DZIEKOŃSKI, Kamil, POPIEL, Michał, WIECZOREK, Iga, CYBULSKI, Paweł, SMALA, Kamila, OSTOJEWSKA, Justyna, BIEŃ, Katarzyna, SZAFRANEK, Adam, WACŁAWEK, Wiktoria, KWIECIEŃ, Iga, and BARTOSZEWSKA, Karolina. The Influence of Physical Activity and Carbohydrate Management on Glycemic Control in Type 1 Diabetes: Exploring the Potential of Artificial Intelligence in Diabetes Care. Quality in Sport. 2025;41:60303. eISSN 2450-3118.
https://doi.org/10.12775/QS.2025.41.60303
https://apcz.umk.pl/QS/article/view/60303

The journal has had 20 points in 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 declare that there is no conflict of interests regarding the publication of this paper.
Received: 14.04.2025. Revised: 19.04.2025. Accepted: 02.05.2025. Published: 05.05.2025

The Influence of Physical Activity and Carbohydrate Management on Glycemic Control in Type 1 Diabetes: Exploring the Potential of Artificial Intelligence in Diabetes Care

Kamil Dziekoński
Corten Dental
Makolągwy 21, 02-811 Warsaw, Poland
dziekondent@gmail.com
https://orcid.org/0009-0001-9958-1348

Michał Popiel
The Little Prince Hospice of Lublin
Lędzian 49, 20-828 Lublin, Poland
michal.popiel7@gmail.com
https://orcid.org/0009-0002-9726-6296

Iga Wieczorek
Non-Public Health Care Institution Medical Clinic "SANATIO"
Lipowa 21, 64-120, Wijewo, Poland
iga2309@gmail.com
https://orcid.org/0009-0003-2995-9813

Paweł Cybulski
Non-Public Health Care Institution Medical Clinic "SANATIO"
Lipowa 21, 64-120, Wijewo, Poland
cybulski.med@gmail.com
https://orcid.org/0009-0001-9754-2388

Kamila Smala
Medical University of Lublin
Aleje Racławickie 1, 20-059, Lublin, Poland
kama363669@gmail.com
https://orcid.org/0000-0001-8536-1101

Justyna Ostojewska
Klinika Kardiologii Wieku Dziecięcego i Pediatrii Ogólnej Uniwersteckie Centrum Kliniczne Warszawskiego Uniwersytetu Medycznego
ul. Żwirki i Wigury 63A, 02-091 Warszawa, Polska
gj.ostojewska@gmail.com
https://orcid.org/0009-0006-6329-5338

Katarzyna Bień
Klinika Położnictwa i Ginekologii
Instytut Matki i Dziecka
ul. Kasprzaka 17A, 01-211 Warszawa, Polska
kaasiabien@gmail.com
https://orcid.org/0000-0001-6626-3063

Adam Szafranek
Centrum Medyczne HCP
ul. 28 Czerwca 1956r. 194, 61-485 Poznań, Polska
adam66200@gmail.com
https://orcid.org/0009-0001-0928-0323

Wiktoria Wacławek
Przychodnia Wojskowej Akademii Technicznej
Kartezjusza 2, 01-480, Warsaw, Poland
wiktoria_waclawek@wp.pl
https://orcid.org/0009-0003-3889-1320

Iga Kwiecień
Medical University of Warsaw
Żwirki i Wigury 61, 02-091 Warsaw, Poland
ikwiecien8@gmail.com
https://orcid.org/0009-0008-8391-1366

Karolina Bartoszewska
Medical University of Warsaw
Żwirki i Wigury 61, 02-091 Warsaw, Poland
karos.bartos@gmail.com
https://orcid.org/0009-0002-4637-4529

ABSTRACT

Purpose: Managing Type 1 Diabetes Mellitus (T1DM) involves balancing mental health, diet, and physical activity (PA). For T1DM patients, maintaining stable glucose levels is difficult due to the risk of both low blood sugar after meals (postprandial hypoglycemia) and complications from high blood sugar (hyperglycemia). This study explores how PA influences glucose regulation and examines carbohydrate intake strategies, control methods, and the potential role of artificial intelligence (AI) in diabetes management.

Design/methodology/approach: A systematic review of studies on exercise, diet, and glycemic control in T1DM patients was conducted. Data from meta-analyses, randomized trials, and observational studies were sourced from PubMed, Google Scholar, and ResearchGate.

Findings: Regular PA improves glycemic control, lowering glycated hemoglobin (HbA1c), insulin needs, and body mass index (BMI). Structured high-intensity exercise programs lasting over 24 weeks are particularly effective for glycemic control. However, fear of hypoglycemia and work schedules can be barriers. Aerobic exercise reduces visceral fat, while anaerobic exercise enhances glucose uptake and insulin sensitivity.

Keywords: Type 1 Diabetes Mellitus, physical activity, glycemic control, carbohydrate intake, artificial intelligence

1. Introduction

Type 1 diabetes mellitus (T1D) arises from autoimmune destruction of pancreatic β-cells, resulting in a deficiency of insulin secretion and the need for external insulin administration [1]. Disregulated glucose levels in T1D contribute to microangiopathies and macroangiopathies, significantly increasing the risk of cardiovascular disease (CVD), which is, according to the World Health Organisation (WHO), the leading cause of mortality worldwide. These complications manifest earlier in people with T1D compared to the general population [2], underscoring the crucial importance of a healthy lifestyle and regular physical activity in managing the disease.

Numerous cross-sectional studies have confirmed the beneficial effects of exercise on glycaemic control in people with diabetes. For example, Bohn et al. [3] conducted a study involving 18,028 patients with T1DM (aged 18-80 years), demonstrating a reduction in glycated haemoglobin (HbA1c) levels after regular physical activity. HbA1c reflects average blood sugar levels over the past 90 days and is a key indicator to assess glucose control. In addition, a reduction in daily insulin requirements and body mass index (BMI) was observed compared to the control groups [3]. Similar results were reported in a study presented by Carral et al. [4] involving 130 adults with T1DM, highlighting the significant improvement in HbA1c values associated with intense exercise of more than 150 minutes per week. García-Hermoso et al. [5] advocated structured exercise programs as an adjunctive therapy for the treatment of T1DM.

Their systematic review and meta-analysis of randomised controlled trials involving 509 adolescents with T1D showed positive effects on glycaemic control after participation in programs lasting more than 24 weeks, with sessions involving at least 60 minutes of highintensity exercise.

Despite these positive results, there are still significant gaps between scientific evidence and practical knowledge among people with T1DM. Moser et al. [6], developed the Barriers to Physical Activity in Diabetes (type1) (BAPAD1) scale, a 12-item questionnaire highlighting critical barriers to PA such as fear of hypoglycaemia, work schedules and concerns about diabetes managemen

1. Methodology

A systematic review of literature on exercise types, dietary strategies, and glycemic control methods for T1DM patients was conducted. Meta-analyses, randomized controlled trials, and observational studies were analyzed using PubMed, Google Scholar, ResearchGate

2. Results

Physical Activity

There are different types of physical activity. These can be divided into aerobic exercise, such as walking, running, cycling and swimming, which engage large muscle groups and improve cardiovascular endurance, and anaerobic exercise, including resistance training such as weight lifting, sprinting and high-intensity interval training (HIIT).

Aerobic exercise, in turn, supports weight control by reducing visceral adipose tissue, which is often insulin resistant and associated with increased inflammation and impaired glucose metabolism. Obesity-associated adipose tissue increases immune cell infiltration, releasing proinflammatory cytokines that exacerbate insulin resistance [7]. This requires higher doses of insulin for glycaemic control, complicating diabetes management affects fasting glucose levels and increases the risk of baseline hypoglycaemia.

Anaerobic exercise requires the immediate use of glucose in muscle cells. They deplete and replenish glycogen stores, increasing the ability of muscles to store more glucose as glycogen during recovery and increase muscle mass [8,9]. During muscle exercise, blood glucose levels are lowered via an insulin-independent pathway. Muscle contractions during exercise facilitate the translocation of glucose transporter type 4 (GLUT4) to the cell membrane, promoting glucose uptake [10]. High-intensity anaerobic exercise triggers also the release of catecholamines and anabolic hormones. Epinephrine and norepinephrine briefly increase blood glucose levels by promoting hepatic glucose production. Testosterone and growth hormone (GH) can increase muscle growth and improve insulin sensitivity in the long term [11]. The disadvantage is that due to the acute hormonal response and high energy requirements, anaerobic exercise can cause rapid fluctuations in blood glucose levels, further increasing the risk of hypoglycaemia [12].

The long-term benefits reduce the frequency and severity of both hyperglycaemic and hypoglycaemic episodes and reduce insulin requirements through insulin sensitivity of muscle cells [13]. That can persist for several hours to days after training, depending on the intensity and duration of exercise. That's why consistency is key. The reduced insulin dose decrease the risk of insulin-related side effects, such as hypoglycaemia or weight gain, and improves overall diabetes control even if hypoglycaemia, by itself, can be severe and occur during or a few hours after exercise [14].

Commonly accepted training guidelines include at least 150 minutes of moderate aerobic activity per week or 75 minutes of more intense activity per week [15]. This can be spread over 3 days, with a maximum of 1 day off without training [15]. Alternatively- anareobic HIIT or resistance training 2-3 times a week- not day after day [16]. Finally, it is important to integrate spontaneous physical activity throughout the day to combat a sedentary lifestyle.

Nutrition

Diabetics are advised to adhere to the Mediterranean diet, which comprises 45-65% carbohydrates (CHO), 20-35% fat, and 10-35% protein. For individuals engaging in regular exercise, the recommended daily CHO intake equals approximately 3-7 g/kg body weight [7]. The effects of carbohydrates, proteins, and fats on glycemia vary, and additional factors such as muscle mass, age, gender, fitness level, stress, and genetics also play crucial roles.

For patients with T1DM, planning PA involves evaluating current glycemic levels, CHO consumption, meal timing relative to exercise, and the exercise's duration and intensity [12]. As exercise intensity increases, the body transitions from using free fatty acids (FFAs) to CHO its primary energy source [17]. Muscles utilize stored glycogen and glucose for adenosine triphosphate (ATP) production, but T1DM impair mitochondrial function and skeletal muscle metabolism, leading to delayed phosphocreatine regeneration [18]. Thus, carbohydrates are essential for both performance and the prevention of hypoglycemia [18].

To balance glycemia and optimize performance, CHO intake should be managed according to the glycemic index (GI) of foods. Low-GI foods consumed prior to exercise can provide a sustained CHO release, reducing insulin needs. Conversely, high-GI foods can quickly raise blood glucose levels [12]. If baseline glycemia is low or if the activity involves endurance training, high-GI foods might be necessary, with an intake of 45 g/kg body weight [9].

For exercise lasting less than 45 minutes or when glycemic levels are around 126 mg/dl, CHO supplementation is not typically required; however, an intake of 0.1-0.3 g/kg of CHO is recommended to prevent hypoglycemia [19]. For longer exercises, consuming 1.0-1.2 g/kg body weight of carbohydrates per hour for up to four hours post-exercise is advised to replenish glycogen stores [19]. Alternatively, CHO intake can be reduced to 0.8 g/kg per hour if proteins are added to the meal at 0.2-0.4 g/kg per hour [9]. For endurance activities, a CHO intake of 30-60 g/kg (up to 90 g/kg for activities exceeding 90 minutes) is suggested [13,19,20]. The mean CHO amount required to maintain euglycemia between activities is approximately 25.6 ± 13.3 g [21]. To prevent late-night hypoglycemia, a snack with low-GI carbohydrates, protein, and fat is recommended [19,22].

Riddell et al. [14] suggest that for activities lasting less than one hour, initial glucose concentrations should be 126–180 mg/dl (7–10 mmol/l) for aerobic exercise and 90–126 mg/dl (5–7 mmol/l) for anaerobic exercise. Exercise should not commence if ketone levels are elevated or if severe hypoglycemia (≤2.8 mmol/l or <50 mg/dl) occurred within the last 24 hours [23].

When planning exercise approximately 2-3 hours post-meal, insulin doses should be matched to the meal to avoid hyperinsulinemia, which can inhibit fat oxidation and increase glucose utilization, raising the risk of hypoglycemia. Adjustments include reducing basal insulin by 20-50%, modifying postprandial insulin doses, or increasing CHO intake. Bolus insulin may be reduced by up to 75% with careful monitoring [24,25,26]. A reduction in bolus insulin and consumption of a low-GI snack up to an hour before training can mitigate hyperglycemia. Reducing basal insulin by 80% at the start of exercise is more effective than basal insulin suspension and is associated with a reduced risk of hypoglycemia during and after activity [24,25,26]. Insulin should be administered in areas not actively involved in muscle contraction [24,25,26].

Nocturnal Hypoglycemia

To manage nocturnal hypoglycemia effectively, consider exercise timing, type, and glucose management. Resistance exercises or high-intensity interval training (HIIT) performed in the afternoon or evening can help stabilize blood glucose levels, whereas morning aerobic exercise capitalizes on the "dawn phenomenon," which increases glucose levels [28]. Adjusting insulin doses post-exercise, adhering to American Diabetes Association (ADA) recommendations for additional glucose intake, and setting narrow alarm limits on continuous glucose monitoring (CGM) devices assist in nocturnal glucose control [28].

Reducing basal insulin rates by 20% for six hours post-exercise is particularly beneficial for those using insulin pumps [21]. An evening snack rich in carbohydrates is recommended, but excessive insulin boluses should be avoided to prevent rebound hyperglycemia. Awareness of daily physical activity's cumulative effect on nocturnal glycemia requires similar adjustments throughout the day [21]. Utilizing CGM systems with overnight alarms allows real-time monitoring, supporting timely interventions to prevent hypoglycemia [29]. Additionally, reducing overnight basal insulin rates by 20% and adjusting bolus insulin doses by up to 50% for post-exercise meals further enhances nocturnal glycemic control [29]

Management way with AI support

Effective glycemic management during and after exercise in individuals with Type 1 Diabetes Mellitus (T1DM) necessitates a comprehensive approach that integrates several key strategies These include optimizing exercise timing, managing carbohydrate intake based on glycemic index (GI), and making precise insulin adjustments. Such strategies are critical for maintaining stable glycemic control and reducing the risk of nocturnal hypo- and hyperglycemic episodes [19,21,27,28,29]

Continuous glucose monitoring (CGM) systems provide real-time glucose data, enabling immediate detection and management of glycemic fluctuations during physical activity. By continuously monitoring glucose levels, CGM systems facilitate the prevention of hypoglycemic episodes and allow for timely adjustments to maintain glucose within target ranges [30-32]. Hybrid closed-loop insulin delivery systems, which autonomously adjust insulin delivery based on CGM data, are effective in maintaining glucose levels within desired ranges and reducing hypoglycemia risk during exercise [21]. Combining CGM with continuous subcutaneous insulin infusion (CSII) pumps or automated insulin delivery (AID) systems leverages artificial intelligence (AI) to optimize glucose control and adapt insulin dosing in real-time [27,33].

Recent advances in AI offer promising solutions for enhancing diabetes care. AI-based systems can facilitate personalized treatment plans by adapting strategies based on individual patient data, thus improving glycemic control and reducing complications. AI-enabled devices and applications support remote monitoring and provide real-time feedback during exercise, enhancing management precision [34].

Research has shown that AI can significantly impact insulin dosing strategies. For instance, Tyler et al. [35] utilized methods for optimizing insulin dosing, while Pesl et al. [36] developed the ABC4D bolus calculator for mealtime dosing recommendations. Bergenstal et al. demonstrated that automated insulin titration guidance improves glycemic control. AI systems, such as those described by Kodama et al. [37], have shown high accuracy in predicting hypoglycemia, with a sensitivity and specificity of 0.79 and 0.80, respectively. Furthermore, Alotaibi et al. [38] designed the SAED mobile management system, which reduced HbA1c levels and enhanced diabetes knowledge. Hamon and Gagnayre [39] used natural language processing to identify knowledge gaps in diabetes education.

Despite these advances, the integration of AI into diabetes management faces challenges, including data privacy concerns and the need for seamless integration with existing healthcare infrastructure. Looking forward, the future of AI in diabetes management involves developing AI-enabled ecosystems that integrate various digital health technologies to create comprehensive systems for diabetes prevention and management. Continued research and technological development hold promise for transforming diabetes care by improving predictive accuracy, optimizing treatment plans, and providing personalized support [16,20,22,27,29,40,41]. Artificial intelligence truly has the potential to revolutionize diabetes management, enhancing patient outcomes and reducing the disease's economic burden. Ongoing advancements in AI underscore its capacity to improve glycemic control and offer personalized care strategies.

Discussion

This review highlights the importance of regular physical activity (PA) in managing glycemic control for individuals with Type 1 Diabetes Mellitus(T1DM). Research supportsthat engaging in structured exercise, especially high-intensity sessions, leads to reductions in HbA1c levels, insulin use, and body mass index (BMI). However, practical challenges, such as the risk of hypoglycemia and competing life demands, often limit consistent participation in PA. Additionally, tailoring carbohydrate intake and insulin dosing to match exercise parameters remains a complex, individualized process. Emerging technologies, like continuous glucose monitoring (CGM) systems and artificial intelligence (AI), show promise in bridging the gap between current evidence and day-to-day diabetes management by enabling real-time adjustments and more personalized care strategies

Conclusions

Engaging in regular physical activity is a proven strategy to improve glycemic control in individuals with Type 1 Diabetes Mellitus (T1DM). It effectively lowers HbA1c levels, reduces the need for insulin, and decreases BMI. To optimize outcomes, carbohydrate intake and insulin dosing should be carefully tailored to the intensity and duration of exercise to minimize the risk of hypoglycemia and hyperglycemia. Recent advancements in continuous glucose monitoring (CGM) and artificial intelligence (AI) are paving the way for more effective, real-time glucose management and personalized treatment, offering great potential for future improvements in diabetes care

Disclosure:Author's Contribution Statement:

Conceptualization: Kamil Dziekoński, Michał Popiel

Methodology: Iga Wieczorek, Paweł Cybulski

Investigation: Kamila Smala, Justyna Ostojewska

Writing – rough preparation: Katarzyna Bień, Adam Szafranek

Writing – review and editing: Wiktoria Wacławek, Iga Kwiecień

Project administration: Karolina Bartoszewska

All authors have read and agreed with the published version of the manuscript. Fundi ng Statement: The study did not receive special funding.

Conflict of Interest Statement: There is no conflict of interest.

References:

1. Bizjan BJ, Šmigoc Schweiger D, Battelino T, Kovač J. Pathogenesis of Type 1 Diabetes: Established Facts and New Insights. Genes. 2022;13(4):706. https://doi.org/10.3390/genes13040706
2. Pesantez M, Osagie Ebekozien, Francesco Vendrame. Type 1 Diabetes and Cardiovascular Health. Endocrinol Metab Clin North Am. 2024;53(1):151-163. 10.1016/j.ecl.2023.07.003
3. Bohn B, Herbst A, Pfeifer M, et al. Impact of Physical Activity on Glycemic Control and Prevalence of Cardiovascular Risk Factors in Adults with Type 1 Diabetes: A Cross-

sectional Multicenter Study of 18,028 Patients. Diabetes Care. 2015;38:1536-1543. https://doi.org/10.2337/dc15-0030

4. Carral F, Gutiérrez JV, del Carmen Ayala M, et al. Intense physical activity is associated with better metabolic control in patients with type 1 diabetes. Diabetes Res Clin Pract. 2013;101:45-49. 10.1016/j.diabres.2013.04.006

5. García-Hermoso A, Ezzatvar Y, Huerta-Uribe N, et al. Effects of exercise training on glycaemic control in youths with type 1 diabetes: A systematic review and meta-analysis of randomised controlled trials. Eur J Sport Sci. 2023;23:1056-1067. 10.1080/17461391.2022.2086489

6. Moser O, Eckstein ML, Mueller A, et al. Pre-Exercise Blood Glucose Levels Determine the Amount of Orally Administered Carbohydrates during Physical Exercise in Individuals with Type 1 Diabetes-A Randomized Cross-Over Trial. Nutrients. 2019;11:1287. https://doi.org/10.3390/nu11061287

7. Zatterale F, Longo M, Naderi J, et al. Chronic Adipose Tissue Inflammation Linking Obesity to Insulin Resistance and Type 2 Diabetes. Int J Mol Sci. 2019;20(15):4058. 10.3389/fphys.2019.01607

8. Riddell MC, Peters AL. Exercise in adults with type 1 diabetes mellitus. Nat Rev Endocrinol. 2023;19:98-111. 10.1038/s41574-022-00756-6

9. Riddell MC, Scott SN, Fournier PA, et al. The competitive athlete with type 1 diabetes. Diabetologia. 2020;63:1475-1490. https://doi.org/10.1007/s00125-020-05183-8

10. Cockcroft EJ, Narendran P, Andrews RC. Exercise-induced hypoglycaemia in type 1 diabetes. Exp Physiol. 2020;105:590-599. 10.1113/EP088219

11. Gharahdaghi N, Phillips BE, Szewczyk NJ, et al. Links Between Testosterone, Oestrogen, and the Growth Hormone/Insulin-Like Growth Factor Axis and Resistance Exercise Muscle Adaptations. Front Physiol. 2020;11:76. 10.3389/fphys.2020.621226

12. Scott S, Kempf P, Bally L, Stettler C. Carbohydrate Intake in the Context of Exercise in People with Type 1 Diabetes. Nutrients. 2019;11:3017. https://doi.org/10.3390/nu11123017

13. Gomez AM, Gomez C, Aschner P, et al. Effects of performing morning versus afternoon exercise on glycemic control and hypoglycemia frequency in type 1 diabetes patients on sensor-augmented insulin pump therapy. J Diabetes Sci Technol. 2015;9(3):619-624. 10.1177/1932296814566233

14. Riddell MC, Gallen IW, Smart CE, et al. Exercise management in type 1 diabetes: A consensus statement. Lancet Diabetes Endocrinol. 2017;5:377-390. https://doi.org/10.1016/S2213-8587(17)30014-1
15. Colberg SR, Sigal RJ, Yardley JE, et al. Physical activity/exercise and diabetes: a position statement of the American Diabetes Association. Diabetes Care. 2016;39:2065-2079. https://doi.org/10.2337/dc16-1728
16. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020;54:1451-1562. https://doi.org/10.1136/bjsports-2020-102955
17. Brooks GA. Mammalian fuel utilization during sustained exercise. Comp Biochem Physiol B Biochem Mol Biol. 1998;120:89-107. 10.1016/s0305-0491(98)00025-x
18. Monaco CMF, Gingrich MA, Hawke TJ. Considering type 1 diabetes as a form of accelerated muscle aging. Exerc Sport Sci Rev. 2019;47:98-107. https://doi.org/10.1249/JES.0000000000000184
19. Thomas DT, Erdman KA, Burke LM. American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. Med Sci Sports Exerc. 2016;48:543-568. https://doi.org/10.1249/MSS.0000000000000852
20. Riddell MC, Scott SN, Fournier PA, et al. The competitive athlete with type 1 diabetes. Diabetologia. 2020;63:1475-1490. https://doi.org/10.1007/s00125-020-05183-8
21. Molveau J, Rabasa-Lhoret R, Taleb N, et al. Minimizing the Risk of Exercise-Induced Glucose Fluctuations in People Living with Type 1 Diabetes Using Continuous Subcutaneous Insulin Infusion: An Overview of Strategies. Can J Diabetes. 2021;45:666-676. 10.1016/j.jcjd.2021.01.003
22. Cavallo M, De Fano M, Barana L, et al. Nutritional Management of Athletes with Type 1 Diabetes: A Narrative Review. Nutrients. 2024;16:907. 10.3390/nu16060907
23. Colberg SR, Sigal RJ, Yardley JE, et al. Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. Diabetes Care. 2016;39:2065-2079. https://doi.org/10.2337/dc16-1728
24. Umpierre D, Ribeiro PAB, Kramer CK, et al. 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;305:1790-1799. https://doi.org/10.1001/jama.2011.576

25. Cheng F, Yuan G, He J, et al. Aberrant expression of miR-214 is associated with obesity-induced insulin resistance as a biomarker and therapeutic. Diagn Pathol. 2020;15:18. 10.1186/s13000-019-0914-1
26. Roberts CK, Hevener AL, Barnard RJ. Metabolic syndrome and insulin resistance: Underlying causes and modification by exercise training. Compr Physiol. 2013;3:158. https://doi.org/10.1002/cphy.c110062
27. Fitzpatrick R, Davison G, Wilson JJ, et al. "Exercise, type 1 diabetes mellitus and blood glucose: The implications of exercise timing". 2022. 10.3389/fendo.2022.1021800
28. Schubert-Olesen O, Kröger J, Siegmund T, et al. Continuous Glucose Monitoring and Physical Activity. Int J Environ Res Public Health. 2022. 10.3390/ijerph191912296
29. D'Angelo S, Mazzeo F, Alfieri A, et al. Nutritional Management of Athletes with Type 1 Diabetes: A Narrative Review. 2024. 10.3390/nu16060907
30. Campbell MD, Walker M, Trenell MI, et al. A low-glycemic index meal and bedtime snack prevents postprandial hyperglycemia and associated rises in inflammatory markers, providing protection from early but not late nocturnal hypoglycemia following evening exercise in type 1 diabetes. Diabetes Care. 2014;37:1845-1853. 10.2337/dc14-0186
31. Sherr JL, Tauschmann M, Battelino T, et al. ISPAD Clinical Practice Consensus Guidelines 2018: Diabetes technologies. Pediatr Diabetes. 2018;19:302-325. 10.1111/pedi.12731
32. DiMeglio LA, Acerini CL, Codner E, et al. ISPAD Clinical Practice Consensus Guidelines 2018: Glycemic control targets and glucose monitoring for children, adolescents, and young adults with diabetes. Pediatr Diabetes. 2018;19:105-114. https://doi.org/10.1111/pedi.12737
33. Gitsi E, Livadas S, Angelopoulos N, et al. A Nutritional Approach to Optimizing Pump Therapy in Type 1 Diabetes Mellitus. Nutrients. 2023;15:4897. 10.3390/nu15234897
34. Guan Z, Li H, Liu R, et al. Artificial intelligence in diabetes management: Advancements, opportunities, and challenges. Cell Rep Med. 2023.
35. Tyler NS, Mosquera-Lopez CM, Wilson LM, et al. An artificial intelligence decision support system for the management of type 1 diabetes. Nat Metab. 2020;2:612-619. 10.1016/j.xcrm.2023.101213
36. Pesl P, Herrero P, Reddy M, et al. Case-Based Reasoning for Insulin Bolus Advice. J Diabetes Sci Technol. 2017;11:37-42. 10.1177/1932296816629986
37. Kodama S, Fujihara K, Shiozaki H, et al. Ability of Current Machine Learning Algorithms to Predict and Detect Hypoglycemia in Patients With Diabetes Mellitus: Meta-analysis. JMIR Diabetes. 2021;6:e22458. https://doi.org/10.2196/22458

38. Alotaibi MM, Istepanian R, Philip N. A mobile diabetes management and educational system for type-2 diabetics in Saudi Arabia (SAED). mHealth. 2016;2:33. 10.21037/mhealth.2016.08.01
39. Hamon T, Gagnayre R. Improving knowledge of patient skills thanks to automatic analysis of online discussions. Patient Educ Counsel. 2013;92:197-204. 10.1016/j.pec.2013.05.012
40. Zaharieva DP, Turksoy K, McGaugh SM, et al. Lag Time Remains with Newer Real-Time Continuous Glucose Monitoring Technology during Aerobic Exercise in Adults Living with Type 1 Diabetes. Diabetes Technol Ther. 2019;21:313-321. 10.1089/dia.2018.0364
41. Guan Z, Li H, Liu R, i wsp. Artificial intelligence in diabetes management: Advancements, opportunities, and challenges. Cell Rep Med. 2023; 4(10): 101213. https://doi.org/10.1016/j.xcrm.2023.101213