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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.

GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.

ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ, რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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CROSS SECTIONAL EVIDENCE FOR OPPOSING EFFECTS OF HYPERGLYCAEMIA AND HYPERLIPIDAEMIA ON CHOLINESTERASE ACTIVITIES

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Abstract.

Background: Diabetes mellitus is increasing globally, creating a need for affordable biomarkers to supplement blood glucose and HbA1C monitoring. Plasma butyrylcholinesterase (BChE) and erythrocyte acetylcholinesterase (AChE) are promising candidates because they are easily measured and have known associations with metabolic disorders. This study examined whether BChE and AChE activities reflect diabetes type, glycemic control, chronic complications, and coexisting dyslipidemia.

Methods: In a cross-sectional study, plasma BChE and erythrocyte AChE activities were measured using an electrometric assay in 298 patients: they were divided according to diagnosed either with type 2 diabetes on monotherapy, or with type 2 diabetes on combination therapy, or with type 1 diabetes, and another group with isolated dyslipidemia. Thirty age- and sex-matched healthy individuals served as controls. Subgroups were stratified by glycemic control, complication status, therapy regimen, and comorbid conditions.

Results: Both plasma BChE and erythrocyte AChE activities were significantly lower in nearly all type 2 diabetes subgroups compared to controls ($p < 0.05$). The largest reduction in enzyme levels was observed in patients with poorly controlled type 2 diabetes and chronic complications. The diabetes treatment regimen (monotherapy versus combination therapy) did not significantly influence enzyme levels. Concurrent hypertension was associated with a modest, inconsistent reduction in AChE activity only. In type 1 diabetes, a significant AChE decrease was observed only in well-controlled patients, indicating a weaker relationship between cholinesterase activity and type 1 disease. By contrast, patients with isolated dyslipidemia showed significantly elevated BChE and AChE levels relative to controls ($p < 0.05$).

Conclusion: Declining cholinesterase activity—especially erythrocyte AChE—parallels worsening glycemic control and vascular complications in type 2 diabetes, whereas isolated dyslipidemia is associated with increased cholinesterase levels. Cholinesterase assays could serve as low-cost adjunct biomarkers in diabetes management, although prospective studies are needed to validate their prognostic utility.

Key words. Cholinesterase, dyslipidemia, diabetes mellitus, hyperglycemia.

Introduction.

Diabetes mellitus (DM) is a range of metabolic conditions characterized by impaired carbohydrate metabolism, leading to inadequate utilization of glucose as a source of energy and excessive production due to dysregulated gluconeogenesis and glycogenolysis, leading to hyperglycemia [1]. Conventionally diabetes is categorized into various clinical types such as type 1 and type 2 diabetes along with other less prevalent forms [2].

What has brought our awareness is the changing face of the complications of diabetes [3]. As mortality from vascular diseases has declined, cancer and dementia have become leading causes of death among people with diabetes mellitus [4,5]. However, early detection and management of diabetes is crucial to avoid complications and assist in reducing the risk of severe health problems [6].

Diabetes can be diagnosed using HbA1c or blood sugar parameters. The parameters for blood sugar encompass either the fasting plasma glucose (FPG), or oral glucose tolerance test (OGTT), or random glucose along with traditional manifestations of hyperglycemia (e.g., frequent urination, excessive thirst, and unjustified loss of weight) [2].

While these assays of glucose testing are affordable and easily accessible, their drawbacks may involve a high diurnal variation of glucose and recommendations for fasting which is somewhat difficult, or people may give false information about their fasting state. Additionally, recent physical exertion, sickness, or sudden stress may influence glucose levels [2]. Glycolysis is a significant and occasionally neglected issue in glucose testing. Improper and delayed handling of samples before analysis will result in inaccurately low glucose values [7].

On the other hand, HbA1c has numerous benefits over FPG and OGTT, such as enhanced convenience (no need for fasting), superior preanalytical stability, and less variability with stress, dietary changes, or sickness. However, it is important to acknowledge that the sensitivity of HbA1c at the designated threshold is inferior to that of 2-hour plasma glucose, along with restricted accessibility in certain regions globally [2].

HbA1c serves as indirect indicator of glucose intake, and variables influencing hemoglobin levels or red cells turnover such as thalassemia or folate insufficiency may impact HbA1c results [8]. HbA1c may not serve as an appropriate analytic tool for those with anemia, patients managed with erythropoietin EPO, or those doing blood dialysis or subjects on HIV medications [1]. So, the need to adopt alternative approaches is crucial.

The enzyme family of cholinesterase has two thoroughly related primary types: butyrylcholinesterase (BChE, commonly referred to as pseudo-cholinesterase) and acetylcholinesterase (AChE) [9]. AChE possesses an exact and clear role at the site of synapse and neuromuscular junction, if it quickly resolves acetylcholine to end the spread of nerve impulses [9,10]. The role of BChE is, however, less defined. It may substitute for AChE but resolves some additional chemical substrates and

serve as a detoxifier, for nerve agents and insecticides [9].

Prior minor researches indicated higher concentrations of BChE in obese subjects [11-13], and patients having metabolic syndrome [13,14]. Reports on the correlations between glycaemia and type 2 diabetes, are conflicting, with some indicating elevated [15,16], while others indicating diminished BChE action [14]. Consequently, the exact function of BChE in systemic glucose metabolism and metabolic disorders remains ambiguous. Thus, we investigated the correlation between ChE activity (BChE, AChE) and the glycemic state in a cross-sectional study involving different groups of diabetic patients to seek whether ChE enzymes can be a potential biomarker in the diagnosis of diabetes mellitus and its related causes and complications.

Materials and Methods.

Study design: This study employed an analytical observational design done from December 2024 to May 2025 using a cross-sectional approach and was conducted in Duhok City, Iraq. The population comprised of patients, both male and female, aged between 30-55 years, diagnosed with diabetes who attended the Azadi Teaching Hospital/Diabetic Center. The study protocol, with reference number 27112024-10-4, was authorized by the Duhok Directorate General of Health's institutional ethical committee and the College of Pharmacy's Postgraduate Studies Committee at the University of Mosul. The informed consent form was signed by each patient.

Patients with conditions associated with any unrelated diseases like liver, renal, nervous, muscular, bone diseases or even malignancies or pregnancies and smoking or alcoholic patients were excluded from the study. Additionally, any patients with a known history of exposure to ChE inhibitors (drugs or insecticides) or with any situation known to affect the ChE enzymes were also excluded.

Diabetic patients are defined as either having a documented history of diabetes or meeting any of the American Diabetes Association (ADA) laboratory criteria at the study visit [2].

American Diabetes Association criteria include a fasting plasma glucose (FPG) level ≥ 126 mg/dL after at least 8 hours without caloric intake; a 2-hour plasma glucose level ≥ 200 mg/dL during a 75-g oral glucose tolerance test (OGTT); a hemoglobin A1C level ≥ 6.5%, measured empoloying a technique accredited by the National Glycohemoglobin Standardization Program (NGSP) as a traceable to the Diabetes Control and Complications Trial (DCCT) standardized assay; or a random plasma glucose concentration ≥ 200 mg/dL accompanied by traditional manifestations of hyperglycemia [2].

In the absence of unequivocal hyperglycemia, the diagnosis must be confirmed by a repeat abnormal result from the same or a different test on a separate day [2].

Blood samples were drawn from a resting, seated participant by trained phlebotomists. FPG specimens were placed on ice and processed promptly to minimize glycolysis. HbA1c analysis was carried out in a CLIA-certified laboratory. The participant's final glycemic status was calculated as the mean of at least two concordant abnormal values obtained on the same day.

The study involved 273 diabetic patients (controlled, uncontrolled, complicated, or uncomplicated), The activity of cholinesterase in human plasma and erythrocyte was investigated in all of them and they were divided into three major groups based on their clinical diagnoses.

Group A: This group included 102 diabetic type 2 patients on mono-diabetic therapy, further subdivided into four subgroups based on glucose level control and the presence of complications:

- Controlled type 2 diabetes without complications: 25 patients
- Uncontrolled type 2 diabetes without complications:25 patients
- Controlled type 2 diabetes with complications: 26 patients
- Uncontrolled type 2 diabetes with complications: 26 patients

Group B: This group included 121 diabetic type 2 patients on multiple diabetic therapy and again subdivided into four subgroups based on glucose level control and the presence of complications:

- Controlled diabetic type 2 patients on multiple therapy without complications: 26 patients
- Uncontrolled diabetic type 2 patients on multiple therapy without complications: 32 patients
- Controlled diabetic type 2 patients on multiple therapy with complications: 30 patients
- Uncontrolled diabetic type 2 patients on multiple therapy with complications: 33 patients

Group C: This group included 50 diabetic type 1 patients and subdivided into two subgroups based on glucose level control and the presence of complications:

- Controlled diabetic type 1 patient without complications: 26 patients
- Uncontrolled diabetic type 1 patient without complications: 24 patients

In addition to the above-mentioned groups, and as they have a high association with cardiac diseases, a fourth group, which is a hyperlipidemia group, is considered. This final group included 25 patients diagnosed based on serum lipid profile analysis to have hyperlipidemia alone without any further related or associated complications. Hyperlipidemia, including high total cholesterol (TC), high total triglyceride (TG), high low-density lipoprotein cholesterol (LDL-C), lowered high-density lipoprotein cholesterol (HDL-C) all of which may be present either individually or in various combinations [17,18].

The control group included 30 healthy individuals (age range 30–55 years) and their history was free of DM or dyslipidemia or exposure to anti-ChE insecticides or drugs. None of the subjects in the control group were taking any pharmacological therapy or were suffering from any diseases.

Blood samples: Blood specimens were obtained in 5 ml EDTA tubes and subsequently centrifugated at 3000 rpm for 15 min. The red cells and plasma were stored separately at -20 °C in preparation for ChE testing. The reminder of the specimen was utilized for the other assays such as lipid panel test and others as indicated for each case.

ChE activity assessment: The revised electrometric technique used to test activity of ChE was validated in humans [19,20]. Three milliliters of distilled water, 0.2 milliliters of plasma or

red blood cells, and three milliliters of pH 8.1 barbital phosphate buffer made up the reaction mixture in a 10-milliliter beaker [21].

Utilizing a PH-meter, the pH of the mixture (pH1) was determined, subsequently 0.1 ml of (7.5%) an aqueous solution of acetylthicholine was introduced into reaction mixture which was then transferred to water bath to be incubated at 37°C for twenty minutes. Then (pH2) which is the -PH of reaction mixture at end of incubation- was assessed. The following formula was used to determine the enzyme activity:

Activity of cholinesterase (ΔpH/twenty minutes) = (pH1-pH2)-blank ΔpH

The blank included no RBC or plasma sample. The buffer system comprises 1.24 g sodium barbital, 0.163g potassium dihydrogen phosphate, and 35.07g NaCl went in solution of 1000 ml distilled water [19,20]. Using 1N HCL, the buffer's pH was brought down to 8.1.

Biochemical parameters: TC, TG, and HDL measured based on manufacturer instructions using kits supplied by Biolabo kit (France). LDL were calculated by standard equation. FSG measured by Biocon company (Germany) and Hb A1c measured by Stanbio (USA) kit.

Statistical analysis: Data expressed as mean and standard deviation. Minitab18 program and sigma plot 12.5 were used to conduct statistical analysis using ANOVA (One-way analysis of variance) test with post-hoc Turkey's test to determine significant group at p value of less than 0.05.

Results.

The level of ChE in T2D-treated with monotherapy:

Uncontrolled uncomplicated T2DM patients have significantly ($p<0.05$) higher plasma ChE (1.06 ± 0.16) than controlled uncomplicated patients (1.06 ± 0.16). However, in uncontrolled patients, complications significantly lower plasma ChE (1.08 ± 0.15). Only the uncontrolled T2DM uncomplicated group is not significantly different from healthy controls (1.16 ± 0.14). All other diabetic groups (controlled uncomplicated, controlled complicated, uncontrolled complicated) have significantly lower plasma ChE activity than the control group (Table 1).

The control group has the highest RBC ChE (0.98 ± 0.014) activity compared to all diabetic subgroups. All four T2DM patient groups were not significantly different from each other but are all significantly lower than the control group (Table 1).

Diseases in the controlled complicated T2D-treated with monotherapy:

Plasma ChE results using ANOVA revealed significant ($p < 0.001$) differences, indicating that the disease presentation has a significant effect on Plasma ChE levels. Post-hoc test demonstrated that dyslipidemia subgroup has the lowest level (0.99±0.17) and CABG + dyslipidemia subgroup is not significantly different from it (1.01±0.05). The CABG+D and IHD groups were not significantly different. The IHD + Dyslipidemia subgroup has the highest mean among patient groups (1.11±0.14). The control group (1.16±0.14) is significantly higher than all patient groups (Table 2).

The ANOVA resulted in significant ($p < 0.001$) differences between groups, indicating that the disease presentation has a significant effect on RBC ChE levels. Post-hoc test revealed that hypertension and hypertension + dyslipidemia subgroups have the lowest RBC ChE activity compared to all other groups. The ischemic heart disease, dyslipidemia, control group, ihd + dyslipidemia, and cabg + dyslipidemia subgroups were not significantly different from each other (Table 2).

Diseases in the uncontrolled complicated T2DM:

ANOVA revealed significant difference ($p < 0.001$), indicating that the disease presentation has a significant effect on Plasma ChE levels in uncontrolled patients. Post-hoc test revealed that IHD + hypertension + dyslipidemia and dyslipidemia subgroups have the lowest plasma ChE activity. They are significantly ($p<0.05$) lower than all other groups. The IHD+Hypertension +Dyslipidemia is significantly different from the control. The ischemic heart disease subgroup has intermediate activity, significantly different from other groups. The hypertension, hypertension + dyslipidemia, and control group are not significantly different from each other (Table 2).

ANOVA yield significant result ($p < 0.001$), indicating that the disease presentation has a significant effect on RBC ChE levels. Post-hoc analysis test likely showed that the hypertension + dyslipidemia subgroup has the lowest RBC ChE activity (0.80±0.03). The hypertension subgroup is not significantly different from the hypertension + dyslipidemia group (0.80±0.03). IHD subgroup forms a distinct group. The IHD+ hypertension+ dyslipidemia group is not significantly different. The dyslipidemia subgroup has the highest activity among patients (0.94±0.08). The control group (0.98±0.014) is significantly higher than all patient groups (Table 2).

Type 2 Diabetic on multiple (T2DP) therapy group:

Plasma ChE, ANOVA yield significant result ($p < 0.05$), indicating that the patient group has a significant effect on Plasma ChE levels. Post-hoc test revealed that controlled T2D groups (both complicated and uncomplicated) and the uncontrolled uncomplicated group have the lowest plasma ChE activity and they are significantly lower than the control group. The uncontrolled T2D complicated group has intermediate activity. It is not significantly different from the uncontrolled uncomplicated group but is also not significantly different from the control. The control group has the highest activity (1.16 ± 0.14) (Table 3).

RBC ChE, ANOVA yield significant result ($p < 0.001$), indicating that the patient group has a significant effect on RBC ChE levels. Post-hoc test revealed that the uncontrolled uncomplicated, controlled complicated, and uncontrolled complicated groups have the lowest RBC ChE activity. They are significantly lower than the control group and the controlled uncomplicated group. The controlled uncomplicated group has intermediate activity. It is significantly lower than the control (0.98 ± 0.014) (Table 3).

The level of ChE in T2D-treated with multiple therapy:

Plasma ChE levels: The ANOVA yield significant result ($p < 0.05$), indicating that the type of complication has a significant effect on Plasma ChE levels. The Dyslipidemia subgroup (Mean = 0.80) has significantly lower Plasma ChE activity than all other complication subgroups ($p < 0.05$). There is no significant

Table 1. *Plasma and RBC ChEs levels in T2DM subgroups using monotherapy.*

Group	No of Cases	FBS Range	HBA1c range	Δ pH/20 min	
				Plasma ChE ± SD	Erythrocyte ChE ± SD
Controlled T2DM uncomplicated	25	93-117	5.2-6.9	1.06 ± 0.16b	0.91±0.18b
Uncontrolled T2DM uncomplicated	25	134-293	7.5-12.5	1.18 ± 0.22a	0.93±0.19b
Controlled T2DM complicated	26	87-121	4.9-7	1.08 ± 0.15b	0.88±0.12b
Uncontrolled T2DM complicated	26	133-338	7.2-9	1.05 ± 0.16b	0.87 ± 0.11b
Control group				1.16 ± 0.14a	0.98 ± 0.014a
ChE values are expressed as means ± SD, n=3/sample Similar letters indicates non-significant differences while different letters indicates significantly difference at p<0.05 using one way ANOVA with post-hoc Turkey's test.					

Table 2. *Plasma and RBC ChE mean for controlled and uncontrolled complicated T2DM patients using monotherapy.*

Diseases in the controlled complicated T2DM			
Diseases	**No of Cases**	**Δ pH/20 min**	
		Plasma ChE±SD	**Erythrocyte ChE±SD**
Hypertension	6	1.07 ± 0.09b	0.86 ± 0.10b
Hypertension + Dyslipidemia	8	1.10 ± 0.11b,c	0.84 ± 0.09b
Ischemic Heart Disease + Dyslipidemia	5	1.11 ± 0.14c	0.97 ± 0.11a
Ischemic Heart Disease	2	1.09 ± 0.1b,c	0.94 ± 0.06a
Dyslipidemia	2	0.99 ± 0.17a	0.97 ± 0.16a
Coronary Artery Bypass Grafting + Dyslipidemia	3	1.01 ± 0.05a,b	0.99 ± 0.06a
Control group		1.16 ± 0.14d	0.98 ± 0.014a
Diseases in the uncontrolled complicated T2DM			
Diseases	**No of Cases**	**Δ pH/20 min**	
		Plasma ChE±SD	**Erythrocyte ChE±SD**
Dyslipidemia	7	0.90 ± 0.13a	0.94 ± 0.08c
Ischemic Heart Disease + Hypertension + Dyslipidemia	4	0.87 ± 0.12a	0.91 ± 0.12b,c
Ischemic Heart Disease	4	0.99 ± 0.11b	0.89 ± 0.06b
Hypertension + Dyslipidemia	2	1.11 ± 0.06c	0.80 ± 0.03a
Hypertension	9	1.08 ± 0.09c	0.86 ± 0.1a,b
Control group		1.16 ± 0.14c	0.98 ± 0.014d
ChE values are expressed as means ±SD, n=3/sample Similar letters indicates non-significant differences while different letters indicates significantly difference at p<0.05 using one way ANOVA with post-hoc Turkey's test.			

Table 3. *Plasma and RBC ChEs levels in the T2DP subgroups using multiple therapy.*

Group	No of Cases	FBS Range	HBA1c range	Δ pH/20 min	
				Plasma ChE ± SD	Erythrocyte ChE ± SD
Controlled T2D on multi therapy uncomplicated	26	97-118	5.7-7	1.03 ± 0.15a	0.93 ± 0.15b
Uncontrolled T2D on multi therapy uncomplicated	32	158-347	7.5-16	1.05 ± 0.23a,b	0.76 ± 0.2a
Controlled T2D on multi therapy complicated	30	96-109	5.4-7	1.01 ± 0.23a	0.8 ± 0.19a
Uncontrolled T2D on multi therapy complicated	33	148-336	7.5-13	1.1 ± 0.27b	0.84 ± 0.16a,b
Control group				1.16 ± 0.14c	0.98 ± 0.014c
ChE values are expressed as means ±SD, n=3/sample Similar letters indicates non-significant differences while different letters indicates significantly difference at p<0.05 using one way ANOVA with post-hoc Turkey's test.					

Table 4. *Plasma and RBC ChE for controlled and uncontrolled complicated T2DP patients using multiple therapy.*

Diseases in the controlled complicated T2D			
Diseases	**No of Cases**	**Δ pH/20 min**	
		Plasma ChE ± SD	**Erythrocyte ChE ± SD**
Hypertension + Dyslipidemia	12	1.08 ± 0.14a	0.79 ± 0.12b
Hypertension	7	0.99 ± 0.11a	0.89 ± 0.1a
Dyslipidemia	4	0.8 ± 0.21b	0.9 ± 0.07a
Ischemic Heart Disease + Dyslipidemia	4	1.02 ± 0.17a	0.9 ± 0.09a
Ischemic Heart Disease + Hypertension + Dyslipidemia	3	0.97 ± 0.08a	0.8 ± 0.09b
Diseases in the uncontrolled complicated T2D			
Drugs	**No of Cases**	**Δ pH/20 min**	
		Plasma ChE ± SD	**Erythrocyte ChE ± SD**
Ischemic Heart Disease	3	1.18 ± 0.17a	0.8 ± 0.1b
Hypertension	9	1.18 ± 0.1a	0.76 ± 0.13b
Hypertension + Dyslipidemia	8	1.07 ± 0.07a	0.87 ± 0.1b
Dyslipidemia	8	0.92 ± 0.28	0.81 ± 0.18b
Ischemic Heart Disease + Hypertension + Dyslipidemia	5	0.78 ± 0.15	0.79 ± 0.12b
Control group		1.16 ± 0.14	0.98 ± 0.014a
ChE values are expressed as means ±SD, n=3/sample Similar letters indicates non-significant difference, while different letters indicates significant difference at p<0.05 using one way ANOVA with post-hoc Turkey's test.			

Table 5. *Plasma and RBC ChEs levels in the T1D subgroups.*

Group	**No of Cases**	**FBS range**	**HBA1c range**	**Δ pH/20 min**	
				Plasma ChE ± SD	**Erythrocyte ChE ± SD**
Controlled T1D uncomplicated	26	80-113	5-6.5	1.04 ± 0.15b	0.90 ± 0.13b
Uncontrolled T1D uncomplicated	24	138-363	7.5-13.4	1.07 ± 0.20b	0.95 ± 0.17b
Control group				1.16 ± 0.14a	0.98 ± 0.014a
ChE values are expressed as means ±SD, n=3/sample Similar letters indicates non-significant differences while different letters indicates significantly difference at p<0.05 using one way ANOVA with post-hoc Turkey's test.					

Table 6. *Dyslipidemia group with their mean plasma and RBC ChE levels.*

Group	**TC**	**TG**	**LDL-C**	**HDL-C**	**No of Cases**	**Δ pH/20 min**	
						Plasma ChE ± SD	**RBC ChE ± SD**
Dyslipidemia patients	279	250	150	38.5	25	1.22± 0.11a	1.08 ± 0.07a
Control group					25	1.16± 0.14b	0.98 ± 0.014b
ChE values are expressed as means ±SD, n=3/sample Similar letters indicates non-significant differences while different letters indicates significantly difference at p<0.05 using t-test.							

Table 7. *Distribution of plasma and erythrocyte ChE activity across ranges in dyslipidemia patients.*

ChE Range	**No of Cases**	**Plasma ChE ± SD Δ pH/20 min**	**ChE Range**	**No of Cases**	**RBC ChE ± SD Δ pH/20 min**
1.0 - 1.1	4	1.08 ± 0.02b	0.9 - 1.0	2	0.98 ± 0.001b
1.1 - 1.2	5	1.13 ± 0.03b	1.0 - 1.1	14	1.04 ± 0.03a
1.2 - 1.3	10	1.22 ± 0.02a	1.1 - 1.2	9	1.13 ± 0.04a
1.3 - 1.5	6	1.38 ± 0.06a			
Control group		1.16 ± 0.14b			0.98 ± 0.014b
ChE values are expressed as means ±SD, n=3/sample Similar letters indicates non-significant differences while different letters indicates significantly difference at p<0.05 using one way ANOVA with post-hoc Turkey's test.					

difference in plasma ChE among the other four complication subgroups.

The ANOVA yield significant result ($p < 0.05$), indicating that the type of complication has a significant effect on RBC ChE levels. Post-hoc Tukey's test. The subgroups hypertension + dyslipidemia (0.79) and IHD + hypertension + dyslipidemia (0.80) have the lowest RBC ChE activity and were not significantly different from each other. The subgroups hypertension alone (0.89), IHD + dyslipidemia (0.90), and dyslipidemia alone (0.90) all have significantly higher RBC ChE activity than the groups.

Uncontrolled complicated T2D:

Plasma ChE, only the IHD + Hypertension + Dyslipidemia group is significantly lower than the control group ($p < 0.001$). The Dyslipidemia, Hypertension + Dyslipidemia, Hypertension, and Ischemic Heart Disease groups are not statistically different from the healthy control group ($p > 0.05$). RBC ChE, the control group (0.98) is significantly higher than all patient groups.

Type 1 Diabetic (T1DM) group:

Plasma ChE: The ANOVA revealed a significant overall effect ($p < 0.05$). The post-hoc Tukey's test showed that both T1D groups (controlled and uncontrolled) have significantly lower plasma ChE levels than the healthy control group. There is no significant difference in plasma ChE between the controlled and uncontrolled T1D groups.

RBC ChE: The ANOVA revealed a significant overall effect ($p < 0.05$). The pattern is the same as for plasma ChE: the post-hoc test showed that both T1D groups have significantly lower RBC ChE levels than the control group, while there is no significant difference between the two diabetic groups (Table 5).

The independent samples t-test analysis reveals two key findings:

Elevated Enzyme Activity: Patients with dyslipidemia exhibit significantly elevated levels of both plasma and erythrocyte cholinesterase compared to healthy controls.

Systemic Effect: The fact that both types of ChE are affected suggests that dyslipidemia may be associated with a systemic alteration in cholinesterase metabolism or regulation, rather than an effect confined to one specific compartment (e.g., just plasma or just red blood cells) (Table 6).

The statistical analysis reveals a clear and significant trend in plasma ChE:

There is a highly significant overall difference in plasma ChE activity among the defined ranges and the control group (ANOVA, $p < 0.05$).

Post-hoc analysis confirms that patients in the lowest ChE activity range (1.0-1.1) have significantly reduced plasma cholinesterase levels compared to:

Patients in all higher ChE activity ranges (1.1-1.2, 1.2-1.3, and 1.3-1.5) and the control group.

This suggests that a specific subset of dyslipidemia patients with very low plasma ChE activity (Δ pH/20 min between 1.0 and 1.1). The control group's activity, while significantly higher than the lowest group, shows greater variability (larger standard deviation, SD=0.14) (Table 7).

The statistical analysis reveals a clear and specific finding in RBC ChE:

There is a significant overall difference in RBC ChE activity among the groups (One-Way ANOVA, $p < 0.05$).

Post-hoc testing shows that dyslipidemia patients with higher RBC ChE activity (ChE Range, 1.0 - 1.1 and 1.1 - 1.2) have significantly elevated enzyme levels compared to those in the lowest range (ChE Range, 0.9 - 1.0).

The most critical finding is that the RBC ChE activity in the lowest patient group (0.9-1.0) is statistically indistinguishable from the control group (0.98). This suggests that for erythrocyte ChE, the disease state (dyslipidemia) alone does not cause a uniform depression of enzyme activity. Instead, only a subset of patients exhibits significantly altered (in this case, higher) levels (Table 7).

Discussion.

The results demonstrated a significant decrease in both plasma ChE (BChE) and RBC ChE (AChE), except plasma ChE in the uncontrolled uncomplicated T2DM group. Although a decrease was observed in BChE, it was less pronounced than the significant decrease observed in AChE when compared to the control group. The complicated uncontrolled group exhibited the lowest results for both ChE types. This suggests a correlation between ChE activity and the progression of T2D. This aligns with a study conducted by Abed Hussein et al. in 2024 [22], which concluded that AChE activity is significantly decreased in patients with type 2 diabetes compared to healthy individuals. They associated this reduction with diabetic complications such as autonomic neuropathy, which can impair the function of enzymes involved in neurotransmission.

An important study by Markowicz-Piasecka et al. in 2017 demonstrated that metformin can inhibit AChE in vitro with moderate potency (IC_{50} = 2.35 μmol/mL) and shows low activity against BChE, indicating a degree of selectivity for AChE. Moreover, modified sulfonamide prodrugs of metformin exhibited significantly stronger and more selective inhibition of ChEs, particularly BChE, at nanomolar concentrations. These findings suggest that biguanides like metformin may have a neuroprotective role in diabetic patients by mitigating cholinergic dysfunction through ChE inhibition [23].

The results indicated that only hypertension, either alone or in combination with other diseases, affects the RBC ChE level to a significant degree in the controlled complicated patients. However, when hypertension is combined with dyslipidemia and ischemic heart disease in the uncontrolled group, it does not show such an effect. This suggests a low correlation, which may be related to diabetic control in these patients. The other complicated diseases, whether alone or in combination, do not affect both ChE levels across both controlled and uncontrolled groups. This suggests that complicated diseases in diabetic patients have no direct effect on ChE levels (with the possible exception of hypertension's effect on RBC ChE, which may warrant further investigation). Instead, any correlation is solely with the severity and poor control of diabetes.

The results in demonstrated a comparable picture to the T2DM group, showing a significant decrease in both plasma ChE (BChE)

and RBC ChE (AChE) in all subgroups. Here, too, the decrease in BChE is less pronounced than the significant decrease observed in AChE compared to the control group. The uncomplicated controlled group exhibited the lowest significant decrease in ChE levels. This may also suggest a correlation between ChE activity and the progression of T2DM. Specifically, more uncontrolled and complicated diabetic patients will have lower AChE and BChE. This aligns with a study conducted in 2021, which tested the effects of both metformin and glibenclamide (in combination) on AChE, BChE, and liver biochemical profile activities in two groups of type 2 DM patients (with and without nonalcoholic fatty liver disease). The activity of both enzymes (AChE & BChE) in both clusters 1 and 2 was notably decreased and was more pronounced in cluster 2 compared to cluster 1 and the control [24].

The results for the T2DP groups present a contrasting picture compared to the T2DM groups. Here, hypertension, whether alone or in combination with other diseases, does not consistently affect ChE levels across all cases (showing variability). This suggests a low correlation with ChE levels. Furthermore, the data indicates that other complicated diseases, whether alone or in combination, do not affect both ChE levels across both controlled and uncontrolled groups. This suggests that complicated diseases in diabetic patients have no direct effect on ChE levels. Instead, any correlation is solely with the severity and poor control of diabetes, as previously noted in the T2DM groups.

The results revealed a significant decrease in RBC ChE (AChE) only in the controlled uncomplicated T1DM subgroup. This observation presents a stark contrast to the patterns seen in both T2DM and T2DP groups, suggesting a low correlation between ChE activity and T1DM. This might be related to the controlled diabetic state of the patients in this group, as their life patterns, including insulin doses, are managed from the early stages of the disease, leading to a controlled and manipulated diabetic state. Although the uncontrolled group shows a decrease in ChE levels, it is not to a significant level.

Hyperlipidemia (DLIP) is highly related to diabetes, as both conditions can cause or worsen each other's morbidity. In many cases, DLIP may be associated with diabetes without being diagnosed by a physician or known by the patients. Numerous research papers indicate the association of dyslipidemic states with the ChE enzyme [25-27].

The results revealed elevated plasma and RBC ChE activity compared to the control group. This elevation in both ChEs contrasts with the results observed in the diabetic groups, all of which showed reduced and significantly reduced ChE levels. This observed elevation is consistent with many previous studies. In 2015, a large epidemiological and cross-sectional investigation revealed positive correlations between BChE activity and total cholesterol, LDL-C, and triglycerides, as well as inverse associations with HDL-C. These observations are echoed in groups with abdominal obesity [28].

Another study by Stojanov et al. in 2011 investigated the association of serum BChE activity with risk factors for cardiovascular disease in a cross-sectional population of 1512 healthy young individuals aged 18-25. Results showed higher BChE activity was associated with triglycerides, total cholesterol, and LDL-C in males [29].

Additionally, according to Vallianou et al. (2014), the relationship between BChE and lipid levels was assessed in a cross-sectional study involving 490 healthy adults as indicators of cardiovascular disease development. Results showed that LDL-cholesterol, total cholesterol, and triglycerides were positively associated with serum BChE activity, and abnormal BMI or waist circumference being the most important predictors [30].

Another study was conducted in Thailand by Tangvarasittichai et al. (2015) to investigate the association between abdominal obesity and elevated serum BChE activity and changes in the serum lipid profile. The study involved 642 women aged over 40 years, with 500 having abdominal obesity and 142 non-abdominally obese women as the control group. Results showed that women with abdominal obesity had significantly higher BMI, BP, glucose, LDL-C, triglycerides, and BChE, and significantly lower HDL-C [28].

The results indicated a significant correlation between hyperlipidemia and both types of ChEs. Nearly all ChE ranges were elevated compared to the control group. It's worth noting that this elevation contrasts with the reduced ChE levels observed in all diabetic groups. This phenomenon suggests that the presence of a hyperlipidemic state will cause an elevation in ChE levels. If ChE levels are already decreased by another cause (like diabetes or other morbidities), and hyperlipidemia is underlying or associated, it will cause ChE levels to rise, potentially bringing them near or even above the normal range. This is clearly visible in the previous complicated diabetic groups, where no significant reduction in ChEs was observed, or levels were near the control group, whenever hyperlipidemia was present (alone or with other diseases).

In contrast, to the above results, other studies present a modulated picture. ChE activity was assessed in patients with DM, hypertension, and DM/hypertension in a study conducted in 2006 by Inacio Lunkes et al. ChE activity was considerably lower in the control group than in the DM and hypertensive DM groups. Both the DM and DM/hypertensive groups had higher blood glucose levels. They concluded that in diabetic individuals, there is a correlation between increased serum ChEs and vascular problems, which may be triggered by levels of glycemia and dyslipidemia [16].

Another research, by Rao et al. in 2007, declared that subjects having T 2 DM have increased BChE and AChE activities in their plasma and RBCs. They suggested that measuring these enzymes can help predict prognosis and response to management in T 2 DM. Additionally, their plasma levels may be accurate indicators of low-grade systemic inflammation [31].

Furthermore, an elevated serum BChE was found to be independently associated with an increased risk of developing type 2 diabetes in a prospective cohort study conducted in 2014 that included 8,470 Japanese men aged between 40–55 years who did not have type 2 diabetes at baseline [32].

In parallel to the above, Mushtaq et al. (2014) showed that higher levels of AChE and BChE are found in people with type 2 DM. Specifically, BChE activity is elevated in both type 1 and

type 2 DM. They declared that BChE may contribute to type 2 DM by causing insulin resistance and increasing lipoprotein synthesis [33]. However, case-control comparative research in 2019 tested patient plasma and red blood cells ChE level in five groups of diabetic patients with different levels of DM. Results showed that BChE and diabetes were related, while no such relation with AChE. Dyslipidemia also affected both types of ChE enzymes. Inadequately controlled DM and dyslipidemia may increase both kinds of ChE enzymes, but less than dyslipidemia alone [27].

Another study conducted in 2022 examined the correlation between glutathione peroxidase (GPX) activity, BChE level, fasting serum glucose (FSG), and Lipoic acid synthetase (LIAS) levels in type 2 DM subjects[33]. Results showed higher FSG and HbA1c levels in diabetics, lower GPX activity, and increased BChE concentration compared to control. In contrast, LIAS level in the control was insignificantly elevated compared to patients with diabetes. The study concluded that HbA1c, FSG, LIAS, BChE, and GPX are valuable biomarkers for disease monitoring and ought to be utilized in standard clinical diagnostic processes to assess patient clinical conditions [34].

There is a controversy between the results of this cross-sectional study and other conducted studies regarding the elevation or reduction of ChE enzymes as a potential biomarker for DM. The results of this study indicate a significant reduction of the ChEs with the bad control or bad morbidity state of the DM, while in contrast, others find the same correlated results but in an elevation of the ChEs. Therefore, further follow-up studies across all DM disease types and stages in different community sections will be needed. These proposed additional studies are required to fully understand the link between these enzymes and DM.

Conclusion.

This study shows that plasma BChE and red-cell AChE both fall as type 2 diabetes progresses irrespective of therapy. Red-cell AChE is the more sensitive marker, dropping the most in those with the poorest metabolic control. In type 1 diabetes, this trend is absent, and people with isolated high lipid levels have higher enzyme values. Therefore, clinicians must consider disease type and lipid profile when interpreting cholinesterase results. Our findings indicate that cholinesterase testing may enhance regular assessments of glucose, HbA1c, and lipid profiles to more effectively evaluate metabolic stress and cardiovascular risk in type 2 diabetes. Because this study cannot prove cause and effect and earlier research sometimes shows opposite results, larger and multi-center investigations employing standardized methodologies are required to validate its prognostic significance.

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