International Journal of Clinical Biochemistry and Research 2023;10(4):277–283

Content available at: https://www.ipinnovative.com/open-access-journals

International Journal of Clinical Biochemistry and Research

Journal homepage: https://www.ijcbr.in/

Original Research Article

Biochemical profile of patients in ketosis-prone diabetes state in Côte d'Ivoire

Dere Kwadjo Anicet Luc[1,2]*, Koffi Konan Gervais[3], Manhan Kahissie Noel[1,2], Fofana Seguenan[1,2], Tuo Wako-Tianwa Alice[1], Tiahou Gnomblesson Georges[1,2]

[1]*Laboratory of Clinical Biochemistry of Bouake Medical School, Cote d'Ivoire*
[2]*Laboratory of Clinical Biochemistry and Nutrition of Alassane Ouattara University, Cote d'Ivoire*
[3]*Laboratory of Medical Biochemistry of Felix Houphouet-Boigny University and Treichville Medical School, Cote d'Ivoire*

ARTICLE INFO

Article history:
Received 18-11-2023
Accepted 06-12-2023
Available online 10-02-2024

Keywords:
Ketonuria
Ketosis- prone diabetes
Biochemical profile

ABSTRACT

Background: Diabetes keto-acidosis is the most serious hyperglycemic emergency in patients with diabetes. DKA has long been considered a key clinical feature of T1D. In this study, we assessed biochemical disorders focused on lipid and renal parameters in KPD.
Methodology: We carried out a case-controls study for one year, encompassing 200 participants in total. Patients were outpatients newly diagnosed diabetics attending for the first time hospitals, controls were no-ketosis participants. Blood samples were taken, after 10 to 12 hours of fasting from the day before, in different tubes for each intended analyses according to instructor's recommendation.
Results: The increased mean value of fasting blood glucose together with HbA1c are corrolated with ketonuria. As regard to cardio-metabolic risk, ketosis-prone patients were at greater risk than no-ketosis controls**.** The mean AIP value was higher in KPD women than in men, with no significant statistical correlation. Uremia and creatininemia, two kidney parameters commonly prescribed to explore glomerular filtration, were correlated with some social indicators. The mean values of these both parameters increased significantly with age in KPD group. Creatinine increased significantly with age in patients, in line with glomerular filtration rate (GFR). The older the participants, the higher the mean values of these parameters.
Conclusion: These biochemical parameters, high atherogenic index and lower glomerular filtration rate, documented in our study, must be sought out when inaugural ketosis is suspected for improving the clinical prognosis of patients in the initial step of management.

1. Introduction

Diabetes keto-acidosis (DKA) is the most serious hyperglycemic emergency in patients with diabetes. DKA has long been considered a key clinical feature of T1D, an auto-immune disorder characterized by severe and irreversible insulin deficiency. In recent years, number of KA cases without precipitating causes have also been reported in children, adolescents and adult subjects with T2D.[1] For a handful of those suffering from ketonuria, aggressive diabetes management results in significant improvement in beta-cell function and insulin sensibility leading to discontinuation of insulin therapy. This clinical presentation has been primarily reported in Africans, African-Americans and also in other minority ethnic groups. This variant of diabetes has been referred to in literature as idiopathic T1D, atypical diabetes, flatbush diabetes and more recently as ketosis-prone diabetes (KPD).[2,3] Many authors compared the accuracy of classification schemes that have attempted to predict long-term beta-cells function and insulin dependance in

* *Corresponding author*.
E-mail address: dere.kwadjoanicetluc@gmail.com (D. K. A. Luc).

https://doi.org/10.18231/j.ijcbr.2023.051

patients with DKA and the presence of Auto-antibobies (AA). They proposed the AB classification scheme based on the presence or absence of beta cell auto-antibodies and the beta-cell function. The classification scheme divided patients into four groups: Patients with AA with absent (A+B-) or preserved (A+B+) beta cell function and those without AA with absent (A-B-) or preserved (A-B+) beta cell function. Patients with beta cell function despite AA markers (A+B+) represent 7% of newly diagnosed patients with DKA and constitute the LADA group (latent auto-immune diabetes of adult).[3,4]

Mauvais-Jarvis et al[5] define KPD as: "new-onset diabetes without precipitating illness (infection, stress), with the presence of strong ketosis (urinary ketones >80 mg/dL) or DKA, and in the absence of islet cell autoantibodies (AA) and GAD65 autoantibodies". The group of major interest include those patients without AA but preserved beta-cell function (A-B+). Despite the presentation with severe metabolic decompensation, most of patients showed clinical and biochemical characteristics of T_2 Diabetes. Most of A-B+ subjects had newly- onset diabetes and more obese, middle age males with a strong family history of T2D.

Accurate diagnosis of T1D in Africa is challenging due to several atypical forms and limited ressources. Also, the peak age on onset of T1D is a decade above in western countries with lower rate of age ranging from 20-60% in sub-sahara Africa (SSA). The problem is that in SSA clinical diagnosis criteria (low BMI, younger age and ketonuria) are only used which overlap with other forms of diabetes leading to a misdiagnosis, misclassification and mistreatment.[6] In this cae-controls study, we tried to assess biochemical disorders focused on lipid and renal parameters at the moment of diagnosis of KPD in order to help in the better management of this emergency.

2. Materials and Methods

2.1. Study design

We carried out a case-controls study for approximately one year, from december 2020 to september 2021. Patients were outpatients newly diagnosed diabetics, attending one of the three different hospitals designated to implement this study. This study took place in Cote d'Ivoire (West Africa), precisely at Bouaké in the centre of the country.

2.2. Inclusion criteria

Cases were new-onset diabetes for subjects above 18 years old, with high fasting hyperglycemia above 11 mmol/ liters, ketonuria and absence of precipitating factors (fever, infectious diseases, metabolic and degenerative complications). For controls they were no-ketonuria subjects, naive of diabetes without any screening test before there inclusion in the study. Amongst controls, some participants were in hyperglycemia state. To better compare the two different populations, we strove to get the same criteria related to socio- demographic characteristics.

2.3. Data collection

We pursued our recruitment in order to get the same number of cases as controls. We have got 100 participants in ketosis-prone diabetes state and 100 participants in no-ketosis state. We registered demographic information (date of birth, urban/rural dwelling, socioeconomic status) through our study questionnaire. Anthropometrics (weight, height, body mass index (BMI) and its standard deviation (SD), waist circumference and their percentiles were also notified. BMI and WC were categorized, using the current range according to World Health Organization (WHO).[7] Blood samples were taken in different tubes for each intended analyses after 10 to 12 hours of fasting from the day before (red, grey and pink). Standard analyses encompassed of routinely parameters HbA1c, glucose, urea, creatinine and lipid prameters have been realized according to instructor's recommendation. With these results we computed and calculated atherogenic index of plasma (AIP) and glomerular filtration rate (GFR).

2.4. Ethical considerations

Approval for the study was obtained from the agreement of the scientific and medical director of the different hospitals in which the survey took place. Written informed consent was obtained from all participants (patients and controls). For patients with sub-literacy, the consent form was read aloud and signed in the presence of a witness. We recruited some people to help us for interview.

2.5. Data analysis

We computed data as part of excel and the others statistical software such as SPSS or Graph Pad Prism5. Partial data were compared between cases and controls. The comparison of means was obtained by the T-test. Results were expressed in means ± standard deviation. The level of significance of the tests used was set at $\alpha = 5\%$, difference was considered significant for P value < 0.0 5.

3. Results

In our study, we reported that the mean fasting blood glucose value increased gradually as ketonuria increased. The same trend was observed with the mean value of HbA1c. Considered in isolation, the mean values of lipid parameters were little affected by the severity of ketonuria. These disturbances were compounded by lipid disorders marked by an increasing values in both patients and controls. The maximum values obtained were 2.65 g/l, 2.19 g/l and 1.95 g/l respectively for total cholesterol, triglycerides and LDL-cholesterol in no-ketosis participants

in comparison with 3.52 g/l, 5.49 g/l and 2.25 g/l respectively in KPD patients. We mentioned a significant impact of inaugural ketosis on the renal function in ketosis patients, as mean glomerular filtration rate (GFR) values were lower in KPD patients than in no-ketosis controls. Kidney function became more impaired as the number of ketones augmented in urine (Table 1).

Severe fasting hyperglycemia, was found in all patients, with values ranging from 2.10 g/l to 6.64 g/l. High HbA1c values were also recorded in almost all KPD patients. Amongst the controls, naive of diabetes, one participant had a blood glucose level of 1.68 g/l and consequently a high value of HbA1c reaching 6%. In our cohort, we reported that the increased mean value of fasting blood glucose is corrolated with ketonuria. The same trend is observed with the mean glycated hemoglobin level (Table 2).

With regard to cardio-metabolic risk, ketosis-prone diabetes were at greater risk than no-ketosis controls, both in terms of atherogenic index and consequently in cardio-metabolic risk, which increased with the degree of ketonuria. The mean values of the atherogenic index of plasma (AIP) according to the different indicators were above the reference values, and there was a significant statistical correlation between AIP, which is also a marker of insulin resistance**.** The mean AIP value was higher in women than in men, with no significant statistical correlation even with the other socio-demographic indicators (Table 3).

Uremia and creatininemia, two kidney parameters commonly prescribed to explore glomerular filtration, were correlated with some social indicators. The mean values of these both parameters increased with age in both groups. Creatinine increasing was statistically significant with age for patients, in line with glomerular filtration rate (GFR) (Table 3). Overall, age had a negative influence on the glomerular filtration parameters such as urea and creatinine. The older the participants, the higher the mean values of these parameters.

4. Discussion

By implementing this study we strove to recruit patients having socio-demographic parameters similar to no-ketosis participants. After our previous publication based on socio-anthropometric features in ketosis-prone diabetes,[8] we pursued controls (no-ketosis participants) recruitment to have the same number of participants in both groups; so 200 participants in total. Ketosis-prone diabetes is defined as a commun syndrome, emerging with different phenotypes characterized by patients who show at the time of diagnosis a ceto-acidosis without any breaking factors and who don't have necessary the typical phenotype of auto-immun type 1 diabetes.[9,10] Thus, amongst patients there were a large range of age varying from 18 to 87 years with a mean value of 51.82 years justifying different disease forms within this studied population. This trend corroborates those reported in different Sub-Sahara Africa studies.[11,12] Traditionally, the peak age of onset of type 1 diabetes has mostly been studied amongst children and adolescents. However, recent evidence suggests that the incidence of T1D in adults may be almost as high as that seen in children and adolescents in developed countries (data from low-and-middle income countries is lacking).[13] Interestingly, a later peak age of onset seems disproportionately reported in the African literature. Most studies from SSA have consistently reported that the peak age of onset of T1D occurs about a decade later than the age of diabetes onset observed in people with T1D in Caucasian populations.[14,15] The reason for this observed difference in the peak age of onset of diabetes between patients of African and European ancestry is unknown.

High hyperglycemia, main inclusion criterion for patients, was found with values ranging from 2.10 g/l to 6.64g/l, justifying the state of ketosis including a significant presence of glucose and ketones in the urines. These disturbances were compounded by lipid disorders marked by an important lipid disorders in plasma revealed by total cholesterol, triglycerides, HDL-C and LDL-C. The mean value of atherogenic plasmatic index for all patients was largely above the normal reference, meaning that cardio-vascular risk according to this index was high in almost all patients. We found a significant statistical correlation between aging, waist circumference and AIP of patients. Our results are comparable to those found in the literature. In a nine-year longitudinal study of this index (AIP) in Taiwan, Li et al[16] noted its impact in metabolic disorders assessment. According to these authors, other indicators might play a more central role precisely in women, namely vascular adhesion molecules, dysfunctional HDL-C particles or its apoproteins and complement, which could also have an influence. However, there are few data focusing on the relationship between AIP and future risk of metabolic syndrome, hypertension and type 2 diabetes.[17] Essiarab et al[18] showed a significant association between AIP and metabolic syndrome (MetS) in the elderly, which was consistent with our data. The biological mechanisms of a higher AIP leading to an increased risk of MetS could be explained by dyslipidemia as a well-known risk factor for cardiovascular disease, dyslipidemia also plays an important role in MetS. From a pathophysiological point of view, triglyceride-rich particles have been shown to contribute to both atherosclerotic plaque formation and progression.[19] In addition to their reverse cholesterol transport function, HDL-C particles present a broad spectrum of promising biological activities such as anti-atherosclerotic effects.[20] The combination of hypertriglyceridemia and reduced HDL-C levels is not only closely linked to an increased risk of cardiovascular disease, but is also the lipid profile most frequently observed in overweight adolescents and adults.[21,22]

Table 1: Mean value of different analyzed parameters in KPD patients versus no-KPD participants

Mean value of parameters	Ketonuria (+)	Ketonuria (++)	Ketonuria (++)	No-Ketonuria
Fasting glycemia (g/l)	3.45	4.04	4.15	0.92
HbA1c	11.29	12.08	11.86	2.22
Total cholesterol (g/l)	2.05	2.06	1.89	1.62
Triglyceride (g/l)	1.36	1.65	1.46	0.83
HDL-Cholesterol (g/l)	0.47	0.49	0.45	0.41
LDL- Cholesterol (g/l)	1.43	1.21	1.15	1.04
AIP	0.41	0.46	0.47	0.28
Urea (g/l)	0.28	0.29	0.30	0.21
Creatinine (g/l)	11.18	11.39	11.51	10.01
Glomerular filtration rate (ml/min)	86.43	80.94	79.86	93.75

Range of HbA1c : Min. : 6.4% Max. : 15.5%
Range of fasting glycemia: Min.: 2.10 g/l Max.: 6.64g/l.

Table 2: Impact of clinical features on glucid parameters in KPD patients versus no-KPD participants

		KPD Patients				No-KPD Participants			
	Stratification	Glucose Mean ± SD	P	HbA1c Mean ± SD	P	Glucose Mean ± SD	P	HbA1c Mean ± SD	P
Age	< 30	3.65 ± 1.19	0.57	11.23 ± 1.26	**0.03** *	0.89 ± 0.13	0.12	2 ± 00	0.17
	30-60	3.95 ± 1.19		11.84 ± 2.20		0.93 ± 0.16		2.23 ± 0.78	
	> 60	3.84 ± 1.08		11.76 ± 1.63		0.93 ± 0.16		2.57 ± 0.97	
Gender	F	3.67 ± 0.97	0.69	11.66 ± 2.09	0.52	0.91 ± 0.18	0.58	2.32 ± 0.88	0.83
	M	4.36 ± 1.33		12.06 ± 1.13		0.94 ± 0.08		2.05 ± 0.32	
BMI	< 18	3.38 ± 0.67	0.33	11.22 ± 1.88	0.11	0.86 ±0.08	**0.04** *	2 ± 00	0.12
	18-24	3.68 ± 1.07		11.28 ± 1.76		0.92 ± 0.13		2.33 ± 0.74	
	>24	4.20 ± 1.21		12.27 ± 2.15		0.92 ± 0.16		2.22 ± 0.74	
Waist C.									
Female	≤ 88	3.78 ± 1.05	0.29	11.39 ± 1.83	0.05	0.86 ± 0.14	0.17	2.14 ± 0.66	0.08
	>88	3.59 ± 0.91		11.84 ± 2.26		0.93 ± 0.20		2.43 ± 0.98	
Male	≤ 102	4.20 ± 1.20		11.92 ± 1.90		0.94 ± 0.09		2.05 ± 0.32	
	>102	5.11 ± 1.76		12.73 ± 2.08		0.94 ± 00		2 ± 00	

*Statistically significant

Table 3: Impact of clinical features on lipid and renal parameters in KPD patients versus no-KPD participants

		KPD Patients				No-KPD Participants			
	Stratification	AIP Mean ± SD	P	GFR Mean ± SD	P	AIP Mean ± SD	P	GFR Mean ± SD	P
Age	< 30	0.60 ± 0.25	**0.05** *	103 ± 35	**0.03** *	0.19 ± 0.17	0.28	97 ± 19	0.06
	30-60	0.44 ± 0.22		83 ± 22		0.28 ± 0.18		94 ± 21	
	> 60	0.46 ± 0.26		76 ± 23		0.44 ± 0.17		84 ± 16	
Gender	F	0.43 ± 0.23	0.61	81 ± 26	0.42	0.30 ± 0.17	0.58	94 ± 22	0.52
	M	0.49 ± 0.23		85 ± 23		0.24 ± 0.21		93 ± 17	
BMI	< 18	0.40 ± 0.16	0.09	101 ± 12	**0.04** *	0.12 ± 0.11	0.17	110 ± 20	0.09
	18-24	0.49 ± 0.24		94 ± 23		0.22 ± 0.15		100 ± 18	
	>24	0.43 ± 0.23		92 ± 20		0.31 ± 0.20		90 ± 21	
Waist C.									
Female	≤ 88	0.39 ± 0.19	**0.01** *	94 ± 18	**0.02** *	0.27 ± 0.14	0.07	104 ± 17	0.20
	>88	0.46 ± 0.25		95 ± 23		0.32 ± 0.19		88 ± 23	
Male	≤ 102	0.50 ± 0.23		91 ± 10		0.25 ± 0.21		94 ± 17	
	>102	0.41 ± 0.21		109 ± 11		0.06 ± 00		65 ± 00	

In KPD patients, increased creatinine leading to a reduction in glomerular filtration rate were observed in correlation with the importance of ketonuria, with a significant correlation with age and weigh. Our results are in line with literature. There is an adverse effect of aging in renal changes, both anatomically and physiologically. Renal aging is accompanied by progressive renal atrophy, mainly in the cortex. Histologically, there is a progressive reduction in the number of functional nephrons, which begins around the age of 40 and increases with age. Like other organs, the kidneys undergo a gradual reduction in functional mass, replaced by fat and fibrous tissues. The most significant change is the progressive reduction of renal blood flow by 10% per decade from the age of 40[23,24] reducing glomerular filtration rate and limiting renal elimination capacity.[25] Despite this drop in glomerular filtration rate, creatinine levels in the elderly are generally comparable to younger subjects, due to the reduced muscle mass they undergo. This process is aggravated by hypertension or diabetes mellitus. Diabetic nephropathy is a serious complication of both type 1 and type 2 diabetes. For the other social indicators, no statistically significant relationship was found. The impact of age and gender on variations in these metabolites was also found in non-diabetic participants.

We found a high mean value for lipid parameters in correlation with anthropometric parameters such as body mass index and waist circumference in both groups. Mean values in controls were normal, while in diabetics they reached pathological thresholds. The correlation between triglyceride levels and these anthropometric parameters was statistically significant in diabetics, thus we noted triglycerides increasing in overweight individuals, in contrast to total cholesterol levels. In addition, an increase in the cardiovascular risk factor was observed in overweight and obese patients in terms of mean LDL-C and IAP index values. In our series, mean LDL-C values increased in the same direction as BMI and waist circumference. Our results corroborate those reported in the literature.[26] There was also a significant relationship between atherogenic index of plasma and waist circumference in ketosis patients, and the same trend was observed in no-ketosis. Waist circumference might therefore be a better indicator for assessing cardiovascular risk, as it reflects abdominal obesity, which might be the clinical expression of the insulin resistance syndrome and the substratum for numerous metabolic disorders.

Otherwise, the atherogenic index of plasma is used as a marker to assess the state of insulin resistance, making it possible to evaluate the rate of insulin secretion and/or its action in diabetics. Computing this index might be highly beneficial in our limited ressource context for the management and monitoring of patients without healthcare insurance, and might avoid needing costly investigations such as insulinemia or C-peptidemia in managing and monitoring of diabetes mellitus. Hermans et al.[26] reported a high prevalence of atherogenic dyslipidemia within type 2 diabetes cohort through this index and stated that it was strongly linked to a cardiometabolic phenotype characterized by insulin resistance, metabolic syndrome, hyperinsulinemia, central fat accumulation, hepatic steatosis and sedentary lifestyle. Finally, this ratio was linked to decreased insulin secretion, loss of β-cell function, poor glycemic control and higher frequency of microangiopathies. In their report, Li et al. mentioned that diabetic dyslipidemia could prevent glucose into the cell, leading to impaired glucose oxidation, hence insulin resistance. In addition, increasing triglyceride levels alter both the quantity and activity of insulin receptors on adipocytes.[27] Decreased HDL-C concentrations could play a negative role in β-cell function by decreasing insulin sensitivity and secretion. On the other hand, elevated triglyceride and free fatty acid levels, together with a drop in HDL-C, could be the result of insulin resistance. The both phenomena may interact at the same time, illustrating the "vicious circle" of dyslipidemia-insulin resistance and hyperinsulinemia.[28]

Urea and creatinine mean values, for no-ketosis participants, increased in the same direction as BMI and waist circumference in men as in women with and without disease. These values were statistically significant in correlation with BMI, as were mean glomerular filtration rate values. This suggests that overweight and obesity have a straight impact on glomerular filtration rate parameters. This trend was also observed with waist circumference and was significant with creatinine in ketosis patients. Numerous population-based studies have shown an association between measurement of obesity and the development and progression of renal failure.[29] A higher BMI is associated with the presence[30] and development of proteinuria in people without renal disease.[31–33] Furthermore, in numerous large-scale population-based studies, higher BMI appears to be associated with the presence[34] and development of low glomerular filtration rate (GFR),[35] with a loss of estimated GFR over time.[36] A few studies examining the association of abdominal obesity using waist circumference with chronic kidney disease, describe an association between higher circumference and albuminuria,[37] a decrease in GFR.[30] In general, associations between obesity and renal outcome persist even after adjustments because of possible mediators of the cardiovascular and metabolic effects of obesity, such as hypertension and diabetes mellitus, suggesting that obesity may affect kidney function by mechanisms partly unrelated to these complications.

5. Conclusion

We noted the initial biochemical disorders that appear with the disease, namely the increased cardio-metabolic risk

in patients, with a high atherogenic index of plasma and a significant failure in glomerular filtration rate. These biochemical indicators, documented in our study, must be sought out when inaugural ketosis is suspected for improving the clinical prognosis of patients in the initial step of management. Most patients with ketosis-prone diabetes can discontinue insulin therapy within a few months of treatment. Thus, a patient newly diagnosed with ketoacidosis, particularly if overweight/obese and from a minority ethnic group, is more likely to present with clinical and immunological features of type 2 rather than type 1 during follow-up. However, the characterization of this nosological entity, inaugural ketosis, with several confounding elements in the discrimination with type 2 diabetes and type 1 diabetes, requires more appropriate biological explorations in order to make a precise and unequivocal diagnosis. Since diagnosis is based on the presence of preliminary signs, we need research units in our laboratories capable of carrying out immunological analyses, through the search for autoantibodies, and above all genotypic analyses based on HLA and the genome wide association study (GWAS), enabling stratification in order to adopt the right treatment for each type of diabetes.

6. Source of Findings

This study was in large part granted by GNCDP (global non communicable disease program) of Mc Gill University with the support of Prof. Polychronakos and Julia Von O.

7. Conflict of Interest

None.

References

1. Singh GC, Ahmed M, Zaid M, Hasnain S. Biochemical, serological, and genetic aspects related to gene HLA-DQB1 and its association with type 1 diabetes mellitus (T1DM). *Mol Genet Genomic Med*. 2020;8(5):e1147.
2. Al-Mutairi HF, Mohsen AM, Al-Mazidi ZM. Genetics of type 1 diabetes mellitus. *Kuwait Med J*. 2007;39(2):107.
3. Katsarou A, Gudbjörnsdottir S, Rawshani A, Dabelea D, Bonifacio E, Anderson BJ, et al. Type 1 diabetes mellitus. *Nat Rev Dis Primers*. 2017;3:17016.
4. Diagnosis and classification of diabetes mellitus. *Diabetes Care*. 2014;37(Suppl 1):81–90.
5. Mauvais-Jarvis F, Sobngwi E, Porcher R, Riveline JP, Kevorkian JP, Vaisse C, et al. Ketosis-prone type 2 diabetes in patients of sub-Saharan African origin: clinical pathophysiology and natural history of β-cell dysfunction and insulin resistance. *Diabetes*. 2004;53(3):645–53.
6. Katte JC, Mcdonald TJ, Sobngwi E, Jones AG. The phenotype of type 1 diabetes in sub-Saharan Africa. *Front Public Health*. 2023;11:1014626.
7. Tchang BG, Saunders KH, Igel LI. Best Practices in the Management of Overweight and Obesity. *Med Clin North Am*. 2021;105(1):149–74.
8. Dere KAL, Djoupo AP, Djenebou C, Seguenan F, Tiahou GG. Socio-anthropometric features and lifestyle in ketosis-prone diabetes vs controls. *Int J Clin Biochemis Res*. 2022;9(2):141–7.
9. Maldonado MR, Otiniano ME, Cheema F, Rodriguez L, Balasubramanyam A. Factors associated with insulin discontinuation in subjects with ketosis-prone diabetes but preserved beta-cell function. *Diabet Med*. 2005;22(12):1744–50.
10. Otiniano ME, Balasubramanyam A, Maldonado M. Presence of the metabolic syndrome distinguishes patients with ketosis-prone diabetes who have a type 2 diabetic phenotype. *J Diabetes Complications*. 2005;19(6):313–8.
11. Balcha SA, Phillips DIW, Trimble ER. Type 1 diabetes in a resource-poor setting: malnutrition related, malnutrition modified, or just diabetes? *Curr Diab Rep*. 2018;18(7):47.
12. Asanghanwa M, Gorus FK, Weets I, Auwera BV, Aminkeng F, Mbunwe E, et al. Clinical and biological characteristics of diabetic patients under age 40 in Cameroon: relation to autoantibody status and comparison with Belgian patients. *Diabetes Res Clin Pract*. 2014;103(1):97–105.
13. Harding JL, Wander PL, Zhang X, Li X, Karuranga S, Chen H. The Incidence of adult-onset type 1 diabetes: a systematic review from 32 countries and regions. *Diabetes Care*. 2022;45(4):994–1006.
14. Kalk WJ, Huddle KR, Raal FJ. The age of onset and sex distribution of insulin-dependent diabetes mellitus in Africans in South Africa. *Postgrad Med J*. 1993;69(813):552–6.
15. Alemu S, Dessie A, Seid E, Bard E, Lee PT, Trimble ER, et al. Insulin-requiring diabetes in rural Ethiopia: should we reopen the case for malnutrition-related diabetes? *Diabetologia*. 2009;52(9):1842–5.
16. Li YW, Kao TW, Chang PK, Chen WL, Wu LW. Atherogenic index of plasma as predictors for metabolic syndrome, hypertension and diabetes mellitus in Taiwan citizens: a 9-year longitudinal study. *Sci Rep*. 2021;doi:10.1038/s41598-021-89307-z.
17. Onat A, Can G, Kaya H, Hergenc G. Atherogenic index of plasma" (log10 triglyceride/high-density lipoprotein-cholesterol) predicts high blood pressure, diabetes, and vascular events. *J Clin Lipidol*. 2010;4(2):89–98.
18. Essiarab F, Taki H, Lebrazi H, Sabri M, Saile R. Usefulness of lipid ratios and atherogenic index of plasma in obese Moroccan women with or without metabolic syndrome. *Ethn Dis*. 2014;24(2):207–12.
19. Ginsberg H. New perspectives on atherogenesis: Role of abnormal triglyceride-rich lipoprotein metabolism. *Circulation*. 2002;106(16):2137–42.
20. Rye KA, Bursill CA, Lambert G, Tabet F, Barter PJ. The metabolism and anti-atherogenic properties of HDL. *J Lipid Res*. 2009;50:195–200.
21. Christian JB, Juneja MX, Meadowcroft AM, Borden S, Lowe KA. Prevalence, characteristics, and risk factors of elevated triglyceride levels in US children. *Clin Pediatr (Phila)*. 2011;50(12):1103–9.
22. Lima S, Lyra CO, Pinheiro LGB, deAzevedo PRM. Association between dyslipidemia and anthropometric indicators in adolescents. *Nutr Hosp*. 2011;26(2):304–10.
23. Jaeger C. Physiologie du vieillissement. *EMC - Kinésithérapie Méd Phys Réadap*. 2018;14:1–11.
24. Muhlberg W, Platt D. Age-dependent changes of the kidneys: pharmacological implications. *Gerontology*. 1999;45(5):243–53.
25. deLeeuw PW. Renal function in the elderly: results from the European working party on high blood pressure in the elderly trial. *Am J Med*. 1991;90(3A):45–9.
26. Hermans MP, Ahn SA, Rousseau MF. The atherogenic dyslipidemia ratio [log(TG)/HDL-C] is associated with residual vascular risk, beta-cell function loss and microangiopathy in type 2 diabetes females. *Lipids Health Dis*. 2012;11:132.
27. Goodpaster BH, Kelley DE. Skeletal muscle triglyceride: Marker or mediator of obesity-induced insulin resistance in type 2 diabetes mellitus? *Curr Diab Rep*. 2002;2(3):216–22.
28. Steiner G, Vranic M. Hyperinsulinemia and hypertriglyceridemia, a vicious cycle with atherogenic potential. *Int J Obes*. 1982;6(Suppl1):117–24.
29. Kovesdy CP, Furth SL, Zoccali C, Zoccali. Obesity and Kidney Disease: Hidden Consequences of the Epidemic. *Can J Kidney Health Dis*. 2017;4:1–10.
30. Pinto-Sietsma SJ, Navis G, Janssen WMT, deZeeuw D, Gans ROB, deJong PE, et al. A central body fat distribution is related to

renal function impairment, even in lean subjects. *Am J Kidney Dis*. 2003;41(4):733–41.
31. Foster MC, Hwang SJ, Larson MG, Lichtman JH, Parikh NI, Vasan RS, et al. Overweight, obesity, and the development of stage 3 CKD: the Framingham Heart Study. *Am J Kidney Dis*. 2008;52(1):39–48.
32. Kramer H, Luke A, Bidani A, Cao G, Cooper R, Mcgee D. Obesity and prevalent and incident CKD: the Hypertension Detection and Follow-Up Program. *Am J Kidney Dis*. 2005;46(4):587–94.
33. Chang A, Horn LV, Jacobs DR, Liu K, Muntner P, Newsome B, et al. Lifestyle-related factors, obesity, and incident microalbuminuria: the CARDIA (Coronary Artery Risk Development in Young Adults) study. *Am J Kidney Dis*. 2013;62(2):267–75.
34. Ejerblad E, Fored CM, Lindblad P, Fryzek J, Mclaughlin JK, Nyren O. Obesity and risk for chronic renal failure. *J Am Soc Nephrol*. 2006;17(6):1695–1702.
35. Gelber RP, Kurth T, Kausz AT, Manson JE, Buring JE, Levey AS. Association between body mass index and CKD in apparently healthy men. *Am J Kidney Dis*. 2005;46(5):871–80.
36. Lu JL, Molnar MZ, Naseer A, Mikkelsen MK, Kalantar-Zadeh K, Kovesdy CP. Association of age and BMI with kidney function and mortality: a cohort study. *Lancet Diabetes Endocrinol*. 2015;3(9):704–14.
37. Thoenes M, Reil JC, Khan BV, Bramlage P, Volpe M. Abdominal obesity is associated with microalbuminuria and an elevated cardiovascular risk profile in patients with hypertension. *Vasc Health Risk Manag*. 2009;5(4):577–85.

Author biography

Dere Kwadjo Anicet Luc, Biologist Researcher

Koffi Konan Gervais, Biologist

Manhan Kahissie Noel, Biologist

Fofana Seguenan, Biologist

Tuo Wako-Tianwa Alice, Biologist

Tiahou Gnomblesson Georges, Biologist

Cite this article: Luc DKA, Gervais KK, Noel MK, Seguenan F, Alice TWT, Georges TG. Biochemical profile of patients in ketosis-prone diabetes state in Côte d'Ivoire. *Int J Clin Biochem Res* 2023;10(4):277-283.