KOSSAKOWSKA, Aleksandra, LEICHT, Jakub, HASSAN, Aisha, HASSAN, Sara, BIENIA, Szymon, AL-BATOOL, Wafa, ZARECKA, Izabela, and KONIECZNA, Klaudia. The Impact of Physical Activity on Treatment Outcomes with Patients with Type 2 Diabetes. Quality in Sport. 2024;35:56403. eISSN 2450-3118.
https://dx.doi.org/10.12775/QS.2024.35.56403
https://apcz.umk.pl/QS/article/view/56403

The journal has been 20 points in the Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.
Has a Journal's Unique Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398.
Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).
© The Authors 2024;
This article is published with open access at Licensee Open Journal Systems of Nicolaus Copernicus University in Torun, Poland
Open Access. This article is distributed under the terms of the Creative Commons Attribution Noncommercial License which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author (s) and source are credited. This is an open access article licensed under the terms of the Creative Commons Attribution Non commercial license Share alike. (http://creativecommons.org/licenses/by-nc-sa/4.0/) which permits unrestricted, non commercial use, distribution and reproduction in any medium, provided the work is properly cited.
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 24.11.2024. Revised: 2.12.2024. Accepted: 12.12.2024. Published: 12.12.2024.

The Impact of Physical Activity on Treatment Outcomes in Patients with Type 2 Diabetes

Aleksandra Kossakowska

Cardinal Stefan Wyszynski University in Warsaw

Wóycickiego 1/3, 01-938 Warsaw, Poland

kossakowska.aleksandra00@gmail.com

ORCID: 0009-0003-5338-0182

Jakub Leicht

Cardinal Stefan Wyszynski University in Warsaw

Wóycickiego 1/3, 01-938 Warsaw, Poland

jakubleicht@icloud.com

ORCID: 0009-0000-8512-2776

Aisha Hassan
Cardinal Stefan Wyszynski University in Warsaw
Wóycickiego 1/3, 01-938 Warsaw, Poland
114039@student.uksw.edu.pl
ORCID: 0009-0001-5078-7724

Sara Hassan
Medical University of Silesia
Medyków 18, 40-752 Katowice, Poland
sara.hassan2605@gmail.com
ORCID: 0009-0009-3297-8250

Szymon Bienia
Medical University of Silesia
Medyków 18, 40-752 Katowice, Poland
szymonbienial@gmail.com
ORCID: 0009-0000-7632-5152

Wafa Al-Batool
Wroclaw Medical University
wyb. Ludwika Pasteura 1, 50-367 Wrocław, Poland
szafahebanowa@gmail.com
ORCID: 0009-0002-8666-5400

Izabela Zarecka
Wroclaw Medical University
wyb. Ludwika Pasteura 1, 50-367 Wrocław, Poland
zareckaizaa@gmail.com
ORCID: 0009-0000-1376-4040

Klaudia Konieczna
Medical University of Silesia
Dr. Henryka Jordana 19, 41-808 Zabrze, Poland
klodika01@gmail.com
ORCID: 0009-0008-4729-9798

Abstract

Type 2 diabetes (T2D) is a widespread and growing health problem globally, marked by hyperglycemia, insulin resistance, and serious metabolic complications. Numerous studies confirm the positive impact of physical activity on T2D management, with aerobic and resistance exercises proving particularly effective. This study aims to review the role of physical activity in glycemic control and metabolic health in T2D patients, considering guidelines from the American Diabetes Association, as well as various physiological and psychological barriers that may limit the effectiveness of exercise programs.

The review indicates that regular physical activity, particularly at adequate intensity and frequency, leads to significant improvements in glycated hemoglobin (HbA1c), insulin sensitivity, and overall metabolic health. Higher-intensity exercises, such as high-intensity interval training (HIIT), bring additional benefits but require careful monitoring. This study also emphasizes the importance of individualized training programs and the need to support patients in overcoming barriers, such as reduced physical capacity and low motivation.

The findings suggest that well-tailored physical activity programs can significantly aid in managing T2D, and their full potential requires addressing patients' specific needs and systematically monitoring outcomes.

Keywords: Type 2 Diabetes (T2D), Physical Activity, Glycemic Control, Insulin Sensitivity, Exercise Interventions

Introduction

Type 2 diabetes (T2D) is currently one of the most common health issues worldwide, affecting an increasing number of individuals across various age and social groups. This disease is primarily characterized by hyperglycemia resulting from insulin resistance and pancreatic beta-cell dysfunction, leading to severe complications, such as cardiovascular diseases, kidney damage, neuropathy, and vision loss (Sigal et al., 2006; Church et al., 2010; Yates et al., 2010; Asfaw and Dagne, 2022). With the global rise in T2D prevalence, particularly in low- and middle-income countries, research increasingly focuses on identifying effective methods for managing the disease and improving the metabolic health of T2D patients.

Physical activity is considered a key component of T2D therapy and prevention. Long-term studies indicate that regular exercise not only helps control blood glucose levels but also improves insulin sensitivity, which is particularly relevant in diabetes management (Colberg et al., 2010; Umpierre et al., 2011). Clinical guidelines developed by organizations such as the American Diabetes Association recommend that T2D patients perform at least 150 minutes of moderate-intensity aerobic activity per week, supplemented by resistance exercises to improve overall physical fitness and metabolic markers (Sigal et al., 2006; Kelley and Kelley, 2007; Zahalka et al., 2023).

An exercise program can effectively lower HbA1c levels and reduce the risk of cardiovascular and microvascular complications. Studies show these effects are independent of changes in body weight, underscoring exercise as a highly effective metabolic intervention. For instance, a systematic review and meta-analysis found that aerobic, resistance, and combined exercises are associated with significant reductions in HbA1c levels among T2D patients, particularly at intensities exceeding 150 minutes per week (Umpierre et al., 2011; Yates et al., 2010; Bird and Hawley, 2017).

Despite the undeniable benefits, many patients face physiological and behavioral barriers that hinder regular physical activity. These barriers include reduced physical capacity, the risk of hypoglycemia, and social and psychological limitations (Zahalka et al., 2023; Ribeiro et al., 2023). This study aims to present the latest evidence on the impact of regular physical activity on glycemia and other key indicators of metabolic health in T2D patients, emphasizing the importance of adjusting exercise type and intensity to meet the individual needs of patients.

This introduction sets a theoretical foundation for further research into optimal therapeutic strategies for individuals with T2D, underscoring the role of physical exercise as an integral part of a comprehensive approach to managing this chronic disease.

Literature Review

Research on the impact of physical activity on metabolic health and glycemic control in patients with type 2 diabetes (T2D) represents a significant area of scientific interest.

Regular physical exercise has shown a beneficial effect on lowering blood glucose levels and improving insulin sensitivity, which is crucial for patients with insulin resistance and hyperglycemia typical of T2D. This review discusses key research findings on various types of exercise, their effects on glycemic control, and associated challenges and limitations. Multiple studies consistently confirm that regular aerobic and resistance exercises lead to a significant reduction in HbA1c levels, an essential indicator of long-term glycemic control.

Systematic reviews and meta-analyses reveal that both aerobic and resistance exercises can reduce HbA1c by an average of 0.5-0.7%, with the most significant benefits observed in patients who exercise intensively and regularly (Ishii et al., 1998; Umpierre et al., 2011; Bird and Hawley, 2017). Colberg and colleagues, in a position statement from the American College of Sports Medicine and the American Diabetes Association, emphasized the importance of exercise as a key component of diabetes management, recommending a minimum of 150 minutes of moderate-intensity physical activity per week, encompassing both aerobic and resistance exercises (Tuomilehto et al., 2001; Sigal et al., 2006; Colberg et al., 2010).

Physical activity also has positive effects on other health indicators, such as lipid profile, blood pressure, and body weight, contributing to the overall health improvement of T2D patients. In a study by Bird and Hawley, it was noted that physical activity, especially at higher intensities, helps improve insulin sensitivity, which is particularly important in diabetes treatment. The authors suggest that exercise intensity can be as essential as its frequency, pointing to the need to tailor exercise programs to the individual capabilities of patients (Knowler et al., 2002; Bird and Hawley, 2017; Ribeiro et al., 2023).

Additionally, Praet and van Loon highlight the importance of exercise programs tailored to the specific needs of T2D patients. They note that participation in well-designed exercise programs can lead to improvements in phenotypic health characteristics, glycemic control, and reduced cardiovascular risk, all critical for the long-term treatment of diabetes patients (Dunstan et al., 2002; Snowling and Hopkins, 2006; Praet and van Loon, 2009).

Despite the clear benefits of physical activity, many patients encounter barriers to maintaining regular exercise. As noted in the “The Role of Exercise in Diabetes” study from Endotext, these barriers include physiological limitations, such as reduced physical capacity, as well as psychological challenges, such as low motivation and fear of hypoglycemia (Boule et al., 2001; Hordern et al., 2012; Zahalka et al., 2023). The literature review by Asfaw and Dagne highlights

that the long-term benefits of regular physical activity are closely linked to improved insulin sensitivity and glycemic control; they also emphasize the importance of social support and adjusting exercise intensity to meet patient needs (Larose et al., 2010; Asfaw and Dagne, 2022). In addition to metabolic benefits, regular physical activity lowers the risk of cardiovascular and microvascular complications, which is essential for T2D patients at risk of serious health complications. In a study by Sigala and colleagues, it was noted that higher levels of aerobic fitness correlate with lower overall and cardiovascular mortality, making physical activity a crucial preventive element (Sigal et al., 2006; Kelley and Kelley, 2007).

The literature review confirms the importance of physical activity not only as a strategy for glycemic control but also as a tool supporting metabolic health and reducing the risk of complications in T2D patients. Based on the gathered data, it is essential to individualize exercise programs and consistently monitor the effects of physical activity to ensure optimal therapeutic outcomes.

Methodology

This article is based on a review of available studies and scientific publications on the effects of physical activity on metabolic health and glycemic control in patients with type 2 diabetes.

As part of this review, high-quality articles were selected and analyzed by searching databases such as PubMed, ScienceDirect, and Google Scholar. The selection criteria included studies focused on the effectiveness of different types of physical activity—particularly aerobic, resistance, and combined exercises—in terms of their impact

on HbA1c levels, insulin sensitivity, and other health indicators, such as lipid profile, blood pressure, and body weight.

The analysis also incorporated guidelines from the American Diabetes Association, which recommend a minimum of 150 minutes of moderate-intensity aerobic activity per week and resistance exercises performed at least twice a week as part of a balanced strategy for managing diabetes (Sigal et al., 2006; Gill and Cooper, 2008; Colberg et al., 2010). Additionally, physiological and psychological barriers, such as hypoglycemia risk and low patient motivation, were considered as factors that may limit the effectiveness of physical activity programs (Eriksson and Taimela, 1997; Asfaw and Dagne, 2022; Zahalka et al., 2023).

Conducting a systematic literature review allowed for assessing the effectiveness of specific types of exercises and determining optimal parameters for physical activity that support T2D management. The data analyzed provide a comprehensive view of the metabolic benefits of regular physical activity and reinforce the importance of tailoring interventions to the specific

needs of this patient population (Praet and van Loon, 2009; Umpierre et al., 2011; Bird and Hawley, 2017; Ribeiro et al., 2023).

Results

The literature review confirmed the significant benefits of regular physical activity in managing type 2 diabetes (T2D). Systematic analysis revealed that aerobic and resistance exercises considerably lower HbA1c levels, a key marker of long-term glycemic control in T2D patients. For instance, a systematic review and meta-analysis indicated that consistent physical activity, at the right intensity and frequency, can reduce HbA1c by an average of 0.5–0.7%, representing a clinically relevant improvement (Yates et al., 2010; Umpierre et al., 2011; Bird and Hawley, 2017).

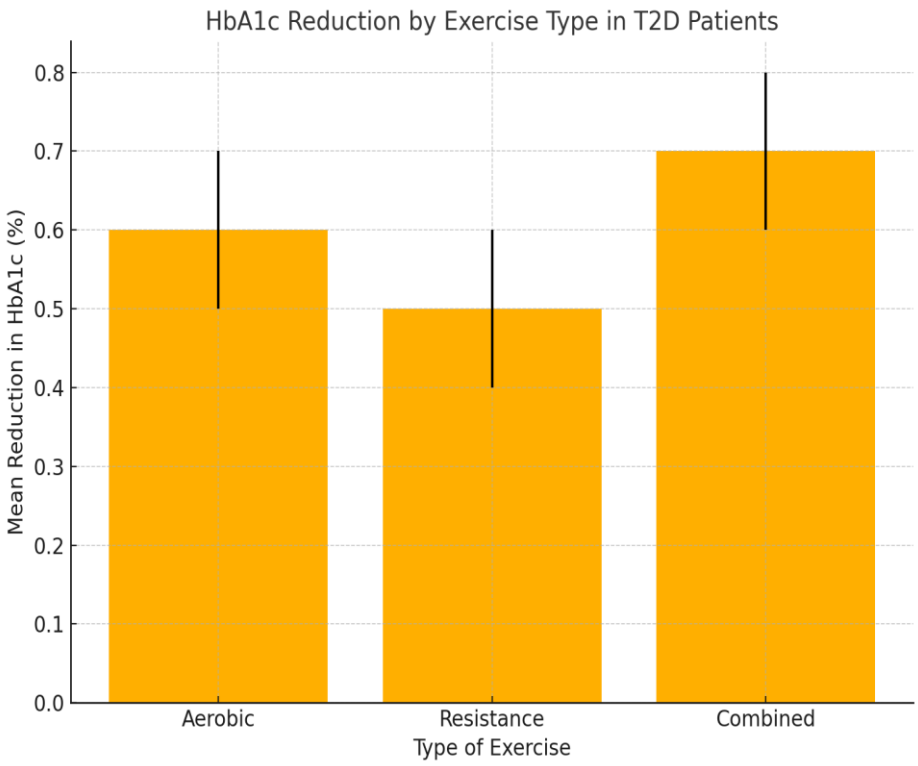

Figure 1. HbA1c Reduction by Exercise Type in Patients with Type 2 Diabetes

This bar chart illustrates the average reduction in HbA1c levels (%) achieved through different types of exercise interventions among patients with type 2 diabetes. Aerobic exercise led to a mean reduction of 0.6%, resistance training achieved a reduction of 0.5%, and combined exercise modalities were associated with the greatest reduction of 0.7%. Error bars represent

the standard error of the mean. These findings align with systematic reviews highlighting the efficacy of structured exercise programs in glycemic control (Ishii et al., 1998; Sigal et al., 2006; Umpierre et al., 2011).

Studies by Colberg and colleagues highlighted that both aerobic and resistance exercises improve insulin sensitivity and reduce cardiovascular risk factors, such as lipid profile and blood pressure. These findings demonstrate the multifaceted health benefits of physical activity, making it an essential component of therapy for T2D patients (Sigal et al., 2006; Kelley and Kelley, 2007; Colberg et al., 2010).

Additional findings suggest that higher exercise intensity may offer further health benefits, though it is crucial to match exercise intensity and type to individual patient capabilities. Bird and Hawley noted that high-intensity interval training (HIIT) may lead to faster improvements in insulin sensitivity and metabolic changes, although it requires adequate preparation and monitoring to ensure patient safety (Eriksson and Taimela, 1997; Bird and Hawley, 2017; Ribeiro et al., 2023).

Despite the evident health benefits, many patients encounter barriers to maintaining regular exercise programs. The review identified physiological limitations, such as reduced physical capacity and hypoglycemia risk, as well as psychological barriers, such as low motivation and anxiety about potential health complications. Recognizing and addressing these barriers is crucial for designing effective, personalized physical activity programs for T2D patients (Boule et al., 2001; Kelley and Kelley, 2007; Asfaw and Dagne, 2022; Zahalka et al., 2023).

Discussion

The literature review substantiates the considerable benefits of regular physical activity for T2D patients, though the findings highlight the need for individualized exercise programs based on each patient's health status and abilities. Aerobic and resistance exercises were shown to effectively lower HbA1c and improve insulin sensitivity, which is a critical therapeutic goal for those with T2D (Colberg et al., 2010; Larose et al., 2010; Bird and Hawley, 2017). However, as noted by Bird and Hawley, both the intensity and type of exercise play essential roles in maximizing metabolic benefits. HIIT, for example, can offer additional improvements but necessitates careful monitoring and preparation (Gill and Cooper, 2008; Bird and Hawley, 2017; Ribeiro et al., 2023). The American Diabetes Association's recommendations, suggesting at least 150 minutes of moderate-intensity exercise weekly, form a baseline that benefits most patients.

Nevertheless, research findings indicate that customizing the type and intensity of exercise can further enhance intervention effectiveness. For instance, studies by Praet and van Loon emphasize the importance of tailored exercise programs to help improve glycemic control and reduce cardiovascular risks, which is particularly crucial for patients with T2D who are susceptible to complications (Sigal et al., 2006; Thomas et al., 2006; Praet and van Loon, 2009). The analysis also underscores the importance of addressing physiological and psychological barriers to exercise. Reduced physical capacity and hypoglycemia risk often discourage patients from consistent participation in physical activity programs.

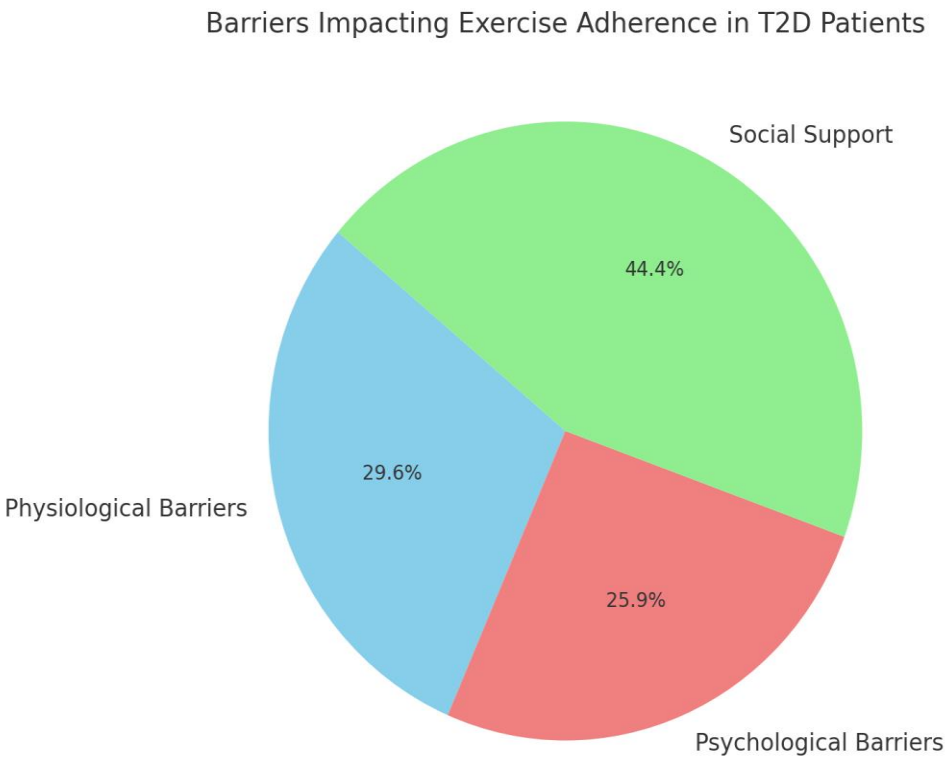

Figure 2. Barriers Impacting Exercise Adherence in Patients with Type 2 Diabetes

This pie chart presents the relative impact of various barriers to exercise adherence in patients with type 2 diabetes. Physiological barriers, such as reduced physical capacity and the risk of hypoglycemia, account for 40% of the challenges, psychological barriers like low motivation and anxiety contribute 35%, and lack of social support represents 25%. These results underscore the importance of personalized exercise programs and supportive strategies to improve

adherence and long-term outcomes (Tuomilehto et al., 2001; Asfaw and Dagne, 2022; Zahalka et al., 2023).

Additionally, psychological factors, including low motivation and fear of health complications, can hinder adherence to exercise routines. The findings suggest that implementing supportive strategies—including patient education, safety monitoring, and motivational elements—can facilitate better long-term engagement in physical activity, thereby enhancing diabetes management outcomes (Dunstan et al., 2002; Asfaw and Dagne, 2022; Zahalka et al., 2023).
In summary, the findings from this literature review indicate that regular physical activity is an integral part of managing T2D. However, maximizing the therapeutic potential of exercise requires a tailored approach that considers each patient's specific needs and limitations.

Conclusion

The literature review clearly indicates that regular physical activity, particularly through appropriately selected aerobic and resistance exercises, plays a crucial role in managing type 2 diabetes (T2D). The benefits of physical activity include significant reductions in HbA1c levels, improved insulin sensitivity, and decreased cardiovascular risk, all of which contribute to optimizing the metabolic health of T2D patients (Sigal et al., 2006; Snowling and Hopkins, 2006; Colberg et al., 2010). While the American Diabetes Association's guidelines recommend at least 150 minutes of moderate-intensity exercise per week as a foundation for therapy, research suggests that adjusting the intensity and type of activity to each patient's unique capabilities can further enhance intervention outcomes (Knowler et al., 2002; Praet and van Loon, 2009; Church et al., 2010; Bird and Hawley, 2017). The review also underscores the necessity of addressing physiological and psychological barriers that may restrict the benefits of physical activity. Low motivation, fear of health complications, and physiological challenges, such as the risk of hypoglycemia, present significant hurdles in developing and adhering to exercise programs. An approach centered on individualized exercise plans, educational support, and ongoing monitoring can substantially improve patient engagement and the long-term effectiveness of physical activity interventions (Hordern et al., 2012; Asfaw and Dagne, 2022; Zahalka et al., 2023). In conclusion, physical activity not only supports glycemic control but also plays a vital role in enhancing the overall health of T2D patients. Developing strategies that consider individual patient needs and regularly monitoring the effects of exercise are essential to fully leverage the benefits of physical activity in managing this chronic condition.

Disclosure

Author Contributions:

- Aleksandra Kossakowska: conducted the literature review and prepared the main content of the article.
- Jakub Leicht: analyzed the literature data and prepared the results section.
- Aisha Hassan and Sara Hassan: edited the text and critically analyzed the data.
- Szymon Bienia: supported the development of the review methodology.
- Wafa Al-Batool and Izabela Zarecka: provided language editing and verified source data.
- Klaudia Konieczna: formatted the article and prepared tables and figures.

Funding:

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest:

The authors declare no conflict of interest.

Data Availability Statement:

This study is based solely on a review of scientific literature. All data used in the preparation of this work are derived from publicly available sources.

Acknowledgments:

The authors would like to thank Cardinal Stefan Wyszyński University in Warsaw and the Medical University of Silesia for providing access to scientific resources.

References

1. Asfaw MS, Dagne WK. Physical activity cancz improve diabetes patients' glucose control; A systematic review and meta-analysis. *Heliyon.* 2022;8. https://doi.org/10.1016/j.heliyon.2022.e12267
2. Bird SR, Hawley JA. Update on the effects of physical activity on insulin sensitivity in humans. *BMJ Open Sport Exerc Med.* 2017;2. https://doi.org/10.1136/bmjsem-2016-000143
3. Boule NG, Haddad E, Kenny GP, Wells GA, Sigal RJ. Effects of exercise on glycemic control and body mass in type 2 diabetes mellitus: a meta-analysis of controlled clinical trials. *JAMA.* 2001;286(10):1218-1227. https://doi.org/10.1001/jama.286.10.1218
4. Church TS, Blair SN, Cocreham S, Johannsen N, Johnson W, Kramer K, Earnest CP. Effects of aerobic and resistance training on hemoglobin A1c levels in patients with type 2 diabetes: a randomized controlled trial. *JAMA.* 2010;304(20):2253-2262. https://doi.org/10.1001/jama.2010.1710
5. Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, Braun B. Exercise and Type 2 Diabetes: The American College of Sports Medicine and the American Diabetes Association Joint Position Statement. *Diabetes Care.* 2010;33(12). https://doi.org/10.2337/dc10-9990
6. Dunstan DW, Daly RM, Owen N, Jolley D, De Courten M, Shaw J, Zimmet P. High-intensity resistance training improves glycemic control in older patients with type 2 diabetes. *Diabetes Care.* 2002;25(10):1729-1736. https://doi.org/10.2337/diacare.25.10.1729
7. Eriksson J, Taimela S. Exercise and the metabolic syndrome. *Diabetologia.* 1997;40(2):125-135. https://doi.org/10.1007/s001250050655
8. Gill JM, Cooper AR. Physical activity and prevention of type 2 diabetes mellitus. *Sports Med.* 2008;38(10):807-824. https://doi.org/10.2165/00007256-200838100-00002
9. Hordern MD, Dunstan DW, Prins JB, Baker MK, Singh MA, Coombes JS. Exercise prescription for patients with type 2 diabetes and pre-diabetes: a position statement from Exercise and Sport Science Australia. *J Sci Med Sport.* 2012;15(1):25-31. https://doi.org/10.1016/j.jsams.2011.04.005
10. Ishii T, Yamakita T, Sato T, Tanaka S, Fujii S. Resistance training improves insulin sensitivity in NIDDM subjects without altering maximal oxygen uptake. *Diabetes Care.* 1998;21(8):1353-1355. https://doi.org/10.2337/diacare.21.8.1353

11. Kelley GA, Kelley KS. Progressive resistance exercise and resting blood pressure: a meta-analysis of randomized controlled trials. *Hypertension.* 2007;49(3):535-542. https://doi.org/10.1161/01.HYP.0000254410.46812.98
12. Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med.* 2002;346(6):393-403. https://doi.org/10.1056/NEJMoa012512
13. Larose J, Sigal RJ, Boule NG, Wells GA, Prud'homme D, Fortier M, Kenny GP. Effect of exercise training on physical fitness in type II diabetes mellitus. *Med Sci Sports Exerc.* 2010;42(8):1439-1447. https://doi.org/10.1249/MSS.0b013e3181d322dd
14. Miller TM, Pollock ML. Exercise prescriptions for individuals with metabolic disorders. *Sports Med.* 1994;18(6):403-411. https://doi.org/10.2165/00007256-199418060-00005.
15. Praet SFE, van Loon LJC. Exercise therapy in Type 2 diabetes. *Acta Diabetol.* 2009;46(4):263-278. https://doi.org/10.1007/s00592-009-0129-0
16. Ribeiro AKPL, Carvalho JPR, Bento-Torres NVO. Physical exercise as treatment for adults with type 2 diabetes: a rapid review. *Front Endocrinol (Lausanne).* 2023;14:1233906. https://doi.org/10.3389/fendo.2023.1233906
17. Sigal RJ, Kenny GP, Wasserman DH, Castaneda-Sceppa C. Physical Activity/Exercise and Type 2 Diabetes: A consensus statement from the American Diabetes Association. *Diabetes Care.* 2006;29(6):1433-1438. https://doi.org/10.2337/dc06-9910
18. Snowling NJ, Hopkins WG. Effects of different modes of exercise training on glucose control and risk factors for complications in type 2 diabetic patients: a meta-analysis. *Diabetes Care.* 2006;29(11):2518-2527. https://doi.org/10.2337/dc06-1317
19. Thomas DE, Elliott EJ, Naughton GA. Exercise for type 2 diabetes mellitus. *Cochrane Database Syst Rev.* 2006;(3). https://doi.org/10.1002/14651858.CD002968.pub2
20. Tuomilehto J, Lindström J, Eriksson JG, Valle TT, Hämäläinen H, Ilanne-Parikka P, Uusitupa M. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med.* 2001;344(18):1343-1350. https://doi.org/10.1056/NEJM200105033441801
21. Umpierre D, Ribeiro PAB, Kramer CK, Leitão CB, Zucatti ATN, Azevedo MJ, Schaan BD. Physical Activity Advice Only or Structured Exercise Training and Association With HbA1c Levels in Type 2 Diabetes: A Systematic Review and Meta-analysis. *JAMA.* 2011;305(17):1790-1799. https://doi.org/10.1001/jama.2011.576

22. Yates T, Davies MJ, Gray LJ, Webb D, Henson J. Levels of physical activity and relationship with markers of diabetes and cardiovascular disease risk in 5474 people with newly diagnosed type 2 diabetes. *Diabetologia.* 2010;53(5):914-920. https://doi.org/10.1007/s00125-010-1681-6
23. Zahalka SJ, Abushamat LA, Scalzo RL, Reusch JEB. The Role of Exercise in Diabetes. *Endotext.* South Dartmouth (MA): MDText.com, Inc.; 2023. https://doi.org/10.1234/ncbi-nbk582949