportional to the uric acid concentration and is measured with the increase in absorbance at 520 nm. The addition of ascorbate oxidase makes it possible to avoid the interference of ascorbic acid. Reference range: (26 - 74) (mg / l).

2.3.6 Urea

Urea can be measured by coupled enzyme reactions that are fast, have high specificity to ammonia and are commonly used. One of these reactions has been proposed as a permissible reference method [13].

$$\text{Urea} + 2H_20 \xrightarrow{\text{urease}} 2NH_4^+ + CO_3^{2-}$$

$$NH_4^+ + \text{2-oxoglutarate} + \text{NADH} \xrightarrow{\text{GLDH}} \text{L-Glutamate} + H_2O + NAD^+$$

2.4 The parameters of the hemogram

Quantitative analyzes of red blood cells, quantitative analyzes of white blood cells and quantitative platelet analyzes [14].

2.5 Analysis devices

The biochemical parameters were analyzed on the Cobas C311 controller, and the blood parameters on a Mindray semi-automatic device.

3 Results and Discussion

3.1 Distribution of patients

3.1.1 According to the distribution by type of diabetes

According to the type of diabetes, the statistical study of this work showed that the group of diabetic patients are divided into 20% of type 1 diabetics (8 patients) and 80% of type 2 diabetics (32 patients) [15], because the number of people with type 2 diabetes increases rapidly at worldwide, this increase is associated with economic development, aging populations, increased urbanization, dietary changes and decreased physical activity and other changes in lifestyle. The results of this study reveal a higher number of type 2 diabetics than that of type 1 diabetics (Figure 1).

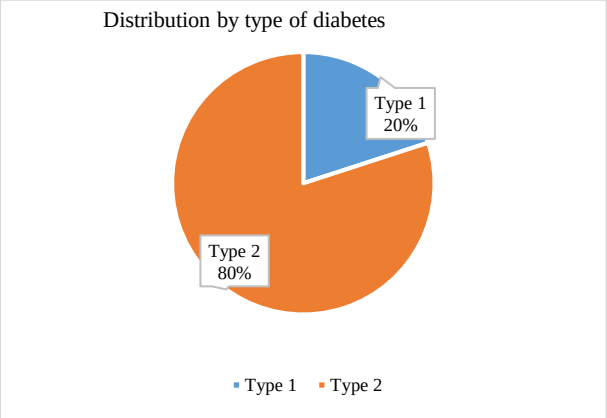

Figure 1: Distribution by type of diabetes

3.2 According to sex

Our study shows that the group of 40 diabetic patients is divided into 92.5% women (37 women) and 7.5% men (3 men) [16] we note here that most of the women in our population studies have RAMED cards (90%) have older women and unemployed. The analyzes are done for free so their main objective is to control their health, which explains the predominance of women (Fig 2) for these reasons we found that the number of women with diabetes higher than men.

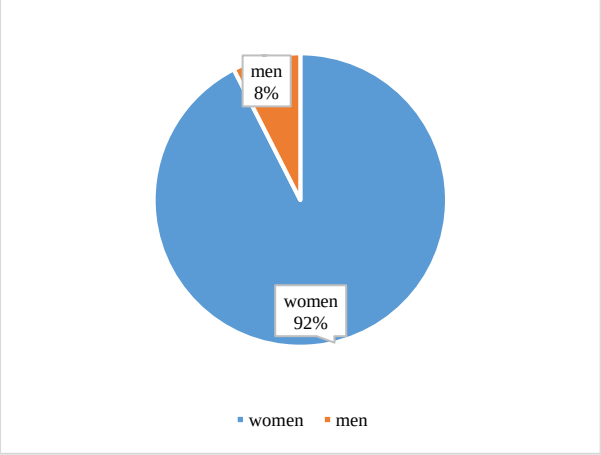

Figure 2: Distribution of patients by gender

3.3 According to age

The study shows that the group of 40 diabetic patients is divided according to age the results are grouped in the following table 1.

Table 1: Distribution of diabetic patients by age.

type of diabetic/Age	Type 1	Type 2	Total	Percentage% of patients by age
[40-50]	1	4	5	12,5%
[50-60]	2	15	17	42,5%
[60-70]	3	10	13	32,5%
[70-80]	2	2	4	10%
[80-90]	0	1	1	2,5%
Total	8	32	40	100%

The results of diabetic patients by age show that diabetic disease can affect all age groups with a predominance in the elderly. Our study shows that the diabetic disease rate in people aged 50 to 60 is 42.50%. However, for the age group of 60 to 70 years, there is a rate of 32.50%, people aged 40 to 50 years the distribution rate is 12.50%, our results also show that the rate The distribution in people aged 70 to 80 is 10% and in people over eighty is 2.50% [17] (figure 3).

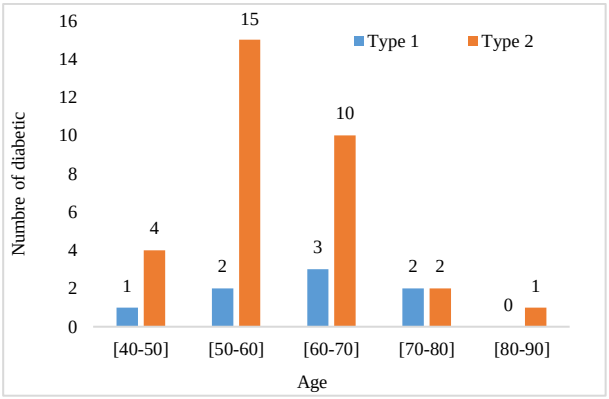

Figure 3: Distribution of diabetic patients by age

The results show that the percentage of type 2 diabetics and the average age of this population are higher compared to the percentage of people with type 1 diabetes because the number of people with type 2 diabetes increases rapidly across the population. In the world, this increase is associated with economic development, aging populations, increased urbanization, changes in diet and reduced physical activity, and other lifestyle changes [4]. Internationally, the increase in the prevalence of diabetes is observed worldwide, in both industrialized and developing countries [18]. The number of people aged 20 to 79 with diabetes in the world is estimated at 425 million in 2017 and is projected to reach 552 million in 2030 [19]. In Morocco, more than 2 million people are diabetic, 50% of whom are unaware of their disease. Unlike some data in the literature which indicates that the number of people with diabetes in the world by sex, men with diabetes are around 14 million more than women in our population we found the opposite is say that the number of diabetic women is more than the number of men [20].

3.4 According to arterial hypertension

The result of the distribution of patients according to the presence of arterial hypertension is grouped in Figure 4. This result shows that 70% of diabetic patients are hypertensive therefore most diabetic diseases have chronic patients.

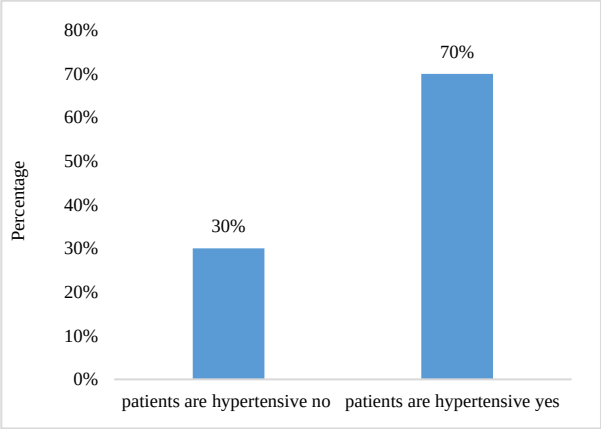

Figure 4: Distribution of patients according to the presence or absence of arterial hypertension

3.5 Comparison of the different parameters studied according to the type of diabetes

The comparison of some biochemical parameters between type 1 and type 2 diabetics is shown in Table 2.

3.6 Fasting blood glucose

Type 2 diabetics have a slightly higher average fasting glucose level of 1.93 versus 1.49 for type 1 diabetics (Tab.2 and figure 4) .The results of fasting blood glucose results indicate that type 2 diabetics have a higher fasting glucose level (1.93) however the study shows that the glucose level in type 1 diabetics is 1.49 (Tab.2). These two values are not normal (0.7 - 1.10) (g / l), according to who these fasting glucose values remain fluctuating and unstable at some patients but no significant differences between one type of diabetes and another (Fig.5) [21].

3.7 Urea in diabetics

The study shows that the average urea rate in type 1 diabetics (0.32) is higher than that in type 2 diabetics (0.25) [22], but both values remain normal (0.10-0.55), the high urea level in blood may be indicative of kidney damage (figure 6). The urea analyzes show that there is a proportional relationship between the age of the patients in diabetics and the urea value, so it is noticed that the urea rate increases with age so the patients might have a kidney and cardiovascular problem in the future. So age in patients with diabetes seems like a cardiovascular and renal risk factor [23]

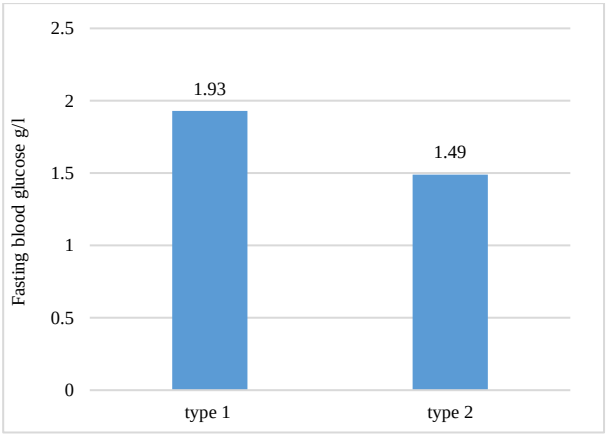

Figure 5: Fasting blood glucose by type 1 and 2

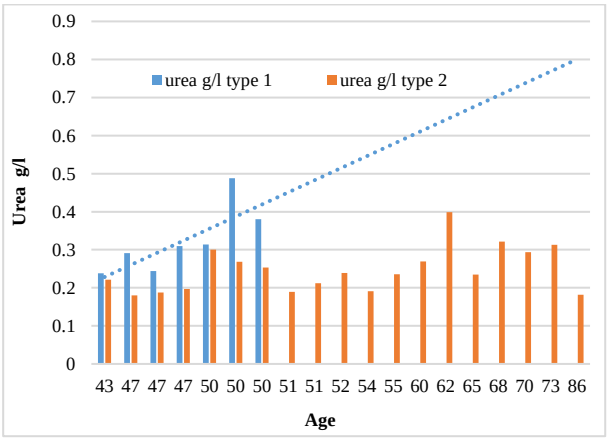

Figure 6: Urea in type 1 and 2 diabetics by age

3.8 Creatinine

From our results, we note that type 1 diabetics have a higher creatinine average 8.62 compared to 6.51 for type 2 diabetics. The increase in creatinine indicates a decrease in filtration rate glomerular, and therefore of renal failure, but our study shows that the two average creatinine values in the two types of diabetic are normal (6-12 mg / l).

Table 2: values of the various parameters analyzed

Parameter	Type 1	Type 2	Total	Standards
Percentage	20%	80%	100%	-
Age (years)	61,5	58,218	58,875	-
Weight (kg)	72,77	69,92	70,49	-
Fasting blood glucose g/l	1,930	1,4975	1,584	0,7-1,1 g/l
Urea g/l	0,323	0,253	0,271	0,10-0,55 g/l
Cholesterol g/l	1,613	1,932	1,879	⩽.2 g/l
HDL g/l	0,36	0,50	0,48	⩾0,4g/l
Creatinine mg/l	8, 625	6,518	7,00	6-12 mg/l
Uric acid mg/l	66,9	48,88	54,430	35-70 g/l

From this result we noticed that the creatinine concentrations increase with age and the creatinine concentrations in people over 60 years are more than that recorded in people under 60 years [24]. (Figure 7).

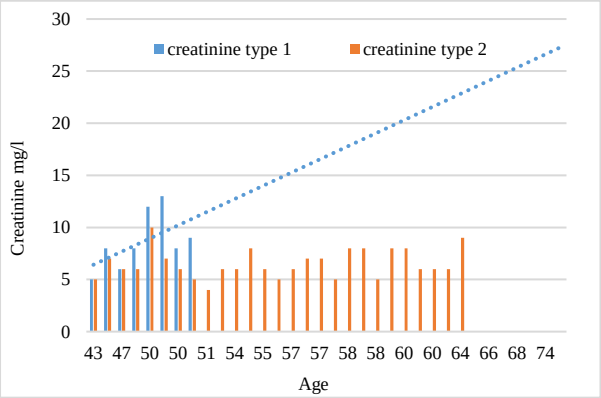

Figure 7: Creatinine values by type of diabetics as a function of age

3.9 Total cholesterol

Total cholesterol (abbreviation CT) includes HDL cholesterol and LDL cholesterol. It is often the first assessment requested by the doctor. The results should generally have a rate less than or equal to 2.00 g / l, with certain tolerances depending on the age of the patient. The total cholesterol results of our study show that the average total cholesterol in type 2 diabetics is 1.93, it seems higher than that of type 1 diabetics (1.61) [25]**.** The results show that, in type two diabetics, the average levels of all the parameters (fasting glucose, urea, creatinine and uric acid) are lower than those recorded in type 1 diabetics. On the other hand, mean levels of cholesterol total and HDL in type 2 diabetics are higher than those seen in type 1 diabetics. In the population, it is noticed that cholesterol levels increase with age, and people aged 65 to 80 have a higher cholesterol level than others. (Fig 8), it is noted here that after recording the result of total cholesterol in diabetic patients is normal [26].

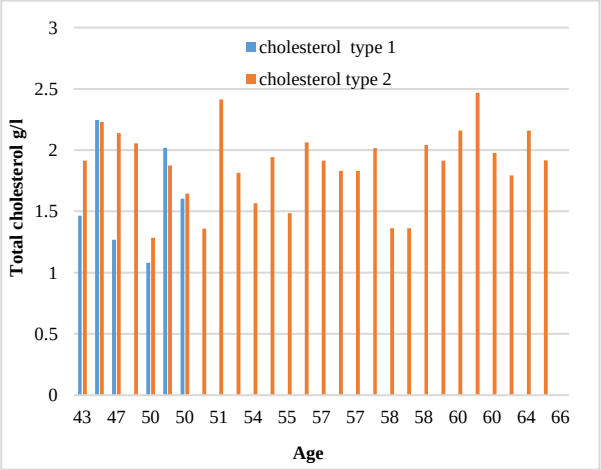

Figure 8: Total cholesterol by type of diabetes by age

3.9 HDL cholesterol

HDL cholesterol is composed of lipoproteins that carry cholesterol from the arteries to the liver. It is often called "good cholesterol" because it helps prevent the build up of cholesterol in the blood vessels. HDL results show that the average HDL value in type 2 diabetics (0,50 mg/l) is higher than the average HDL value in type 1 diabetics (0,36 mg/l) (figure 9), high HDL cholesterol levels are considered to promote protection against cardiovascular complications, including coronary heart disease.

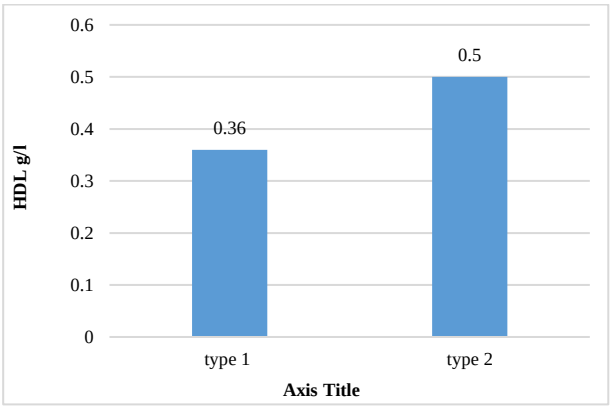

Figure 9: Mean HDL values by type of diabetes

In our population, we have noticed that cholesterol levels increase with age, and people between the ages of 65 and 80 have higher cholesterol levels than others. (Fig 7-8), we note here that we recorded that the result of total cholesterol in diabetic patients is normal, it can be said that our patients are aware of the disadvantages of cholesterol on health more precisely cardiovascular diseases and kidney failure and the second thing may be that our patients stick to their diet so it's a conscious and educated society.

3.10 Uric acid

The result of uric acid shows that type 1 diabetics have a mean uric acid (66.91 mg/l) higher than that of type 2 diabetics (48.88 mg/l). It is noted here that both values are normal (35 - 70) (mg / l). It should be noted that the analysis of the uric acid concentration will make it possible to detect the risk of gout disease or evaluate the functioning of the kidneys [27].

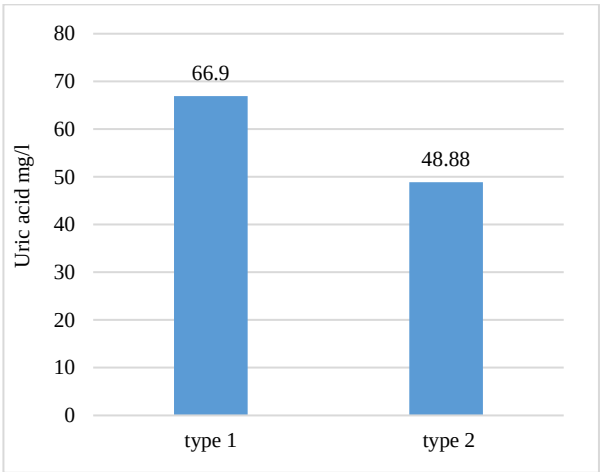

Figure 10: The average values of uric acid

It is concluded that in type 2 diabetics the average levels of all the parameters (fasting glucose, urea, creatinine and uric acid) are lower than those recorded in type 1 diabetics. On the other hand, the average levels of total cholesterol and HDL in type 2 diabetics are higher than those in type 1 diabetics, which probably accounted for the absence of cardiovascular complications in these patients and age is considered a risk factor for cardiovascular and renal diseases.

3.11 Comparison of the different cellular elements of blood that are white blood cells, red blood cells and platelets between type 1 diabetics and type 2 diabetics:

As completive step, we have made comparison of the different blood cellular measures; white blood cells, red blood cells and platelets, between type 1 diabetics and type 2 diabetics for know investigates extent of the relationship the numbers of blood cells and the disease of diabetics. Hematological analyzes between type 1 and type 2 diabetics are shown in Table 3.

3.12 The white blood cell count

The study of hematological analyzes shows that the two average values of white blood cell count in the two types of diabetic are normal (4-10 x10^9 / l). Note that type 1 diabetics have an average white blood cell count is higher 6.96 versus 5.5 for type 2 diabetics. The result of white blood cell counts indicates whether there is a bacterial infection or an inflammatory syndrome, such as rheumatism. This study shows that our patients do not have these complications [29].

3.13 The rate of red blood cells

Hematological analyzes show that type 1 diabetics have a slightly higher average red blood cell count of 4.72 compared to 4.39 for type 2 diabetics (Tab. 3), but both values are normal (4- 5.3 x109 / l). This result shows that our patients do not have anemia problem.

3.14 The platelet count

The platelet count results show that the average value of platelet count in type 2 diabetics (250.66) is higher than the average value of platelet count in type 1 diabetics (238). Generally, if the platelet count is low, it can disrupt the blood clotting process in the event of a hemorrhage [30]. These values are normal.

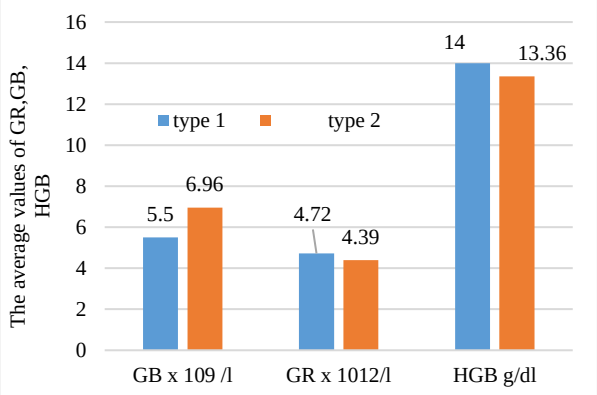

Figure 11: The average values of GR (Red blood cells), GB (White blood cells), HGB (Hemoglobin)

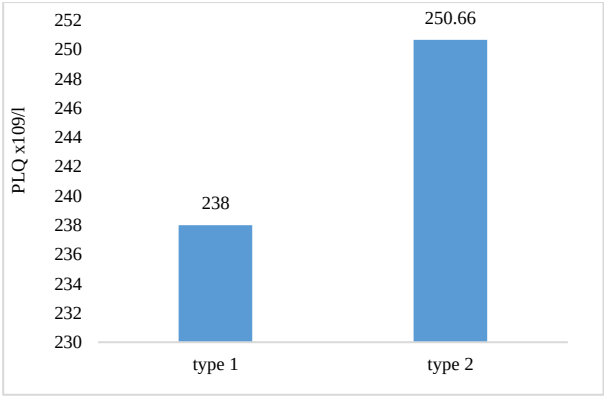

Figure 12: Average platelet values

4 Conclusion

The work was carried out on a population of 40 diabetic people, we observed a slight difference in mean values of each parameter tested between the two types of diabetes. Our results show that in type 2 diabetics the average levels of all parameters (fasting glucose, urea, creatinine and uric acid) are lower than those recorded in type 1 diabetics. However, average cholesterol levels total and HDL in type 2 diabetics are higher than those recorded in type 1 diabetics, which probably explained the absence of cardiovascular complications in the latter. Our results show that age appears to be a risk factor for cardiovascular and renal diseases. The white blood cell, red blood cell and platelet count results show that our patients do not have a problem with bacterial infection, rheumatism, anemia or blood clotting. These results demonstrate the impact of diabetes on the human body. It is a painful disease for the patient, with sometimes dramatic repercussions on the physiological balance. People with diabetes must do an analysis of many biochemical parameters (blood sugar level, lipid balance, renal balance ... etc.) regularly and several times a year in order to carry out a diagnosis and proper monitoring of their disease. The diabetic patient must follow a healthy lifestyle mainly by adapting food and increasing physical activity to live better with diabetes. Our study shows that the average urea level in type 1 diabetics (0.32) is higher than that in type 2 diabetics (0.25) but the two values remain normal (0.20-0 , 50), high urea in the blood may be a sign of kidney damage (glomerulonephritis, pyelonephritis, ischemia), uremic syndrome (destruction of red blood cells), heart damage, dehydration, gastrointestinal bleeding. The increase in serum creatinine indicates a decrease in glomerular filtration rate, and therefore in renal failure. This study remains preliminary, it requires other in-depth studies. In this context, it would be interesting to continue the research by undertaking work on a larger population to seek the factors which influence diabetes disease in order to ultimately raise awareness and reduce the number of diabetic populations in people of the world.

Table 3: The rate of white blood cells, red and platelets

	Type of diabetes 1	Type of diabetes 2	Normal value [28]
White blood cells x 10^9 /l	5,5	6,96	between 4x10^9 and 10 x 10^9/l
Red blood cells x 10^{12}/l	4,72	4,39	between 4 x 10^{12} and 5,3x 10^{12}/l
HGB g/dl	14,0	13,36	The normal value is 13.5 to 17.5 g / dl in men and 12.5 to 15.5 g / dl in women
Platelets x10^9/l	238	250	between 150 x 10^9 and 400x10^9 /l

Acknowledgements

The authors thank the head of the biochemistry laboratory of the national hygiene institute of Rabat. Special thanks must be addressed to the director of the rabat hygiene institutethe authors would like to thank my fellow Biochemistry lab colleagues for their invaluable help and especially Madame fatiha and Charadi.

Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing

References

1. Ignatiev S, Reva GV, Pervov YY, Kotsyurbii EA, and, Yatsenko AK. Morphological evaluation of the effectiveness of immune stimulating drugs in patients with diabetes and removable denture based on the analysis of biopsic material obtained from the oral mucosa. Journal of Environmental Treatment Techniques, 2020; 8: 191-196.
2. Birhan M. Review on: regenerative medicine, tissue engineering and stem cell therapy in diabetes mellitus. Journal of Life Science and Biomedicine, 2019; 9(4): 102-108.
3. Les Critères biologiques D. Sucré, Définition et classification du diabète. Médecine Nucléaire-Imagerie fonctionnelle et métabolique, 2001; 25(2): 91.
4. Srivastava PK, and Singh S. Immobilization and applications of glucose-6-phosphate dehydrogenase: a review. Preparative Biochemistry and Biotechnology, 2013; 43(4): 376-384.
5. DeFronzo RA, Ferrannini E, and Simonson DC. Fasting hyperglycemia in non-insulin-dependent diabetes mellitus: contributions of excessive hepatic glucose production and impaired tissue glucose uptake. Metabolism, 1989; 38(4): 387-395.
6. Bung P, and Artal R. Gestational diabetes and exercise: a survey. In Seminars in perinatology . WB Saunders, 1996; 20(4): 328-333.
7. Maoujoud O, Cherrah Y, Arrayhani M, Zemraoui N, Dkhissi H, El Kabbaj D, and Ahid S. Epidemiology, health economic context, and management of chronic kidney diseases in low and middle-income countries: The case of Morocco. EMJ, 2017; 2(4): 76-81.
8. Mailloux RJ, and Harper ME. Glucose regulates enzymatic sources of mitochondrial NADPH in skeletal muscle cells; a novel role for glucose-6-phosphate dehydrogenase. The FASEB Journal, 2010; 24(7): 2495-2506.
9. Lie RF, Schmitz JM, Pierre KJ, and Gochman N. Cholesterol oxidase-based determination, by continuous-flow analysis, of total and free cholesterol in serum. Clinical chemistry, 1976 ; 22(10): 1627-1630.
10. Owecki M, Nikisch E, Miczke A, Pupek-Musialik D, and Sowinski J. Serum resistin is related to plasma HDL cholesterol and inversely correlated with LDL cholesterol in diabetic and obese humans. Neuroendocrinology Letters, 2010; 31(5): 673.
11. Masson P, Ohlsson P, and Björkhem I. Combined enzymic-Jaffé method for determination of creatinine in serum. Clinical chemistry, 1981; 27(1): 18-21.
12. Nakaminami T, Ito SI, Kuwabata S, and Yoneyama H. Uricase-catalyzed oxidation of uric acid using an artificial electron acceptor and fabrication of amperometric uric acid sensors with use of a redox ladder polymer. Analytical chemistry, 1999; 71(10):1928-1934.
13. Fawcett JK, and Scott J. A rapid and precise method for the determination of urea. Journal of clinical pathology, 1960;13(2): 156-159.
14. Bryk AH, and Wiśniewski JR. Quantitative analysis of human red blood cell proteome. Journal of proteome research, 2017; 16(8): 2752-2761.
15. Hypoglycaemia Study Group UK, Risk of hypoglycaemia in types 1 and 2 diabetes: effects of treatment modalities and their duration. Diabetologia, 2007;50(6): 1140-1147.
16. West DS, Prewitt TE, Bursac Z, and Felix HC. Weight loss of black, white, and Hispanic men and women in the Diabetes Prevention Program. Obesity, 2008;16(6): 1413-1420.
17. Singh PS, Zafar KS, Kumar M, and Yadav SK. Risk of cardiovascular disease among diabetic patients in rural population of Central India. International Journal of Research in Medical Sciences, 2017; 5(4):1563.
18. King H, Aubert RE, and Herman WH. Global burden of diabetes, 1995–2025: prevalence, numerical estimates, and projections. Diabetes care, 1998; 21(9): 1414-1431.
19. Al-Quwaidhi AJ, Pearce MS, Sobngwi E, Critchley JA, and O'Flaherty M. Comparison of type 2 diabetes prevalence estimates in Saudi Arabia from a validated Markov model against the International Diabetes Federation and other modelling studies. Diabetes Research and Clinical Practice, 2014; 103(3): 496-503.
20. Chatterjee S, Peters SA, Woodward M, Arango SM, Batty GD, Beckett N, and Hassing LB. Type 2 diabetes as a risk factor for dementia in women compared with men: a pooled analysis of 2.3 million people comprising more than 100,000 cases of dementia. Diabetes care, 2016; 39(2): 300-307.
21. Emerging Risk Factors Collaboration. Diabetes mellitus, fasting blood glucose concentration, and risk of vascular disease: a collaborative meta-analysis of 102 prospective studies. The Lancet, 2010; 375(9733): 2215-2222.
22. Ivanovski K, Naumovski V, Kostadinova M, Pesevska S, Drijanska K and Filipce V. Xerostomia and salivary levels of glucose and urea in patients with diabetes. Contributions of Macedonian Academy of Sciences and Arts, 2012; 2012: 33:2.
23. Ninomiya T, Perkovic V, De Galan BE, Zoungas S, Pillai A, Jardine M, and Mogensen CE. Albuminuria and kidney function independently predict cardiovascular and renal outcomes in diabetes. Journal of the American Society of Nephrology, 2009; 20(8):1813-1821
24. Shrestha S, Gyawali P, Shrestha R, Poudel B, and Sigdel M. Serum urea and creatinine in diabetic and non-diabetic subjects. Journal of Nepal Association for Medical Laboratory Sciences, 2008; 2008:11-12.
25. Nichols GA, Hillier TA, and Brown JB. Normal fasting plasma glucose and risk of type 2 diabetes diagnosis. The American journal of medicine, 2008; 121(6): 519-524.
26. Ravid M, Brosh D, Ravid-Safran D, Levy Z, and Rachmani R. Main risk factors for nephropathy in type 2 diabetes mellitus are plasma cholesterol levels, mean blood pressure, and hyperglycemia. Archives of internal medicine, 1998; 158(9): 998-1004.
27. Dehghan A, Van Hoek M, Sijbrands EJ, Hofman A, and Witteman JC. High serum uric acid as a novel risk factor for type 2 diabetes. Diabetes care, 2008; 31(2): 361-362.
28. Iftikhar R, Khan NU, Iqbal Z, Kamran SM, and Anwar MI. Haematological Parameters in Different African Populations: An Experience From United Nations Level 3 Hospital. Pakistan Armed Forces Medical Journal, 2017; 67(6):1068-1072.
29. Kilpatrick ES, Rigby AS, and Atkin SL.The effect of glucose variability on the risk of microvascular complications in type 1 diabetes. Diabetes care, 2006; 29(7): 1486-1490.
30. Stark K. D, Van Elswyk ME, Higgins MR, Weatherford CA, and Salem N. Global survey of the omega-3 fatty acids, docosahexaenoic acid and eicosapentaenoic acid in the blood stream of healthy adults. Progress in lipid research, 2016; 63: 132-152.