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ORIGINAL ARTICLE

Serum Electrolyte Levels among Patients with Type 2 Diabetes Mellitus in Sana'a City, Yemen

Abdulhabib R. Alqubaty[1], Ali Alhaj[1*], Farouk Al-qadasi[2]
[1] Department of Biochemistry, Faculty of Medicine and Health Sciences, University of Science and Technology; [2] Department of Statistics, International organization of Migration, Sana'a, Yemen

***Corresponding Author:**
Ali Alhaj
Department of Biochemistry, Faculty of Medicine and Health Sciences, University of Science and Technology, Sana'a, Yemen
email: alhajjj20@yahoo.com

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ABSTRACT

Background: This study was conducted to determine the serum levels of electrolytes (sodium, potassium and chloride) in patients with type 2 diabetes mellitus (T2DM) in Sana'a city, Yemen.

Methods: This cross-sectional study was conducted among 100 T2DM patients compared to 100 non-diabetic subjects from January to April 2019. Sociodemographic and anthropometric data were collected using a questionnaire. Five milliliters of blood were collected, processed and analyzed for fasting blood sugar (FBS) and serum electrolytes. Statistical analysis was performed using appropriate statistical tests, and statistical significance was considered at *P*-values <0.05.

Results: The mean values of serum sodium were comparably equal in T2DM patients and non-diabetic subjects. In contrast, the mean value of potassium was slightly significantly higher in T2DM patients compared to non-diabetic subjects. The mean value of chloride was significantly lower in T2DM patients compared to non-diabetic subjects. On the other hand, the mean value of serum potassium was significantly higher among overweight T2DM patients compared to non-overweight patients. There was a non-significant correlation between the age, body mass index (BMI) and the duration of diabetes and the mean values of serum electrolytes, whereas FBS was negatively correlated with the mean values of serum sodium and chloride.

Conclusions: Altered serum electrolytes levels among T2DM patients in Sana'a city are characterized by hyperkalemia and hypochloremia. The mean value of serum potassium is significantly higher among overweight T2DM patients, and FBS can shows a significant negative correlation with serum sodium and chloride.

Keywords: Type 2 diabetes mellitus; Electrolytes; Fasting blood sugar; Sana'a

INTRODUCTION

Diabetes mellitus (DM) is a heterogeneous group of metabolic disorders characterized by a high blood glucose level (hyperglycemia) with alteration in carbohydrate, lipid and protein metabolism due to defective insulin secretion and/or action [1]. Type 2 DM (T2DM) is a common chronic disease of adults, which presents with acute, sometimes life-threatening, symptomatic hyperglycemia [2]. Lack of insulin, whether absolute or relative, affects the metabolism of carbohydrates, proteins, lipids, water and electrolytes [3].

Electrolytes in body fluids contribute to important functions, including the control of the electrical gradient of body fluids, acid-base balance, nerve signal conduction, blood coagulation and muscle contraction [4]. Sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and chloride (Cl^-) are major body minerals that play a role in metabolism and enzyme activities [5]. Disturbances in serum electrolyte levels are associated with T2DM [6]. Electrolyte imbalance may lead to clinical abnormalities or disorders, which are frequently associated with increased morbidity and mortality [7]. The altered distribution of electrolytes in patients with T2DM is related to hyperglycemia-induced osmotic fluid shifts or total-body deficits due to osmotic diuresis [8]. The relation between blood glucose and

electrolytes is complex and is related to a number of other factors like age and associated conditions [9].

Findings of serum electrolyte levels in T2DM patients are contradictory. No published studies were found from Yemen. Therefore, this study was conducted to determine major serum electrolytes levels in patients with T2DM in Sana'a city, Yemen.

METHODS

Study design, setting and population

This was a comparative, hospital-based cross-sectional study conducted at outpatient clinics of two major hospitals in Sana'a city, Al-Thawra Modern General Hospital (a public hospital) and University of Science and Technology Hospital (a private hospital) from January to April 2019.

The study included 100 patients with confirmed T2DM of both sexes diagnosed with diabetes for more than one year as well as 100 non-diabetic subjects. All study participants were adults aged between 27 and 80 years old. T2DM patients were diagnosed as per the guidelines of the American Diabetes Association, where diabetes was considered if patients had a fasting blood glucose level of ≥126mg/dl (7.0 mmol/L) [10].

Data collection and anthropometric measurements

Demographic data about age, sex and T2DM history and duration were collected using a predesigned, structured questionnaire through interviews. Anthropometric parameters were measured based on WHO guidelines, where body mass index (BMI) was calculated by dividing the weight in kg by the square height of the subject in meters [11]. Participants were classified according to BMI as underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (≥30 kg/m^2) [11]. Diabetic patients with a history of renal disease and those using diuretics during data collection or with other causes of fluid loss and pregnant women were excluded from the study.

The protocol of the study was reviewed and approved by the Research Ethics Committee of the Faculty of Medicine and Health Sciences, University of Science and Technology. Written informed consent was obtained from each participant after explaining the purpose of the study and before starting the interview. The study was done according to The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans. Patients were assured that their information would be used only for research purposes and the information given would be treated with the utmost confidentiality.

Sample collection

Five milliliters of blood were collected after overnight fasting from all participants. Sera were then separated and stored at 4°C for the measurement of fasting blood sugar (FBS) and the serum sodium, potassium, and chloride.

Biochemical measurements

Biochemical measurements of glucose and electrolytes were performed in the Biochemistry Laboratory of the University of Science and Technology Hospital in Sana'a. FBS was measured by the enzymatic reference method using a commercial kit with Cobas c311 analyzer (Roche Diagnostics, USA). Electrolytes were measured by the ion-selective electrode (ISE) method using a commercial kit with Cobas c311 (Roche Diagnostics, USA)

Statistical analysis

Data were analyzed using IBM SPSS Statistics, Version 21.0 (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as frequencies and proportions, while quantitative variables were expressed as mean ± standard deviation (SD). Differences between the means of the two groups were tested using the student's t-test for independent samples, while the chi-square test was used to test the differences between categorical variables. Pearson's correlation was used to test the correlation between quantitative variables. Statistical significance was considered at *P*-values <0.05.

RESULTS

Characteristics of the study participants

Table (1) shows that 58.0% of T2DM patients were males compared to 41.0% in non-diabetic subjects. The mean age and BMI of T2DM patients (47.9 ± 11.7 years and 26.5 ± 5.1 kg/m^2, respectively) were higher than those of non-diabetic subjects (34.6 ± 10.3 years and 24.0 ± 5.1 kg/m^2, respectively). Most T2DM patients (44.0%) were overweight followed by those with normal weight (34.0%) and obese (19.0%), whereas most non-diabetic subjects had normal weight (44.0%) followed by overweight (34.0%) and underweight (12.0%). The mean values of FBS were 177.4 ± 78.5 mg/dl and 86.9 ± 10.3 mg/dl in T2DM patients and their non-diabetic counterparts, respectively. T2DM patients who had a family history of diabetes were 67.0% compared to 54.0% for non-diabetic subjects. The mean duration of the disease among diabetics was 6.7 ± 5.2 years (range: 1 – 26 years).

Comparison of serum electrolytes between T2DM patients and non-diabetic subjects

Table (2) shows that mean values of sodium were comparably equal in T2DM patients and non-diabetic subjects, with no statistically significant difference between the two groups. In contrast, the mean value of potassium was slightly but significantly higher in T2DM patients compared to non-diabetic subjects (4.4 ± 0.4 mmol/L *vs.* 4.2 ± 0.3 mmol/L, respectively; *P* = 0.001), and the mean value of chloride was significantly lower in T2DM patients compared to non-diabetic subjects (107.4 ± 3.1 mmol/L *vs.* 108.4 ± 2.8 mmol/L, respectively; *P* = 0.020).

Comparison of serum electrolytes in T2DM patients in relation to their characteristics

Table (3) shows that the mean value of serum potassium was significantly higher among overweight T2DM patients compared to non-overweight patients (4.5 ± 0.3 mmol/L *vs.* 4.3 ± 0.3 mmol/L, respectively; *P* = 0.039). However, no statistically significant differences between the mean values of serum sodium, potassium, or chloride of T2DM patients according to the sex, age, family history or duration of diabetes and the type of drug used for treatment.

Correlation between serum electrolytes and independent variables in T2DM patients

Table (4) shows a non-significant correlation between the age, BMI and duration of diabetes of T2DM patients and their mean values of serum electrolytes, whereas FBS was negatively correlated with the mean values of serum sodium (*r* = -0.37, *P* <0.001) and chloride (*r* = -0.54, *P* <0.001).

Table 1: Characteristics of T2DM patients and non-diabetic subjects included in the study

Variable	T2DM patients (*N* = 100)		Non-diabetic subjects (*N* = 100)	
	n	(%)	*n*	(%)
Sex				
Male	58	(58.0)	41	(41.0)
Female	42	(42.0)	59	(59.0)
Age (years)				
Mean ± SD:	47.9 ± 11.7		34.6 ± 10.3	
Range:	27-80		20-65	
≤40	32	(32.0)		
>40	68	(68.0)		
BMI (kg/m^2) [a]				
Mean ± SD:	26.5 ± 5.1		24.0 ± 5.1	
Underweight	3	(3.0)	12	(12.0)
Normal	34	(34.0)	44	(44.0)
Overweight	44	(44.0)	34	(34.0)
Obesity	19	(19.0)	10	(10.0)
FBS (mg/dL)				
Mean ± SD:	177.5 ± 78.5		86.9 ± 10.3	
Family history of diabetes				
Yes	67	(67.0)	54	(54.0)
No	33	(33.0)	46	(46.0)
Duration of diabetes (years)				
Mean ± SD:	6.7 ± 5.2		N/A	
Range:	1–26		N/A	

[a]: Underweight (BMI <18.5 kg/m2), normal weight (BMI = 18.5–24.9 kg/m2), overweight (BMI = 25.0–29.9 kg/m2), and obese (BMI ≥30 kg/ m2). FBS: fasting blood sugar; N/A: not applicable; SD: standard deviation; T2DM: type 2 diabetes mellitus.

Table 2. Comparison of serum electrolytes between T2DM patients and non-diabetic subjects attending outpatient clinics of hospitals in Sana'a city, Yemen (2019)

Serum electrolytes (mmol/L)	T2DM patients	Non-diabetic subjects	
	Mean (SD)	Mean (SD)	***P*-value**
Sodium	139.4 (3.4)	139.3 (3.0)	0.776
Potassium	4.4 (0.4)	4.2 (0.3)	0.001
Chloride	107.4 (3.1)	108.4 (2.8)	0.020

SD: standard deviation; T2DM: type 2 diabetes mellitus.

Table 3. Comparison of serum electrolytes in T2DM patients attending outpatient clinics of hospitals in Sana'a city, Yemen (2019) in relation to their characteristics

Characteristics	Mean (SD) values of serum electrolytes (mmol/L)					
	Sodium	*P*-value	Potassium	*P*-value	Chloride	*P*-value
Sex						
Male	139.4 (3.9)	0.882	4.4 (0.4)	0.688	107.0 (3.4)	0.091
Female	139.5 (2.7)		4.4 (0.4)		108.0 (2.4)	
Age (years)						
≤40	138.5 (3.7)	0.058	4.3 (0.3)	0.066	107.0 (3.8)	0.293
>40	139.8 (3.2)		4.4 (0.39)		107.7 (2.7)	
Overweight or obesity [a]						
Yes	139.4 (3.6)	0.896	4.5 (0.3)	0.039	107.6 (3.0)	0.644
No	139.5 (3.2)		4.3 (0.3)		107.3 (3.2)	
Family history of diabetes						
Yes	139.5 (3.3)	0.690	4.4 (0.39)	0.230	107.6 (3.1)	0.550
No	139.2 (3.7)		4.5 (0.33)		107.2 (3.0)	
Duration of diabetes (years)						
≤6	139.7 (3.9)	0.271	4.4 (0.4)	0.884	107.6 (3.1)	0.533
>6	139.0 (2.6)		4.4 (0.4)		107.2 (3.1)	
Type of drug used						
Insulin	139.5 (2.3)	0.974	4.3 (0.4)	0.361	107.5 (3.5)	0.971
Non-insulin [b]	139.4 (3.6)		4.4 (0.4)		107.4 (3.0)	

[a] : Overweight or obesity (BMI ≥ 25.0 kg/m2), while non-overweight (BMI <25.0 kg/ m2); [b]:The non-insulin diabetics used by the patients were metformin, sulfonylurea and meglitinides; SD: standard deviation; T2DM: type 2 diabetes mellitus.

Table 4. Correlation between serum electrolytes and independent variables in T2DM patients attending outpatient clinics of hospitals in Sana'a city, Yemen (2019)

Variable	Serum electrolytes (mmol/L)					
	Sodium		Potassium		Chloride	
	r	*P*-value	*r*	*P*-value	*r*	*P*-value
FBS (mg/dL)	-0.37	<0.001	0.02	0.867	-0.54	<0.001
Age (years)	0.19	0. 066	0.08	0.423	0.13	0. 197
BMI (kg/m^2)	-0.13	0. 203	0.17	0.096	-0.01	0. 954
Duration of diabetes (years)	0.02	0. 876	0.03	0.754	0.08	0. 455

BMI: body mass index; FBS: fasting blood sugar; *r*: Pearson's correlation coefficient; T2DM: type 2 diabetes mellitus.

DISCUSSION

The significantly higher mean potassium level with non-significant difference in the mean sodium levels among Yemeni T2DM patients compared to non-diabetic subjects in the present study are consistent with previously reported findings elsewhere [9, 12-16]. Potassium redistribution from the intracellular to extracellular compartment (shift hyperkalemia) can induce hyperkalemia with no net total body potassium increase. Hyperkalemia is associated with impaired insulin secretion and decreased peripheral glucose utilization, which results in carbohydrate intolerance and hyperglycemia [13]. The present study revealed a significantly higher potassium level among overweight or obese T2DM patients. It is noteworthy that potassium level can be correlated with central obesity and metabolic syndrome [17] and is a risk factor of T2DM [18]. Such high potassium levels can be associated with severe clinical outcomes [19]. On the other hand, Hypernatremia and hyperosmolarity could contribute to the occurrence of DM [20]. Increased or normal plasma sodium concentrations with hyperglycemia indicate a clinically significant deficit in total body water [9, 13, 14]. DM is linked to both hypo- and hypernatremia, reflecting the coexistence of hyperglycemia-related mechanisms that can change serum sodium in opposite directions [21].

The findings of the present study are in disagreement with those reported by other studies [6, 22-25], which showed a significant reduction in serum potassium and sodium levels in subjects with DM. Diabetic hyperglycemia causes shifting of water from the intracellular to extracellular space, leading to the dilution and decrease in extracellular sodium [8]. On the other hand, non-significantly high serum potassium level was observed in Chinese patients with T2DM compared to controls [6], and non-significant variation in sodium and potassium levels was reported among Indian diabetic patients compared to non-diabetics [26].

The significantly lower mean level of chloride among T2DM patients compared to non-diabetics in the present study is consistent with the significantly higher chloride levels among Pakistani patients with uncontrolled T2DM [27]. This finding is also consistent with that reported among Indian patients with T2DM [28], where the abnormalities in serum electrolytes, including hypochloremia, were common in diabetic patients as the renal function started to deteriorate. However, the finding of the present study is in contrast to the finding reported elsewhere by other studies [14, 16, 22, 24], which reported hyperchloremia in diabetic patients. The more frequent presence of hyperchloremia in T2DM patients compared to non-diabetic subjects could be attributed to hypertonicity; however, hyperglycemia has not been shown to have a significant impact on the level of chloride [12]. Diabetic ketoacidosis could lead to hyperchloremia in T2DM patients, where keto acids reduce blood pH and disturb the acid-base balance, leading to hyperchloremia [14, 16]. In contrast to the present study, chloride level was non-significantly higher among Nigerian T2DM patients compared to non-diabetic subjects and appeared not to be affected by hyperglycemia [12]. In the present study, no significant differences were observed in the levels of serum potassium, sodium and chloride between males and females with T2DM. This finding is in line with that reported among T2DM patients from Ethiopia [22] and Sudan [23], where no significant alterations in the levels of serum potassium and sodium were observed.

In the present study, the levels of serum potassium, sodium and chloride were not significantly correlated with age, BMI, or duration of T2DM of the patients. A similar finding was observed among Sudanese T2DM patients [23], where the levels of potassium and sodium showed a non-significant correlation with age and duration of DM. In contrast to the present study, the levels of serum potassium and sodium showed a significant positive association with age among Nigerian T2DM patients [12]. On the other hand, age and BMI were found to have a strong positive correlation with abnormal levels of serum sodium among Ethiopian T2DM patients [22].

In the present study, the level of FBS showed a significant negative correlation with the levels of serum sodium and chloride. This finding is in line with that reported among Ethiopian T2DM patients [22], where FBS was negatively correlated with the levels of serum sodium and chloride. In contrast, FBS was found to be negatively correlated with the level of serum sodium but positively correlated with the level of serum chloride among Indian T2DM patients [14]. The negative correlation between glucose and the extracellular electrolytes of sodium and chloride could be attributed to their dilution by hyperosmolality caused by hyperglycemia.

CONCLUSIONS

Altered serum sodium, potassium and chloride levels among T2DM patients in Sana'a city are characterized by hyperkalemia and hypochloremia, with no significant differences according to age, family history, duration of diabetes, or the type of drug used. However, the mean value of serum

potassium can be significantly higher among overweight T2DM patients compared to non-overweight patients. These alterations may underlie many of the pathophysiologic and clinical characteristics of diabetes or from the types of medications they receive. The levels of serum potassium, sodium and chloride are not significantly correlated with age, BMI, or duration of T2DM of the patients. In contrast, the level of FBS shows a significant negative correlation with the levels of serum sodium and chloride.

Conflict of Interest

None.

Financial Disclosures

None.

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