Annals of Agri-Bio Research **27** (1) : 102-107, 2022

Impact Score : 0.28 (Scopus)

Serum T.Ca, $PO_4^{=}$, Mg^{+2}, Na^{+} and K^{+} in T2DM Patient

ZAINAB HUSSEIN ALHILLAWI*, MUNTADHER MOHAMMAD ALI AND MAHA ABDULSAHIB MUHAMMAD

Department of Chemistry, College of Science, University of Kufa, Iraq
**(e-mail : zainab.alhillawi@uokufa.edu.iq; Mobile : (0964) 07810135111)*

(Received : September 7, 2021; Accepted : November 11, 2021)

ABSTRACT

In Iraq, the prevalence of type 2 diabetes mellitus (T2DM) ranged about 1.4 million which is nearly 8.5%. The patients with diabetes are commonly caused by electrolyte disorders such as calcium ion (Ca^{+2}), phosphate ($PO_4^{=}$), magnesium (Mg^{+2}), sodium (Na^{+}) and potassium (K^{+}). Sixty-five patients participated in this study. Their ages ranged between 45-60 years and the mean of BMI to patients 23.55±4.56. The mean of random blood glucose (RBG) and HbA1c was 288.42±68.63 mg/dl, 9.08±1.9%, respectively. In contrast, apparently 30 people were selected as a control group. Their age range was comparable to that of patients and the mean of BMI equal 22.94±3.15. The mean of RBG and HbA1c was 101.9±11.18 mg/dl and 5.03±0.63%, respectively. Five electrolytes were measured [serum total calcium (T.Ca), $PO_4^{=}$, Mg^{+2}, Na^{+} and K^{+}] by spectrophotometer methods. There was a significant increase in serum T.Ca, $PO_4^{=}$ and K^{+} in diabetes patients, while no significant difference in Mg^{+2} and Na^{+} with healthy group. Increased serum T.Ca formed Ca^{+2}- channels disorder or kidney diseases and metabolic disorders caused defect in serum T.Ca and $PO_4^{=}$. The insulin deficiency and healthy diet increased serum K^{+}, finally uncontrolled blood glucose affecting many tissues and organs that affect electrolytes level.

Key words : Hyperkalemia, calcium, sodium, diabetes mellitus

INTRODUCTION

Diabetes mellitus describes increased level of glucose in the blood (hyperglycemia). This disease is also defined as a metabolic disease (Jürgen *et al.,* 2019). Blood glucose regulated by insulin hormone, therefore any dysfunction of insulin effected on blood glucose level (Schwerin and Svancarek, 2020). Type 2 diabetes mellitus (T2DM) due to both the action of insulin is insufficient (insulin resistance) (Pouya *et al.*, 2019) and reduced insulin released by pancreas. The prevalence of T2DM accounted for 91%, while the type 1 diabetes 6%. In Iraq, the prevalence of T2DM is about 1.4 million which is nearly 8.5% (WHO, 2018). Uncontrolled and prolonged hyperglycemia also causes complex and damage many organs and various tissues such as kidneys, heart, blood vessels, eyes and nerves (Biplab *et al.,* 2018). There are relationship between diabetes mellitus and electrolytes (Liamis *et al.*, 2014) such as T.Ca, $PO_4^{=}$, Mg^{+2}, Na^{+} and K^{+}. These electrolytes play vital roles in the body such as, promoting several metabolic, second messenger, cellular activities, ensuring normal homeostasis, acid base balance, creating electrical gradients and enhancing enzyme activities (Blaine *et al.*, 2015). The patients with diabetes commonly cause electrolyte disorders (Sreenivasulu *et al.*, 2020). These are due to insulin deficiency or resistance manifesting as hyperglycaemia. Continuously hyperglycaemia will lead to hyperketonaemia (Ahmed *et al.,* 2017). The hyponatremia is most frequently seen electrolyte irregularity in T2DM, which is due to raised morbidity and mortality. However, Mg^{+2}, Ca^{+2} and K^{+} disturbances are unclear (Karuppan *et al.*, 2019). Potassium converts a vital indicator in diabetes where it plays a marker role in diabetic nephropathy cases, on the other hand, it acts as indicators in estimating end-stage renal disease and preparing to dialysis (Sreenivasulu *et al.*, 2020). Ca^{+2} plays a central role in biological functions, where the insulin secretion and resistance depend on Ca^{+2} balance (Becerra-Tomas *et al.*, 2014). Any modifications in T.Ca can have a negative effect on β-cell to secrete insulin which causes dysfunction in blood glucose levels. Any increase in T.Ca planes in cytosolic is related with an increased risk for T2DM (Unai *et al.*, 2020). Magnesium is metal

has a vital roles in the cells, cofactor to many enzymes, carbohydrate metabolism, insulin secretion and insulin resistance (Barbagallo, 2015). Any defect in Mg^{+2} levels in patients with diabetes mellitus causes poorly controlled glycemic status. Mg^{2+} deficiency decreases the affinity of glucose binding to glucokinase enzyme and indirectly leads to the impairment of insulin secretion, insulin resistance and increased macrovascular risk (Siddiqui *et al.*, 2014). Diabetic patients are more prone to hypophosphatemia. It is known that increased insulin levels promote the transport of both glucose and phosphate into the skeletal muscle and liver cells (Liamis *et al.*, 2014). The aim of this study is to estimate electrolytes in serum because of their effect on the work of vital organs in the body, which negatively affects patients with T2DM.

MATERIALS AND METHODS

One hundred Arabic Iraqi patients with type 2 diabetes mellitus participated in the present study. Only 65 patients satisfied all biochemical analysis tests. Their ages ranged between 45-60 years and the mean of BMI to patients 23.55±4.56. The random blood glucose and HbA1c were 288.42±68.63 mg/dl and 9.08±1.9%, respectively. These patients were registered as diabetes mellitus patients in "Diabetes and endocrine Unit" at Al, Sadr General Hospital" in Najaf city-Iraq and "Diabetes Unit" at "Al , Hakim General Hospital" in Najaf city-Iraq within January to April period. The patients had diabetes mellitus recorded in their files, and diagnosis was established by clinical symptoms and biochemical test. The present study excluded the patients with hypertension, those with endocrinitis infection and inflammation, heart diseases and also the patients from non-Arabic ethnic group.

Thirty people were selected as a control group. Their ages were comparable to that of patients and the mean of BMI equal 22.94±3.15. The means of random blood glucose and HbA1c were 101.9±11.18 mg/dl, 5.03±0.63%, respectively. The people with anemic or having an obvious systemic diseases were excluded.

Diabetes was diagnosed and established on medical history, current medication intake or American Diabetes Association (ADA) criteria (ADA, 2016). The definition of T2DM was fasting blood glucose ≥126 mg/dl (≥7.1 mmol/L), RBG ≥200 mg/dl (≥11.1 mmol/l), or an HbA1c of 6.5 (ADA, 2016).

Body mass index (BMI) was classified by the World Health Organization. Weight and height were measured according to WHO guidelines; BMI was calculated as weight/height^2 (kg/m^2). Obese individuals were defined as having BMI more than 30 kg/m^2, whereas normal individuals had a BMI of 18-25.

Five milliliters of venous blood samples were drown using a disposable needle and plastic syringes from each patient and control subject. Blood was divided into two anticoagulant tubes and gel tubes. The blood in gel tube was left at room temperature for 15 min for clotting, centrifuged 3000 Xg for 5 min, and then serum was separated and transported into new disposable tubes.

The student T-test was employed to assess differences in scale variables between diagnostic categories and analysis of contingency tables (χ2-test) was used to check associations between nominal variables. Associations among variables were computed using Pearson's product-moment and Spearman's rank-order correlation coefficients. All tests were 2-tailed and a p-value of 0.05 was used for statistical significance. All statistical analyses were performed using IBM SPSS windows version 25, 2017.

RESULTS AND DISCUSSION

There was a significant increase in serum T.Ca, $PO_4^{=}$ and K^{+} in patients with T2DM as compared with controls, while there was no significant change in serum Mg^{+2} and Na^{+} (Table 1).

In this study, there was a significant increase in serum T.Ca level in diabetic patients as compared with control (Rooney *et al.*, 2016). Hyperglycemias led to high free fatty acid that invasion mitochondrial-oxidation system, which accumulated fatty acids (Zhong *et al.*, 2016). Increased blood glucose and fatty acids caused more exposure to oxidative stress and reactive oxygen species that led to Ca^{+2}-channels dysfunction in endoplasmic reticulum (Unai *et al.*, 2020). Continuous hyperglycemia led to prevent Ca^{2+} mobilization and activate proapoptotic signals (Yamamoto *et al.*, 2019). Therefore, increased Ca^{2+} level

Table 1. Serum T.Ca, $PO_4^{=}$, Mg^{+2}, Na^{+} and K^{+} in patients with T2DM as compared with healthy group

Parameters	Mean±STD Patients	Mean±STD Controls	P-value
S. T. Calcium (mmol/l)	2.59±0.16	2.52±0.1	<0.001*
S. Phosphate (mmol/l)	43±0.3	1.0013±0.699	0.005*
S. Magnesium (mmol/l)	2.06±0.3	2.025±0.43	0.68
S. Sodium (mmol/l)	138.76±3.7	142.692±2.85	0.29
S. Potassium (mmol/l)	1.46±0.73	0.93±0.54	<0.001*

in blood resulted from Ca^{2+}- channels disorder that prevented Ca^{2+} entering to cells. Other study pointed out, imbalance in Ca^{2+} level resulting from patients with renal diseases. Changes in serum T.Ca, Mg^{+2} or $PO_4^{=}$ were related to the prevalence of T2DM mainly in combination with obesity (Vaia *et al.*, 2020). The other research showed that there was a significant decrease in the concentration of T.Ca level in the blood of diabetic patients in the group of males and females compared to its concentration in the control samples (Zeinab *et al.*, 2018; Abdulrehman *et al.,* 2019; Nwankwor *et al.*, 2020). Anastasia *et al.* (2020) found that the patients with diabetes had higher T.Ca that played an important role in the vascular diseases. Another study found that there was no difference in serum calcium levels in diabetic patients compared with the healthy controls.

The abnormalities of serum $PO_4^{=}$ contributed with many reasons; renal diseases, bone diseases, insulin concentration, insulin resistance, affecting FGF23 all of these influencing on $PO_4^{=}$ level (Ludmilla *et al.*, 2018; Winiarska, *et al.,* 2021). The unregulated insulin dosage, insulin resistance in T2DM caused defect in $PO_4^{=}$ level. High serum phosphate contributed to vascular and metabolic disturbances in elderly patients with T2DM and renal impairment (Vaia *et al.*, 2020). Metabolic disorders including changes in serum T.Ca, Mg^{+2} or $PO_4^{=}$ affected the prevalence of T2DM (Vaia *et al.*, 2020). Zammit *et al.* (2015) found increased serum $PO_4^{=}$ in patients with T2DM resulting from renal function impairment associated with increased insulin resistance. In contrast, the serum $PO_4^{=}$ decreased in patients than healthy group the lower the serum $PO_4^{=}$ in diabetics, may negatively affect hyperglycemia where increased blood glucose leading to decrease on serum $PO_4^{=}$. Hyperglycemia was bound with low serum $PO_4^{=}$ because of increased T.Ca and $PO_4^{=}$ excretion product from glucosuria (Safaa *et al.*, 2016). Zhong *et al.* (2016) found no significant differences between patients and healthy groups in serum phosphate.

Hajar *et al.* (2019) did not find any significant change between patients and healthy for Mg^{+2}. In contrast, many studies found there was a significant decrease between T2DM and healthy group for Mg^{+2}. Hypomagnesemia due to insulin deficiency and resistance affected tubular reabsorption of magnesium (Anjani Kumar *et al.*, 2018). Decreased serum magnesium in pa-tients with T2DM was more prevalent. This significant association with age, gender, glycemic control hypomagnesemia led to insulin sensitivity and developing risk of secondary complications (Velayutharaj *et al.*, 2016; Kumar *et al.*, 2019). They also demonstrated that hypomagnesemia was linked with diabetic uncontrolled and led to high risk of diabetic retinopathy. Decreased Mg^{+2} level led to reduced dietary intake, impaired insulin metabolism, glomerular hyperfiltration and acid and electrolytes imbalance (Quiddi *et al.*, 2021).

The kidney plays an important role in ensuring glucose homeostasis, gluconeogenesis, and the reabsorption of filtered glucose in the proximal tubules. The sodium glucose co-transporter 2 (SGLT2) present in the proximal tubule was responsible for the glucose reabsorption (Banerjee and Grobelna, 2019). The present study corresponding with other study found no significant increase in patients and controls for Na^{+} (Godwill *et al.,* 2018).The presence of hyperglycemia and increased or normal Na^{+} concentrations in plasma indicated a clinically significant decrease in total body water (Sarguru *et al.,* 2016). Increased urination in hyperglycemia led to loss of electrolytes with water and resulted in the imbalance which disturbed sodium and potassium levels in the body (Sarguru *et al.*, 2016). Studies suggested that uncontrolled DM also induced hypovolemic-hyponatremia due to osmotic diuresis. Increased or normal

plasma sodium concentrations in the presence of hyperglycemia indicated a clinically significant deficit in total body water. In contrast, some studies showed that there was a significant decrease in serum Na^{+} in patients with type 2 diabetes than healthy group (Das and Borkotoki, 2017; Rajagambeeram *et al.*, 2020; Sreenivasulu *et al.*, 2020). The patients with uncontrolled diabetes mellitus had different levels in serum Na^{+}. This difference in sodium level caused hyperglycemia-induced hyponatremia (dilutional-hyponatremia), hypotonic (water losses with increased electrolytes) which led to hypernatremia and decrease in blood volume causing hyponatremia. Serum Na^{+} levels in poorly controlled patients with diabetes mellitus varied since these levels were the result of hyperglycemia-induced hyponatremia (dilutional hyponatremia), osmotic diuresis-induced hypotonic losses (losses of water in excess of electrolytes), which tended to increase serum Na^{+} levels, and hypovolemia-induced decrease in serum Na^{+} levels (Liamis *et al.*, 2014).

The regulation of serum K^{+} occurred by shift hyperkalemia (redistribution of K^{+} from the intracellular to the extracellular compartment) induced hyperkalemia with no net total body K^{+} increase. In diabetic ketoacidosis, the decrease 0.1 from blood pH caused increase by approximately 0.4 mmol/LK^{+}. Potassium increases by many reasons such as insulin deficiency, renal diseases (acute kidney injury and chronic kidney disease) resulted from reduced glomerular filtration of K^{+}, hypertonicity, cell lysis (rhabdomyolysis), and some drugs (e. g., beta blockers and drugs that interfere with potassium remover (Liamis *et al.*, 2014). Other studies illustrated hyperkalemia associated with reduced insulin secretion where the potassium shifting from intra to extra and decreased peripheral glucose utilization resulted in carbohydrate intolerance and hyperglycemia metabolic acidosis and decreased potassium excretion because of impaired glomerular filtration rate hypoaldosteronism and hyporeninemic (Kovesdy, 2017).

Any excess in dietary K^{+} and renaldys function caused hyperkalemia (Ingrid *et al.*, 2021). Counter study in Japan found hypokalemia in T2DM without antihypertensive medications and this result was prediabetic state to T2DM. Lower levels of potassium were found to be associated with a higher risk of diabetes in some studies (Peng *et al.*, 2017). Hypertensive with thiazide will keep potassium level above 4.0 mmol/l preventing induced diabetes.

CONCLUSION

The present study was found a significant increase in serum T.Ca, $PO_4^{=}$ and K^{+} in patients with T2DM as compared with controls, while there was no significant change in serum Mg^{+2} and Na^{+}. Increased serum T.Ca in patients with T2DM may from Ca-channels disorder or kidney diseases and metabolic disorders caused defect in serum T.Ca and $PO_4^{=}$. Diabetic ketoacidosis had effect on pH range. Decreased pH value affected $PO_4^{=}$ and K^{+} levels. The insulin deficiency, healthy diet caused increase in serum K^{+}, finally uncontrolled blood glucose had effect on many tissues and organs that affect electrolytes level.

ACKNOWLEDGEMENTS

The authors would like to thank all physicians, patients and healthy that participated in this study.

REFERENCES

Abdulrehman Ibrahim Hus, Tahleel Babekir, Ahmed Elamin Al Hasan, Eyman Hassan Albagir, Musab Alobaid Mohammad, Samar Salah and Salih Abdelgdir Elmahdi (2019). Serum calcium level in Type 2 diabetes mellitus in Khartoum state. *Clin. Microbiol.* **8** : 5. *DOI: 10.4172/2327-5073.1000331.*

Ahmed, R., Khandker, F. and Khanduker, S. (2017). Electrolyte disturbances in patients with diabetes mellitus. *Bangladesh J. Med. Biochem.* **10** : 27-35.

American Diabetes Association (2016). Standards of medical care in diabetes-2016. *Diabetes Care* **39** : S4-S5.

Anastasia, Poznyak, Andrey, V., Grechko, Paolo Poggio, Veronika, A. Myasoedova, Valentina Alfieri and Alexander N. Orekhov (2020). The diabetes mellitus–Atherosclerosis connection : The role of lipid and glucose metabolism and chronic inflammation. *Int. J. Mol. Sci.* **21** : 1835. *doi:10.3390/ijms21051835.*

Anjani Kumar, C., Sumanas Gopal, Datta Kolli, Seetha Katta and Shubha Katta (2018). Serum magnesium levels in type 2

diabetes patients and its relation with diabetic nephropathy. *Int. J. Med. Res. Health Sci.* **7** : 90-94.

Banerjee, S. and Grobelna, A. (2019). Sodium-glucose co transporter 2 inhibitors for the treatment of diabetic nephropathy : A review of clinical effectiveness [Internet]. Ottawa (ON) : Canadian Agency for Drugs and Technologies in Health *PMID* : 31725208.

Barbagallo, M. (2015). Magnesium and type 2 diabetes. *World J. Diabetes* **6** : 1152-1157.

Becerra-Tomas, N., Estruch, R., Bull, ´ O. M., Casas, R., D´´iaz-Lopez A. (2014). Increased serum calcium levels and risk of type 2 diabetes in individuals at high cardiovascular risk. *Diabetes Care* **37** : 3084-3091.

Biplab Giri, Sananda Dey, Tanaya Das, Mrinmoy Sarkar and Jhimli Banerjee (2018). Chronic hyperglycemia mediated physiological alteration and metabolic distortion lead to organ dysfunction, infection, cancer progression and other pathophysiological consequences : An update on glucose toxicity. *Biomedicine and Pharmacotherapy* **107** : 306-328.

Blaine, J., Chonchol, M. and Levi, M. (2015). Renal control of calcium, phosphate, and magnesium homeostasis. *Clin. J. Am. Soc. Nephrol.* **10** : 1257-1272.

Das, A. and Borkotoki, S. (2016). Evaluation of serum electrolyte levels in T2DM. *Ind. J. Appl. Res.* **6** : 91-93.

Godwill, A. E., Thomas, J., Micheal, C. A., Emmanuela, N. A., Marian, N. U., Ambrose, N. N. and Benjamin, E. Ubi (2018). Influence of type 2 diabetes on serum electrolytes and renal function indices in patients. *J. Clinical Diagnostic Res.* **12** : BC13-BC16.

Hajar Saeed, Safer Haj and Bayar Qasim (2019). Estimation of magnesium level in type 2 diabetes mellitus and its correlation with HbA1c level. *Endocrinol. Diab. Metab.* **2.** *doi : 10.1002/edm2.48.*

Ingrid Hougen, Silvia J. Leon, Reid Whitlock, Claudio Rigatto, Paul Komenda, Clara Bohm and Navdeep Tangri (2021). Hyperkalemia and its association with mortality, cardiovascular events, hospitalizations and intensive care unit admissions in a population-based retrospective. Cohort. *Kidney International Reports* **6** : 1309-1316.

Jürgen Harreiter, Michael, Roden and Wien, Kin Wochenschr (2019). Diabetes mellitus – Definition, Classification, Diagnose, Screening und Prevention **131** : 6-15.

Karuppan, A., Sahay, M. I. and Ravindranathan, R. (2019). Elecrolyte disturbances among diabetic patients admitted in a multi-speciality hospital in Southern India. *J. Clin. Diag. Res.* **13** : OC12-OC15.

Kovesdy, C. (2017). Updates in hyperkalemia : Outcomes and therapeutic strategies. *Rev. Endocr. Metab. Disord.* **18** : 41-47.

Kumar, P., Bhargava, S., Agarwal, P. K., Garg, A. and Khosla, A. (2019). Association of serum magnesium with type 2 diabetes mellitus and diabetic retinopathy. *J. Family Med. Prim. Care.* **8** : 1671-1677.

Liamis, G., Liberopoulos, E., Barkas, F. and Elisaf, M. (2014). Diabetes mellitus and electrolyte disorders. *World J. Clin. Cases* **2** : 488-496.

Ludmilla Bär, Martina Feger, Abul Fajol, Lars-Oliver Klotz, Shufei Zeng, Florian Lang, Berthold Hocher and Michael Föller (2018). Insulin suppresses the production of fibroblast growth factor 23 (FGF23). *Proc. Nat. Acad. Sci. U. S. A.* **115** : 5804-5809.

Nwankwor, H. C., Nwatu, C. B., Okwara, C. C., Young, E. E., Olisaka, L. C. and Ezomike, N. C. (2020). Low serum calcium levels occur in Nigerian adults with type 2 diabetes and correlate negatively with their glycosylated hemoglobin levels : A case-control study. *Niger J. Med.* **29** : 229-233.

Peng, Y., Zhong, G. C., Mi, Q., Li, J., Wang, A., Li., L., Liu, H. and Gangyi, Y. (2017). Potassium measurements and risk of type 2 diabetes : A dose-response meta-analysis of prospective cohort studies. *Oncotarget* **8** : 100603-100613.

Pouya Saeedi, Inga, P., Parasakevi, S., Dominic, B. and Rhys, W. (2019). Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045 : Results from the International Diabetes Federation. *Diabetes Atlas, 9th edition.*

Quiddi, W., Tarmidi, M., Mansouri, A., Amine, M., Baizri, H., Boukhira, A. and Chellak, S. (2021). Magnesium status in a population of type 2 diabetes mellitus in Morocco. *Endocrinol. Metab. Int. J.* **9** : 20-23.

Rajagambeeram, R., Malik, I. and Vijayam, M, (2020). Evaluation of serum electrolytes and their relation to glycemic status in patients with type 2 diabetes mellitus. *Int. J. Clinical Bio. Res.* **7** : 130-133.

Rooney, M. R., Pankow, J. S. and Sibley, S. D. (2016). Serum calcium and incident type 2 diabetes : The atherosclerosis risk in communities (ARIC) study. *Am. J. Clin. Nutr.* **104** : 1023-1029.

Safaa Abed, E. L., Rahman Hassan, Wigdan Abdel, Rahman Elsheikh and Nazik Ibrahim (2016). Serum calcium levels in correlation with glycated hemoglobin in type 2 diabetic

Sudanese patients. *Adv. Diabetes and Metabolism* **4** : 59-64.

Sarguru, D., Vanaja, R. and Balaji Rajagopalan (2016). Evaluation of serum electrolytes in type 2 diabetes mellitus. *Int. J. Pharm. Sci. Rev. Res.* **40** : 251-253.

Schwerin, D. L. and Svancarek, B. E. M. S. (2020). Diabetic protocols for treat and release. In : *Stat Pearls*. Publishing, Treasure Island (FL).

Siddiqui, K., Bawazeer, N. and Joy, S. S. (2014). Variation in macro and trace elements in progression of type 2 diabetes. *Scientific World J.* **2014** : 1-9.

Sreenivasulu Uppara, Bhagyamma Sollapurappa Narayanaswamy, Rama Kishore Akula Venkata, Thanuja Ramanna and Shyam Prasad, B. R. (2020). Study on serum electrolyte imbalance in type-2 diabetes mellitus – A hospital-based study. *J. Evid. Based Med. Healthcare* **7** : 48. *doi : 10.18410/jebmh/2020/583.*

Unai Galicia-Garcia, Asier Benito-Vicente, Shifa Jebari, Asier Larrea-Sebal, Haziq Siddiqi, Kepa B. Uribe, Helena Ostolaza and César Martín (2020). Pathophysiology of type 2 diabetes mellitus. *Int. J. Mol. Sci.* **21** : 6275. *doi : 10.3390/ijms21176275*.

Vaia, D., Raikou, Despina Kyriaki and Sotiris Gavriil Importance (2020). Serum phosphate in elderly patients with diabetes mellitus. *World J. Diabetes* **15** : 416-424.

Velayutharaj, R., Saraswathi, R., Shivakumar, S., Saha, G., Niranjan, R., Ramesh, A. R. and Sreenivasan (2016). Association of serum magnesium with glycemic control and insulin resistance in patients with type 2 diabetes mellitus. *Int. J. Cur. Res. Rev.* **8** : 17-23.

Winiarska, A., Filipska, I., Knysak, M. and Stompór, T. (2021). Dietary phosphorus as a marker of mineral metabolism and progression of diabetic kidney disease. *Nutrients* **13** : 789. *doi : 10.3390/nu13030789*.

World Health Organization (2018). *Diabetes*. Geneva, Switzerland.

Yamamoto, W. R., Bone, R. N., Sohn, P. and Syed, F. T. (2019). Endoplasmic reticulum stress alters ryanodine receptor function in the murine pancreatic beta cell. *J. Biol. Chem.* **294** : 168-181.

Zammit, A. R., Katz, M. J., Derby, C., Bitzer, M. and Lipton, R. B. (2015). Chronic kidney disease in non-diabetic older adults : Associated roles of the metabolic syndrome, inflammation and insulin resistance. *PLoS One* **10** : e0139369.

Zeinab Ali, Osman Ali, Nizar Ali Ahmed, Akram Hamed and Awadalla Elsukar (2018). Assessment of serum magnesium and calcium levels in long standing type 2 diabetic patients in elobied city. *EJPMR* **5** : 22-24.

Zhong nan da xuexuebao and Yi xue ban (2016). Level of serum phosphorus and adult type 2 diabetes mellitus. *J. Central South Univ. Medical Sci.* **41** : 502-506.