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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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ASSOCIATION BETWEEN EXERCISE MODALITIES AND GLYCEMIC CONTROL IN TYPE 2 DIABETES

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Abstract.

Background: Type 2 diabetes mellitus is associated with increased cardiovascular risk, with physical inactivity contributing significantly to metabolic dysfunction. This study aimed to investigate the association between physical activity status and cardiometabolic markers in patients with type 2 diabetes mellitus in the United Arab Emirates. **Methods:** This cross-sectional study was conducted at Thumbay Labs, UAE, between January and October 2025. A total of 185 participants with type 2 diabetes were stratified into active (at least 150 minutes per week for more than 3 months) (n=99) and sedentary (n=86) groups based on physical activity levels. The active group was further subclassified by exercise type: aerobic (n=70), combined (n=17), and resistance training (n=11). Anthropometric measurements and biochemical parameters including fasting glucose, HbA1c, Fructosamine, fasting insulin, HOMA-IR, and lipid profile were assessed. Mann-Whitney U test, Kruskal-Wallis test, and Spearman's correlation were used for statistical analysis. **Results**: The active group demonstrated significantly lower BMI (26.4 vs 28.6 kg/m², $p<0.001$), fasting glucose (127 vs 149 mg/dl, $p<0.001$), HbA1c (6.84% vs 8.07%, $p<0.001$), Fructosamine (303 vs 362 μmol/L, $p<0.001$), fasting insulin (9.03 vs 10.99 μU/mL, $p=0.011$), and HOMA-IR (3.0 vs 4.1, $p<0.001$) compared to the sedentary group. No significant differences were observed in lipid parameters. Among exercise subgroups, resistance training exhibited the most favorable metabolic profile with the lowest HbA1c (6.41%), BMI (23.01 kg/m²), and HOMA-IR (1.9). Correlation analysis revealed significant positive associations between BMI and glycemic markers as well as insulin resistance indices. **Conclusion:** Physical activity is associated with significantly better glycemic control, insulin sensitivity, and body composition in patients with type 2 diabetes. Resistance training demonstrated particularly favorable metabolic outcomes; however, limited sample size restrict generalizability. These findings support the integration of regular physical activity into comprehensive diabetes care strategies.

Key words. Type 2 diabetes mellitus, physical activity, exercise, glycemic control, insulin resistance, HbA1c, HOMA-IR, resistance training.

Introduction.

Type 2 diabetes mellitus is a chronic medical condition characterized by insulin resistance that affects approximately 7% of the global population [1]. Patients with type 2 diabetes are at an increased risk of developing cardiovascular diseases, which also serves as the major cause for the high mortality rate among the type 2 diabetic population [2].

Insufficient physical exercise is believed to contribute to the deaths of over 3.2 million people annually, and it affects about 31% of the world's population aged 15 and over. Sedentary behavior is defined as any waking behavior such as sitting or leaning with an energy expenditure of 1.5 metabolic equivalent task (MET) or less. With rapid changes in the world, the choice of sedentary lifestyle, fast food practices and more exposure to stress, have made type 2 diabetes a global concern [2].

Metabolic syndrome on the other hand, remains as a precursor for cardiovascular disorders in type 2 diabetic individuals. Metabolic syndrome is characterized by various risk factors including– abdominal obesity, dyslipidemia, hypertension and elevated fasting glucose. These factors in turn accelerate the risk of developing atherosclerosis, coronary artery, stroke and peripheral vascular disease in diabetic individuals [3]. A national cohort study found that the prevalence of diabetes was 4.7% among young men (age group 18-29 years) in the UAE [4]. This high prevalence could be a result of rapid lifestyle changes over the past 50 years, adapting into a sedentary, urban, high-income society from a traditional semi-rural lifestyle. Diet and exercise are some renowned non-pharmacological strategies that are followed to reduce cardiovascular risk in diabetic individuals. These changes are said to improve the overall health of the individuals by working effectively in reducing weight, blood glucose and blood pressure levels. Physical activity, on the other hand, helps in the regulation of insulin sensitivity by enhancing the glucose intake resulting in better cardiovascular health by regulating the blood pressure, blood glucose and lipid metabolism [5]. The look AHEAD (action for health in diabetes) explored the impact of lifestyle changes on cardiovascular health in overweight individuals with type 2 diabetes [6].

Cardiovascular diseases are a major cause of mortality in type 2 diabetes patients due to chronic inflammation, stress, and

dyslipidemia [7]. According to a recent study, patients with type 2 diabetes can reduce their insulin resistance indicators and pro-inflammatory cytokines including TNF-a, IL-6, and CRP by engaging in various forms of exercise [8,9].

Diet modifications in type 2 diabetic individuals often involve calorie restriction with increased fruit, vegetable and low-fat dairy intake [10]. This cross-sectional study examined the relationship between patients with type 2 diabetes mellitus' levels of physical activity and cardiometabolic indicators.

Materials and Methods.

This cross-sectional study was conducted at Thumbay Labs, United Arab Emirates, between January and October 2025. Patients with type 2 diabetes were stratified into sedentary and active groups based on physical activity levels (at least 150 minutes per week for more than 3 months); the active group was further subclassified by exercise type (aerobic, resistance, or combined). Sample size was calculated using G*Power analysis (effect size $f^2 = 0.15$, $\alpha = 0.05$, power = 0.80), yielding a minimum requirement of 180 participants. Exclusion criteria included type 1 diabetes, use of insulin therapy, suspected Latent Autoimmune Diabetes in Adults (LADA), prediabetes, other comorbidities, surgical disabilities, and thyroid disorders. Participants completed a structured questionnaire for group allocation. Height and weight were measured following standardized protocols, and BMI was calculated (kg/m^2). Venous blood samples were collected after an overnight fast (≥8 hours). Sodium fluoride plasma, EDTA whole blood, and serum specimens were obtained and processed by centrifugation at 4000 rpm for 10 minutes. Fasting glucose, lipid profile (total cholesterol, triglycerides, HDL, LDL), and HbA1c were measured on the Beckman Coulter DXC 700 analyzer using enzymatic and latex agglutination inhibition methods, respectively. Fasting insulin was determined by chemiluminescent immunoassay (Beckman Coulter DXI 800/900). HOMA-IR was calculated as [fasting insulin (μU/mL) × fasting glucose (mg/dL)] / 405. Fructosamine was measured by colorimetric method using Cobas c 503 Roche kits.

All procedures were validated according to College of American Pathologists (CAP) guidelines. Internal and external quality controls were implemented, with calibration performed per manufacturer specifications. The study was approved by the Institutional Review Board (Ref. No. IRB-COHS-STD-131-Dec-2024). All participants provided written informed consent, and data were anonymized and stored securely.

Data analysis was performed using IBM® SPSS® Statistics Version 30.0. Continuous variables were expressed as median and interquartile range (IQR) due to non-normal distribution of data. The Mann-Whitney U test was employed to compare cardiometabolic markers between active and sedentary groups. Kruskal-Wallis test was used to evaluate differences among exercise type subgroups (aerobic, resistance, and combined) within the active group. Spearman's correlation coefficient was calculated to assess relationships between cardiometabolic variables. Chi-square test was used for gender distribution between the groups. Data visualization including bar charts and correlation heatmaps were generated to illustrate group distributions and inter-variable associations. A p-value less than 0.05 was considered statistically significant, while p-value less than 0.001 was considered highly significant.

Results.

A total of 185 participants with type 2 diabetes mellitus were enrolled in this cross-sectional study. Participants were classified into an active group (n=98) and a sedentary group (n=87). Within the active group, exercise modalities were distributed as follows: aerobic exercise (n=70, 70.7%), combined aerobic and resistance training (n=17, 17.2%), and resistance training exclusively (n=11, 11.1%).

The majority of participants were treated with metformin monotherapy, with smaller proportions receiving combination oral therapy including DPP 4 inhibitors and/or sulfonylureas. Medication distributions were broadly similar between physically active and sedentary groups, with no major qualitative differences in the type of glucose lowering therapy across physical activity strata.

Discussion.

The present cross-sectional study investigated the association between physical activity and cardiometabolic markers in patients with type 2 diabetes mellitus in Ajman, United Arab Emirates during January to October 2025. Study participants was recruited based on their physical activity status into two groups active and sedentary then the active group is subclassified according to the type of exercise into aerobic, resistance or combined.

Our study revealed significantly lower HbA1c levels in the active group compared to the sedentary group (6.84% vs 8.07%, $p<0.001$). This finding aligns with substantial evidence in the literature supporting the beneficial effects of exercise on glycemic control. A network meta-analysis of 158 studies involving 17,059 participants demonstrated that all types of exercise are beneficial for improving glycemic control in adults with type 2 diabetes [11]. The American Diabetes Association position statement confirms that in individuals with type 2 diabetes, regular training reduces HbA1c, triglycerides, blood pressure, and insulin resistance [12].

The clinically meaningful difference in HbA1c observed in our study carries significant prognostic implications. A 1% absolute decrease in HbA1c is associated with a 15–20% reduction in cardiovascular complications, a 37% reduction in microvascular complications, and a 21% reduction in diabetes-related death [13]. Therefore, the approximately 1.2% difference in median HbA1c between active and sedentary groups in our study represents a substantial reduction in complication risk.

Similarly, fasting glucose, fasting insulin, and HOMA-IR were all significantly lower in the active group. A large Korean cohort study of 280,194 individuals demonstrated a significant inverse relationship between physical activity level and HOMA-IR, with health-enhancing physical activity showing lower HOMA-IR values even when individuals decreased their activity level over time, suggesting a cumulative effect of exercise on insulin resistance [14]. These findings support the notion that regular physical activity improves insulin sensitivity through multiple mechanisms, including enhanced glucose uptake by skeletal muscle, improved mitochondrial function, and reduced visceral adiposity.

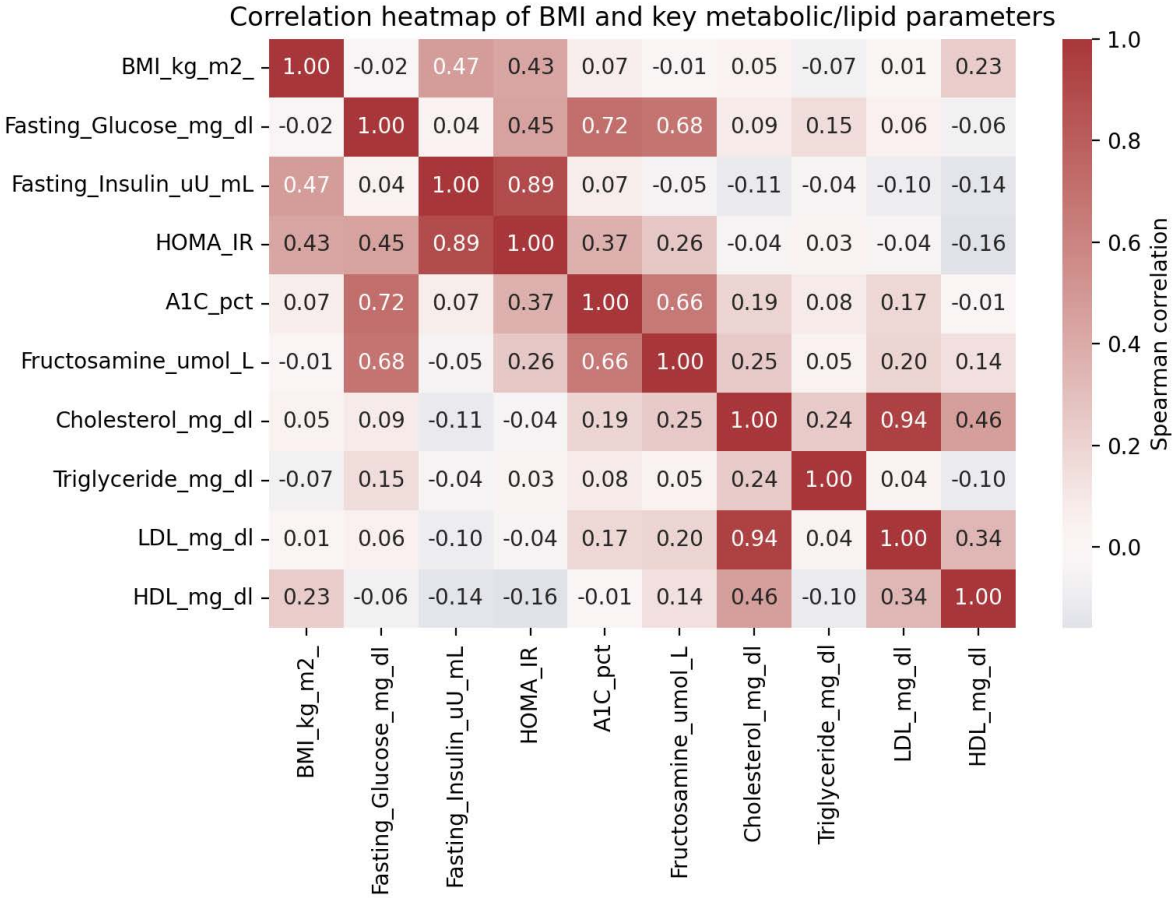

Figure 1. *Displays the correlation matrix illustrating the correlations between BMI and the other cardiometabolic markers. This heatmap visualization identifies significant positive and negative correlations between BMI and glycemic indices, insulin resistance markers, and lipid parameters among study participants.*

Table 1. *Display the gender distribution across exercise subgroups.*

Characteristic		**Aerobic (n:70)**	**Resistance (n:11)**	**Combined (n:17)**	**p-value**
Gender	Female	19 (27.1%)	1 (9.1%)	4 (23.5%)	0.4305
	Male	51 (72.9%)	10 (90.9%)	13 (76.5%)	

Data are presented as n (%) for categorical variables and gender compared using chi-square test.

Table 2. *Summarizes the cardiometabolic parameters between the active and sedentary groups.*

Variable	**Active (N:98)**		**Sedentary (N:87)**		**P.value**
	Median	**IQR**	**Median**	**IQR**	
BMI (kg/m2)	26.4	23.7-30.45	28.6	26.43 -33.4	<0.001
Fasting Glucose (mg/dl)	127	118.8-153.6	149	129.25-201.0	<0.001
Fasting Insulin (µU/mL)	9.03	5.975-13.84	10.99	7.748-19.282	0.011
HOMA IR	3	1.9-4.75	4.1	2.7-8.075	<0.001
A1C (%)	6.84	6.47-8.035	8.07	7.155-9.665	<0.001
Fructosamine µmol/L	303	270.0-369.5	362	319.0-407.0	<0.001
Cholesterol (mg/dl)	179	148.5-211.0	184.5	162.25-218.25	0.296
Triglyceride (mg/dl)	139	98.0-189.0	134	97.25-185.0	0.822
LDL (mg/dl)	107	79.5-131.0	113	96.0-133.0	0.403
HDL (mg/dl)	45	38.0-53.0	46.4	40.5-52.75	0.197

Table 3. *Presents the comparison of cardiometabolic markers among different exercise modalities.*

Variable	Aerobic (n:70)		Combined (n:17)		Resistance(n:11)		P.value
	Median	IQR	Median	IQR	Median	IQR	
Age, years	50.0	44.0-61.2	46	46.0-52.0	42	41.5-42.5	0.0046
A1C (%)	7.38	6.62-8.5	7.05	6.49-7.6	6.41	6.41-6.7	0.0004
BMI (kg/m2)	26.8	24.7-30.5	29.1	27.2-32.7	23.01	19.7-23.7	< 0.001
Cholesterol (mg/dl)	185	146.0-211	149	145.0-206.0	179	171.0-221.0	0.406
Fasting Glucose (mg/dl)	128	118.6-158.5	127	113.0-167.0	122.9	121.9-138.3	0.671
Fasting Insulin (µU/mL)	8.73	6.45-13.455	11.56	10.81-14.125	6.68	4.69-7.11	0.0057
Fructosamine (µmol/L)	319	274.0-386.5	331	251.0-395.0	284	265.0-299.0	0.145
HDL (mg/dl)	45	37.0-54.0	39	38.0-44.0	45	43.0-61.0	0.188
HOMA IR	3.1	2.2-4.75	4.1	3.3-5.65	1.9	1.6-2.1	0.0086
LDL (mg/dl)	106	82.0-130.0	107.8	77.0-132.0	117	97.0-132.0	0.917
Triglyceride (mg/dl)	142	101.5-193.0	72	70.0-120.0	139	104.0-293.0	0.0025

Kruskal–Wallis test, P.value less than 0.05 is considered significant, P.value less than < 0.001is considered highly significant and IQR stands for Interquartile Range.

The active group demonstrated significantly lower BMI compared to the sedentary group (26.4 vs 28.6 kg/m², p<0.001). Cross-sectional studies have shown that higher BMI is positively associated with increased HbA1c levels, and the Look AHEAD trial demonstrated that individuals with type 2 diabetes who achieved modest weight loss experienced significant improvements in glycemic control [15]. The lower BMI observed in our active participants may partially mediate the improvements in glycemic parameters, as adipose tissue, particularly visceral fat, contributes to insulin resistance through inflammatory cytokine release and altered adipokine secretion.

In this study, significant age differences were observed among exercise groups, with the resistance training group being younger and the aerobic and combined exercise groups older (p = 0.0046). This may reflect preferences for specific exercise types in different age categories, potentially affecting training outcomes and cardiometabolic risks. Gender distribution was comparable across groups (p = 0.4305), indicating minimal sex-related confounding. However, the modest sample size in resistance and combined groups necessitates caution in interpreting results, as age and sex residual confounding cannot be fully ruled out.

An intriguing finding of our study was the superior cardiometabolic profile observed in participants performing resistance training exclusively. The resistance training group exhibited the lowest median values for HbA1c (6.41%), BMI (23.01 kg/m²), fasting insulin (6.68 µU/mL), and HOMA-IR (1.9). A meta-analysis of 12 randomized controlled trials found that resistance exercise significantly reduced HOMA-IR level (d = −0.25, 95% CI: −0.43 to −0.06; p < 0.05) and HbA1c levels (d = −0.51, 95% CI: −0.84 to −0.18; p < 0.05), with the largest effect sizes observed for high-intensity and long-term training programs [16]. More recent evidence confirms that resistance training improves markers of insulin resistance, including insulin (MD −1.35 µIU/mL), HOMA-IR (MD −1.15), fasting glucose (MD −6.99 mg/dL), and HbA1c (MD −0.55%), as well as increases muscle mass and both upper and lower body strength in adults with type 2 diabetes [17].

Resistance training benefits for individuals with type 2 diabetes include improvements in glycemic control, insulin resistance, fat mass, blood pressure, strength, and lean body mass [12]. The mechanisms underlying these benefits include increased muscle mass, which serves as the primary site for insulin-mediated glucose disposal, enhanced GLUT4 translocation, and improved mitochondrial function in skeletal muscle.

However, our results should be interpreted cautiously given the small sample size of the resistance training subgroup (n=11) and age bias. Additionally, the cross-sectional design precludes determination of whether individuals with better baseline metabolic profiles preferentially chose resistance training or whether the exercise modality directly contributed to these favorable outcomes.

Contrary to glycemic parameters, no significant differences were observed in lipid profile markers (total cholesterol, triglycerides, LDL, and HDL) between active and sedentary groups. A review of exercise effects on lipids reported that HDL cholesterol is the component of the lipid profile most likely to improve as a result of physical activity, while effects on LDL cholesterol and triglycerides are often inconsistent [18]. The lack of significant differences in our study may be attributed to several factors.

First, lipid metabolism is heavily influenced by dietary intake, medication use, and genetic factors that were not controlled in this cross-sectional analysis. Second, the exercise characteristics of our active participants—including intensity, duration, and frequency—may have been insufficient to elicit measurable changes in lipid parameters. Evidence suggests that a volume of exercise sufficient to elicit changes in fat mass may be required to favourably alter the lipid profile [18]. Third, diabetes tends to lower HDL cholesterol and raise triglycerides through diabetic dyslipidemia, which is linked to insulin resistance [19], and this underlying metabolic disturbance may attenuate the exercise-induced improvements typically observed in non-diabetic populations.

The significantly lower Fructosamine levels observed in the active group (303 vs 362 µmol/L, p<0.001) provide additional confirmation of improved short-term glycemic control. Fructosamine reflects average blood glucose over the preceding 2–3 weeks and serves as a complementary marker to HbA1c. The concordance between these two glycemic markers strengthens the validity of our findings regarding the association between physical activity and glucose homeostasis.

The beneficial effects of physical activity on cardiometabolic parameters in type 2 diabetes involve multiple interconnected pathways. Habitual exercise, consisting of aerobic, resistance, or their combination, fosters improved short- and long-term glycemic control through mechanisms including improved insulin sensitivity, enhanced muscle glucose uptake, and favorable changes in body composition [20]. Acute exercise increases glucose uptake independently of insulin through contraction-mediated GLUT4 translocation, while chronic training enhances insulin signaling pathways and increases mitochondrial density in skeletal muscle. Regular exercise may improve glycemic control, reduce cardiovascular risk factors, contribute to weight loss, and improve well-being among diabetic patients [21].

Furthermore, resistance training exerts modulatory effects on systemic inflammation by reducing circulating levels of pro-inflammatory cytokines, which are well-established contributors to impaired insulin signaling and cardiovascular risk. The combination of improved body composition, enhanced insulin sensitivity, and reduced inflammation collectively contributes to the favorable metabolic profile observed in physically active individuals with type 2 diabetes [17]. Obesity is one of the most important modifiable risk factors for the prevention of type 2 diabetes. An increase in body fat is generally associated with an increase in the risk of metabolic diseases such as type 2 DM, hypertension [22]. and dyslipidemia. The correlation analysis revealed significant positive associations between BMI and glycemic markers (fasting glucose, HbA1c, Fructosamine) as well as insulin resistance indices (fasting insulin, HOMA-IR). These findings are consistent with established literature demonstrating that BMI is strongly linked to insulin resistance and glycemic control, with higher BMI categories associated with progressively worse metabolic profiles [23,24]. The mechanistic basis for these correlations involves excess adipose tissue, particularly visceral fat, which promotes insulin resistance through increased lipolysis, inflammatory cytokine release, and impaired insulin signaling [25]. Studies have shown that changes in body fat mass correlate significantly with changes in fasting glycemia, HbA1c, and lipid parameters independent of weight changes alone [26]. These correlations have important implications for exercise intervention. The significantly lower BMI in our active group (26.4 vs 28.6 kg/m², $p<0.001$) likely contributes to the observed improvements in glycemic and insulin resistance parameters. The Look AHEAD trial demonstrated that a 5% reduction in BMI was associated with 0.13% lower HbA1c and 32% lower odds of insulin use [27]. Similarly, combined exercise training has been shown to reduce BMI, fasting insulin, and HOMA-IR, with improvements in body composition mediating enhancements in insulin sensitivity [28]. The resistance training subgroup exhibited the lowest BMI (23.01 kg/m²) alongside the most favorable metabolic profile, supporting the concept that exercise-induced improvements in body composition contribute substantially to glycemic benefits. These findings reinforce weight management as a critical therapeutic target and highlight exercise as an effective strategy for improving metabolic health through favorable body composition modifications, in addition to that baseline imbalance raises the possibility that apparent HbA1c benefits in the resistance group reflect the enrolment of initially leaner, potentially metabolically healthier individuals rather than superiority of the resistance intervention. Despite current guidelines, the combined exercise group showed less improvement in BMI and HOMA-IR compared to aerobic-only exercise, likely due to confounding by indication. Participants with worse baseline metabolic dysfunction were more likely allocated to combined training, as indicated by higher baseline BMI and HOMA-IR in this group ($p<0.05$). After adjusting for these baseline differences, the outcome discrepancies were significantly reduced, emphasizing the need to control for baseline severity in exercise intervention studies.

Limitations.

Some study limitations should be considered. First, the cross-sectional design prevents causality between cardiometabolic outcomes and physical exercise. Reverse causality may explain the relationships, as people with better metabolic health exercise more. Second, physical activity was self-reported and did not specify intensity, duration, or frequency. Third, our analysis did not adequately account for potential confounders such food, medication, diabetes duration, and socioeconomic characteristics. Fourth, the exercise type subgroups, especially resistance training, have small sample sizes, limiting generalizability and statistical power. Fifth, the absence of adjustment for lipid-lowering medication (statin) usage may account for the lack of observed differences in lipid profiles. Finaly, the primary limitation of the study is the age gap between groups. Over one-third of the Sedentary group was 60 or older, but all Resistance members were under 60. Given the effects of aging on metabolic and physiological outcomes, this age difference may explain the Resistance group's superior performance regardless of exercise modality.

Clinical Implications.

Despite these limitations, our findings have important clinical implications. The substantial differences in glycemic parameters between active and sedentary groups underscore the importance of incorporating physical activity counselling into routine diabetes care. Physical activity advice, which is easy to implement, accessible and unsupervised, should be offered to people with type 2 diabetes to improve glycemic control [11]. Healthcare providers should encourage patients with type 2 diabetes to engage in regular physical activity as a cornerstone of comprehensive diabetes management, alongside pharmacotherapy and dietary modifications.

The favorable metabolic profile observed in participants performing resistance training suggests that this exercise modality deserves greater emphasis in diabetes management guidelines. Diabetes is an independent risk factor for low muscular strength and accelerated decline in muscle strength and functional status [12], making resistance training particularly relevant for this population. A systematic review and meta-analysis demonstrated that exercise interventions significantly decrease glycated hemoglobin, fasting blood glucose, BMI, and waist circumference after exercise intervention [29].

Future Directions.

Future prospective studies with larger sample sizes, objective physical activity measurement, and comprehensive covariate adjustment are needed to confirm these associations and establish optimal exercise prescriptions for patients with type 2 diabetes. Randomized controlled trials comparing different exercise modalities and intensities would provide stronger evidence for clinical recommendations. Additionally, research examining the dose-response relationship between physical activity and glycemic outcomes across different baseline HbA1c levels would help personalize exercise prescriptions [13].

Conclusion.

In conclusion, this cross-sectional study demonstrates that physical activity is associated with significantly better glycemic control, insulin sensitivity, and body composition in patients with type 2 diabetes mellitus. While lipid parameters did not differ significantly between groups, the substantial improvements in glucose homeostasis markers support the integration of regular physical activity into comprehensive diabetes management strategies. The particularly favorable profile observed in the resistance training subgroup warrants further investigation in larger prospective studies.

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Conflict of interest.

The authors declare that there is no conflict of interest.

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