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Comparative Evaluation of Plasma Lipid Profile and Electrolytes in Diabetic and Non-Diabetic Individuals Attending Healthcare Checkup in Everight Laboratory in Owerri, Imo State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Diabetes mellitus is a metabolic disorder characterized by abnormally high blood sugar which poses a serious challenge to public health globally. The measurement of blood sugar levels, serum lipid profiles, and electrolytes are essential in determining one's vulnerability to developing diabetic-related complications such as cardiovascular diseases.

Aim: This was a comparative cross-sectional study designed to assess the dyslipidemia and electrolyte imbalance status of diabetic individuals attending routine healthcare checkups in Everight Diagnostic and Laboratory Services Limited, Owerri branch, using plasma lipid profile (total cholesterol, triglycerides, high-density lipoproteins and low-density lipoproteins) and electrolytes (sodium, potassium, chloride and bicarbonate) as markers.

Methodology: A total of 120 participants consisting of 60 diabetics and 60 non-diabetic individuals were pooled for this study. From both groups, plasma samples upon centrifugation were used for the analyses of glucose, Total Cholesterol (TC), Triglycerides (TG), High-density lipoprotein cholesterol (HDL-C), Low-density Lipoprotein Cholesterol using Erba XL-200 auto biochemistry analyzer, and plasma Sodium (Na^+), Potassium (K^+), Chloride (Cl^-), and Bicarbonate ($HCO3^-$) using Audicom (AC9900) ion selective electrode (ISE) analyzer. Statistical analysis was carried out using version 20.0 and p- values less than 0.05 were considered statistically significant.

Results: The demographic characteristics of the study population show 53% women, 47% men, and average age of 51.28. The fasting plasma glucose level of diabetic subjects (175.96 ± 91.62 mg/dL) was significantly higher ($p<0.05$) than the non-diabetic group (99.54 ± 11.50 mg/dL). More so, there were significant differences ($p<0.05$) between levels of TC (212.9 ± 56.65 mg/dL), TG (165.61 ± 89.05 mg/dL), and LDL-C (130. 59 ± 47.18 mg/dL) amongst diabetic individuals when compared with the levels of TC (169.87 ± 33. 57 mg/dL), TG (98.14 ± 39.14 mg/dL), and LDL (100.57 ± 27.78 mg/dL) of non-diabetic participants. Conversely, there was no significant difference when the plasma levels of HDL-C (52.78 ± 19.10 mg/dL), Na^+ (136.93 ± 3.14 mmol/L), K^+ (4.11 ± 0.54 mmol/L), $HCO3^-$ (22.03 ± 4.66 mEq/L) and Cl^- (101.09 ± 4.33 mmol/L) of test subjects were compared with that of control individuals HDL-C (53.46 ± 15.04 mg/dL), Na^+ (137.11 ± 3.37 mmol/L), K^+ (4.17 ± 0.45 mmol/L), $HCO3^-$ (22.27 ± 3.55 mEq/L) and Cl^- (94.52 ± 10.78) ($p>0.05$).

Conclusion: The results of our study shows significant alteration of fasting lipid parameters amongst diabetics. This suggests that diabetic individuals are associated with dyslipidaemia, which predisposes them to cardiovascular risks.

Keywords: Fasting plasma glucose; lipid profile; diabetes mellitus; electrolytes.

1. INTRODUCTION

Diabetes Mellitus is a metabolic disease of global concern, characterized by chronic hyperglycemia (abnormally high blood sugar) which is triggered by defective insulin production, insulin action, or a combination of both (insulin resistance) [1]. Diabetes mellitus is one of the major causes of diseases like dyslipidemia, renal failure, electrolyte disorder and imbalances, blood vessel degeneration, and cardiovascular diseases [1,2]. According to the World Health Organization (WHO) in 2022, it was reported that an estimated 2 million deaths in 2019 were caused by diabetes and diabetes-induced kidney disease [3]. The prevalence of diabetes is increasing faster in low and middle-income countries than in high-income countries. The prevalence of diabetes increased by 290.74%, with prevalence among adults (18 and above) increasing by 3.8% between 1980 and 2014, diabetes can be divided into four main types or categories: type 1 diabetes mellitus (T1DM), type 2 diabetes mellitus (T2DM), gestational diabetes mellitus (GDM), and diabetes caused or associated with certain specific conditions, pathologies, and/or disorders [3,4]. Reports by International Diabetes Federation Africa (IDF Africa) in 2021 showed that about 24 million adults aged 20 to 79 are living with diabetes in the African region, with the figure projected to increase to 33 million and 55 million by 2030 and 2045 respectively [5].

Hyperglycemia, Obesity, and Insulin resistance functioning together lead to the progression of atherosclerosis, and atherosclerosis has a well-known link with dyslipidemia, multiple risk factors are involved in the actual onset of the disease. Genetics, atmosphere, loss of the very first phase associated with insulin launch, sedentary way of life, lack of physical exercise, smoking, alcoholic beverages, dyslipidemia, reduced β-cell

sensitivity, hyperinsulinemia, and improved glucagon activity are the primary risk elements for prediabetes and DM. [6,7,8,9]. Dyslipidemia is an irregular lipoprotein metabolism (change in size and density of lipoproteins) leading to abnormal lipid profiles which is prevalent among diabetic patients. This is because insulin resistance affects key enzymes and their pathways in lipid metabolism [6]. Examples of key enzymes and pathways are transfer proteins, lipoprotein lipase regulation, production of apoprotein, cholesteryl ester action, and peripheral and hepatic action of insulin [6].

Electrolytes are essential components that are crucially involved in various body functions like controlling body fluids levels, osmotic regulation (Na+, K+, Cl-), acid-base balance (pH), muscle contraction, nerve conduction, blood clotting, and myocardial rhythm [2,6]. Potassium, Phosphate, Magnesium, and Sulfate are the major electrolytes found in the intracellular fluid, while in the extracellular fluid, the electrolytes found are Sodium, Chloride, and Bicarbonate, Potassium (K +), Sodium (Na +) and Chloride (Cl) are important ions in maintaining electrolyte balance. Electrolyte imbalances resulting from kidney failure, dehydration, fever, and vomiting have been suggested as one of the factors that contribute to complications of diabetes and other endocrine disorders. [1,10]. Potassium is known for neuromuscular sensitivity, cardiac action, acid-base equilibrium, and as a co-factor for the enzyme pyruvate kinase. One is said to have hypokalemia when their serum concentration of potassium is low (below 3.5 mmol/L), while when it is high (above 5.1 mmol/L) they have hyperkalemia [11]. Sodium is responsible for the maintenance of osmotic balance, even distribution and conservation of body fluids, and acid-base regulation. Excess serum concentration of sodium (above 150 mmol/L) is hypernatremia, and below 135 mmol/L of sodium concentration is hyponatremia. Chloride also assists in the balance of body fluids in and out of the cells, thus, maintaining blood volume, and acid-base equilibrium [12,13]. The diffusion of K+ out of cells and Na+ into the cells is caused by transmembrane electrical gradients. Insulin and catecholamine hormones stimulate the sodium-potassium ion pump and regulate the movement of these electrolytes to maintain their extracellular and intracellular homeostasis, and their alteration affects the level of serum electrolyte [14,15].

Electrolyte disorder is the first pathogenic sign of most diseases and can be found in both the general population and hospitalized individuals. However, they are mild in the general population, but severe in hospitalized individuals. Electrolyte disorders are the major cause of disease advancement and mortality, altered distribution of electrolytes leads to electrolyte imbalance in patients suffering from diabetes which is due to osmotic fluid shifts induced by hyperglycaemia that is caused by osmotic diuresis. The potassium intake of cells remains normal whereas there is impairment in the insulin mediated glucose intake. [16,17].

Lipids and electrolytes are essential in the function of the body, and changes in their concentration are evidence of disease progression in diseases like diabetes [6].

2. MATERIALS AND METHODS

2.1 Study Area

This cross-sectional study was carried out at Everight Diagnostics and Laboratory Services Limited located in Owerri, Imo State, Nigeria. The subjects; Diabetic subjects (Test) and Non-diabetic individuals (Control) all attended the Laboratory from January, 2022 to November, 2022.

2.2 Study Population and Design

A total of one hundred and twenty (120) participants volunteered for the study. The comprised of sixty (60) diabetic/test subjects, and sixty (60) non-diabetic/control subjects. The participants were sixty-four (64) females, and fifty-six (56) males. The age range of the participants was between 19-89 years.

2.3 Inclusion and Exclusion Criteria

Diabetic subjects were included in the study. However, pregnant women, persons with chronic diseases like renal disease, heavy alcohol consumers, and heavy smokers were all excluded from this study.

Description of Subjects: Naïve diabetic subjects that are not under any form of diabetic medications and are at various stages of the disease were used for this study.

2.4 Sample Collection

This was a cross-sectional survey of data available at the laboratory.

Five (5) mL venous blood sample was collected from the antecubital vein of each of the diabetic patients and control subjects in a fluoride Oxalate and Lithium Heparin bottles for the Fasting Blood Sugar and (Fasting lipid & Electrolyte) respectively. The samples were properly labeled with the subjects' names, between 7 and 9 am after overnight fasting. The withdrawn blood was centrifuged at 3000rpm for 5mins. The serum was dispensed in an eppendorf tube and stored at −20 C until analysis. Blood collection and serum separation were carried out in a dust-free environment.

2.5 Measurement of Biochemical Parameters

As reported by Billah et al. [6], fasting blood glucose was determined by Glucose Oxidase–Peroxidase method [18], cholesterol was determined by Cholesterol Oxidase–Peroxidase method [19], triglycerides was determined by the method of Glycerol Phosphate Oxidase–Peroxidase [20], high density lipoprotein cholesterol was determined by Poly ethylene glycol [PEG] precipitation method [21], and low density lipoprotein cholesterol was determined by the method of Assman et al*.* [22] as reported by Ojiako et al. [23]. Serum electrolytes were analyzed in the hospital using a Sensacore Electrolyte Analyser made in India, and properly followed the manufacturer's operational protocol.

2.6 Statistical Analysis

Microsoft Excel 2013 and XL Miner Analysis ToolPak an add-on on Google sheet were used to analyze the data. Values were expressed as Mean ± standard deviation (SD). One-way Analysis of Variance (ANOVA) was used to compare data between the test group and control group, and p-values of <0.05 were considered statistically significant.

3. RESULTS

Demographic data of participants both test and control are presented in Table 1. The total number of participants involved in the study is 120, which includes 64 females and 56 males at a percentage of 53% and 47% respectively. The mean age of the participants was 51.28 ± 16.72, 55.95 ± 14.93 was the mean age of the test participants while the mean age of the control participants was 46.6 ± 17.21.

The result of the fasting blood sugar of the test and control participants is presented in Fig. 1. The result showed that the level of fasting blood sugar of the test participants was 175.96 ± 91.62 mmol/L which was significantly higher ($p<0.05$) than that of the control participants which was 99.54 ± 11.50 mmol/L.

Fig. 2 shows the result of lipid profiles [Total Cholesterol (TC), Triglycerides (TG), High-density lipoprotein cholesterol (HDL-C), and Low-density lipoprotein cholesterol (LDL-C)] among the test and control participants. The total cholesterol (TC) in the test participants was 212.90 ± 56.65 mg/dL which was significantly higher ($p<0.05$) compared to the control participants which was 169 ± 33.57 mg/dL. The concentration of triglycerides (TG) in the test participants was 165.61 ± 89.05 mg/dL which was significantly higher ($p<0.05$) than that of the control participants at 98.14 ± 39.14 mg/dL. The low-density lipoprotein cholesterol (LDL-C) was significantly higher ($p<0.05$) in the test participants at 130.59 ± 47.18 mg/dL than that of the control participants at 100.57 ± 27.78 mg/dL. Lastly, the concentration of high-density lipoprotein cholesterol (HDL-C) in the test participants at 52.78 ± 19.10 mg/dL was not statistically lower ($p>0.05$) than that of the control participants at 53.46 ± 15.04 mg/dL (Fig. 2).

Table 1. Demographic data of participants (test and control)

Parameters	Test	Control	Total
Number of Participants (n)	60	60	120
Mean Age of Participants	55.95 ± 14.93	46.6 ± 17.21	51.28 ± 16.72
Gender of Participants	Female (32)	Female (32)	Female (64; 53%)
	Male (28)	Male (28)	Male (56; 47%)

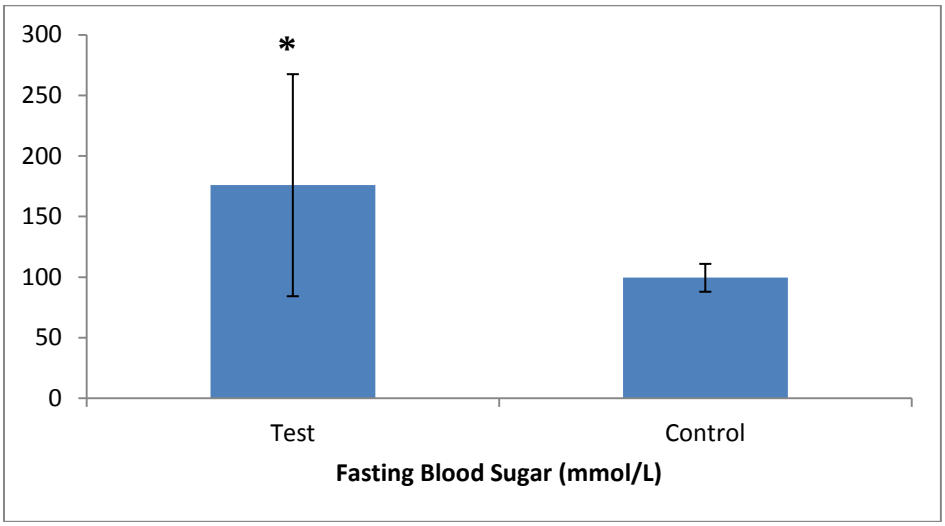

Fig. 1. The level of fasting blood sugar (FBS) in the test and control participants values are expressed as mean ± SD

**shows statistically significance at p < 0.05 compared to control*

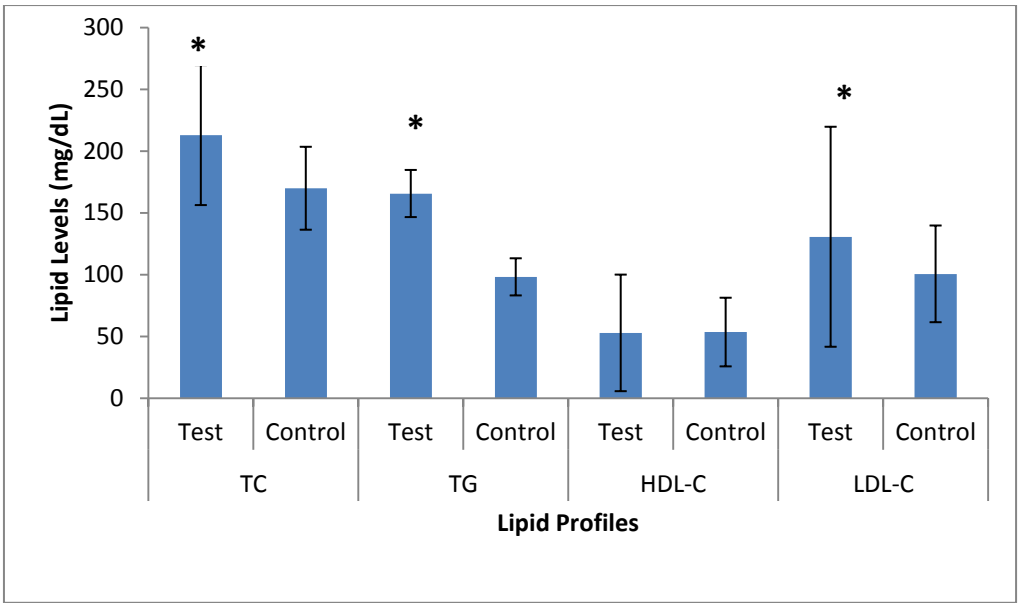

Fig. 2. Chart showing the concentration of lipid profiles in the test and control participants

Values are expressed as mean ± SD

**shows statistically significance at p < 0.05 compared to control*

The level of the different electrolytes [Potassium (K^+), Sodium (Na^+), Chloride (Cl^-), and Bicarbonate (HCO_3^-)] in the test and control participants is presented in Fig. 3. The result showed that there was a reduction of Na^+ in the test participants at 136.93 ± 3.14 mmol/L which was not statistically significant (p>0.05) compared to that of the control participants at 137.11 ± 3.37 mmol/L. The decrease in the level of K^+ in the test participants at 4.11 ± 0.54 mmol/L was not statistically significant (p>0.05) compared to that of the control participants at 4.17 ± 0.45 mmol/L. In Bicarbonate (HCO_3^-), the level at 22.03 ± 4.66 mEq/L in the test participants was not significantly lower (p>0.05) than 22.27 ± 3.55 mEq/L in the control participants. Furthermore, the level of chloride in the test participants at 101.09 ± 4.33 mmol/L was not significantly higher (p>0.05) when compared to that of the control participants at 99.52 ± 10.78 mmol/L (Fig. 3).

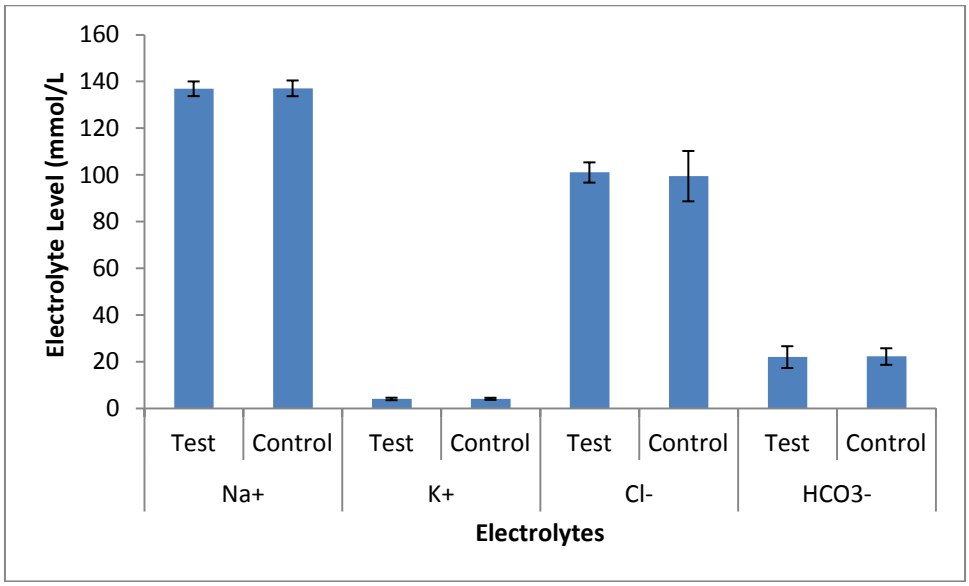

Fig. 3. Chart showing the level of electrolytes in the test and control participants
Values are expressed as mean ± SD
**shows statistically significance at p < 0.05 compared to control*

4. DISCUSSION

The interrelationship between blood glucose, lipid profiles, and serum electrolytes in which they are linked by factors like age, and health conditions has been reported by various studies [24-26,27,28]. Diabetes mellitus, a resulting ailment from hyperglycemia, is a metabolic disorder that is associated with risk factors like electrolyte imbalance, and dyslipidemia has affected people globally irrespective of age, race, and gender, hyperglycaemia in diabetes results in shifting of water from the intracellularto extracellular space thereby diluting the sodium present extracellularly leading to lowered serum sodium levels [29,30]. Previous studies have shown that electrolyte imbalances and abnormal lipid metabolism are common in impaired individuals like type 2 diabetic patients [29]. This study was carried out to compare the concentration of lipid profiles, blood glucose, and serum electrolytes in diabetic and non-diabetic patients. Our study showed that in diabetic patients who were referred to as test participants that the serum electrolytes (Na^+, K^+, and $HCO3^-$) levels all declined, while the level of Cl^- elevated when compared to that of the non-diabetic patients (control participants). However, these declination and elevation of serum electrolytes were not statistically significant (Fig. 3). The test participants experienced a decrease in Na^+ level in the blood (hyponatraemia) which can be attributed to their hyperglycemic condition, which caused osmotic diuresis. Here their bodies retained too much water that diluted the amount of sodium in the blood resulting in the low level of sodium [31]. Our result on the decrease in sodium level in the test participants agrees with the studies of Al-Jameil [32], Wang et al. [33], Talabani [26], and Woyese et al. [2] that all reported decrease in Na+ levels in diabetic patients when compared to nondiabetic patients.

Our study showed a decrease in serum potassium (hypokalemia) among the test participants (Fig. 3). This may be due to the abnormal function of the Na^+--K^+ pump, where the movement of potassium ions in the cell by carrier protein is reversed because of their hyperglycemic condition. It could also be due to the use of insulin in diabetic treatment. Here, the level of serum K^+ has reduced due to its passage along with glucose taken up from insulin treatment through the cell membrane [34]. Our result agrees with Al-Jameil [32], Ugwuja & Eze, [35], Hasona & Elasbali, [29], and Ramadan et al. [34], but disagrees with Engwa et al. [36], and Alqubaty et al. [31] that reported an increase in both Na^+ and K^+ levels in diabetic patients. The elevated level of serum chloride (hyperchloremia) in the test participants when compared to that of the control in our study could be a result of hypertonicity (Fig. 3). This insignificant elevation of chloride in our test participants is similar to the reports of Engwa et al. [36], and Santhosh et al. [25], which reported an insignificant increase in

serum chloride in diabetic patients when compared to nondiabetic patients. It is known that diabetic ketoacidosis; insufficient insulin in the body leading to excessive production of blood acids causes hyperchloremia [36]. These blood acids known as ketone causes hyperchloremia by disrupting the acid-base balance thus reducing the blood pH [31]. Furthermore, metabolic acidosis (excessive reduction of bicarbonate from the blood) was observed in our test participants i.e. a decrease in the level of serum bicarbonate when compared to the control participants (Fig. 3). Bicarbonate ions are vital because they serve as a buffer to maintain and monitor the acidity of the blood and other body fluids, so their reduction is common among individuals suffering from metabolic diseases like diabetes [37]. The finding of our study correlates with that of Li et al. [37] who reported that low levels of serum bicarbonate increase the risk of cardiovascular diseases in type 2 diabetes.

The relationship between serum lipid profiles; Total Cholesterol (TC), Triglycerides (TG), High-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) and diabetes mellitus have been studied by various researchers over the years [27,28,38,39]. Various reports have shown that abnormal lipid metabolism (dyslipidemia) characterized by elevation of TC, TG, LDL-C, and a decline in HDL-C has a strong relationship with type 2 diabetes [40]. Our study showed a significant increase ($p<0.05$) in the levels of TC, TG, LDL-C, and an insignificant decrease ($p>0.05$) in high-density lipoprotein cholesterol in the test participants when compared to the control participants (Fig. 2). The elevation of TC, TG, and LDL in our test participants may be due to poor glycemic control i.e. insulin treatment which also led to the depletion of good cholesterol i.e. HDL-C. Also, among the test participants, there was an increase in the level of fasting blood sugar (Fig. 1) which together with these abnormal lipid profiles are risk factors associated with diabetes and other cardiovascular diseases [27]. Worthy to note that in diabetes, various factors like carbohydrate and lipid metabolism can affect the level of blood lipids. This is because disorders resulting from carbohydrate metabolism progress to a disorder of lipid metabolism and vice versa [40]. People suffering from hypertriglyceridaemia i.e. elevated levels of triglycerides also have reduced levels of HDL-C due to abnormal lipid metabolism, which is common in diabetic patients [41]. Our findings on elevated fasting blood sugar, TC, TG, LDL, and decline in HDL-C in diabetic patients attending Everight laboratory in Owerri concur with the reports of different authors in different locations over the years [27,38,39,42].

5. CONCLUSION

The results of our study show that diabetic patients have elevated blood sugar levels, abnormal lipid profiles, and serum electrolytes compared to nondiabetic patients.

INFORMED CONSENT AND ETHICAL APPROVAL

All participants of the study were briefed on the nature of the study and informed consent was obtained. They filled out a questionnaire form covering information about their age, gender, and medical and family history of chronic diseases. Ethical clearance was obtained by the Institutions Ethical Committee.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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