BŁASZCZAK, Karolina, KRUSZEWSKI, Adrian, PADUSZYŃSKA, Natalia, DĄBROWSKA, Anna, PRZYBYSZ, Paulina, SZYSZKA, Monika and KUCHARSKA, Maja. Sport and type 1 diabetes - a great value but also a challenge. Review of the literature and guidelines. Quality in Sport. 2024;17:52978. eISSN 2450-3118.
https://dx.doi.org/10.12775/QS.2024.17.52978
https://apcz.umk.pl/QS/article/view/52978

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 declare that there is no conflict of interests regarding the publication of this paper.
Received: 01.07.2024. Revised: 15.07.2024. Accepted: 17.07.2024. Published: 18.07.2024.

Sport and type 1 diabetes - a great value but also a challenge. Review of the literature and guidelines

Karolina Błaszczak [KB]
Dr Anna Gostynska Wolski Hospital, Independent Public Health Care Institution, Marcina Kasprzaka 17, 01-211 Warsaw, Poland
https://orcid.org/0009-0000-1534-6977
karolina.blaszczak@onet.pl

Adrian Kruszewski [AK]
Dr Anna Gostynska Wolski Hospital, Independent Public Health Care Institution, Marcina Kasprzaka 17, 01-211 Warsaw, Poland
https://orcid.org/0009-0003-6077-4948
adrkru7@gmail.com

Natalia Paduszyńska [NP]
Dr Anna Gostynska Wolski Hospital, Independent Public Health Care Institution, Marcina Kasprzaka 17, 01-211 Warsaw, Poland
https://orcid.org/0000-0001-9953-662X

natalia_paduszynska@onet.eu

Anna Dąbrowska [AD]
Dr Anna Gostynska Wolski Hospital, Independent Public Health Care Institution, Marcina Kasprzaka 17, 01-211 Warsaw, Poland
https://orcid.org/0009-0003-2289-5909
annaalicjadabrowska06@gmail.com

Paulina Przybysz [PP]
University Clinical Centre of the Medical University of Warsaw, Banacha 1a, 02-097 Warsaw, Poland
https://orcid.org/0009-0004-8141-2409
paulinaprzybysz.01@gmail.com

Monika Szyszka [MS]
Regional Specialist Hospital in Ciechanów, Powstańców Wielkopolskich 2, 06-400 Ciechanów, Poland
https://orcid.org/0009-0005-5054-4465
monika.szyszka@onet.com.pl

Maja Kucharska [MK]
Regional Specialist Hospital in Ciechanów, Powstańców Wielkopolskich 2, 06-400 Ciechanów, Poland
https://orcid.org/0009-0006-4599-8654
maja.kucharska30@gmail.com

Abstract

Introduction: Type 1 diabetes is a disease requiring complex treatment: intensive functional insulin therapy with multiple subcutaneous insulin injections (Multiple daily doses of insulin-MDI) or continuous subcutaneous insulin infusion (CSII) with a personal insulin pump. Type 1 diabetes is a disease with many complications including cardiovascular diseases. A key element in good disease control is adequate patient education. This paper will focus on physical activity and its impact on the course of the disease.

Aim of the study: To research the impact of physical activity on the course of type 1 diabetes. To reinforce medical professionals' knowledge of exercise management among patients with type 1 diabetes.

State of Knowledge: Regular physical exercise is beneficial for diabetes control, at the same time reducing the need for insulin. It also reduces the risk of dangerous late cardiovascular complications. Meta-analyses have shown a significant effect of physical activity on the reduction of HbA1c, BMI, triglycerides and total cholesterol. Continuous glucose monitoring (CGM) systems are recommended for physically active people with type 1 diabetes. Optimal glycaemia at the start and during sport are: for aerobic exercise 126-180 mg/dl (7-10 mmol/l), for anaerobic exercise 90-180 mg/dl (5-10 mmol/l). The reduction in insulin dose depends on the type of exercise, the length of the exercise, the method of treatment, and the pre-exercise blood glucose level.

Conclusion: Physical exercise improves the control of type 1 diabetes and therefore reduces the risk of complications of the disease including cardiovascular diseases. Type 1 diabetes is not a contraindication to both amateur and professional sport. However, many variables need to be considered. Every patient with type 1 diabetes must be properly trained before starting exercise.

Key worlds: Type 1 diabetes, physical activity, sport, insulin, insulin pump

Introduction:

Type 1 diabetes is caused by destruction of pancreatic β-cells by an autoimmune or idiopathic process, leading to absolute insulin deficiency [1]. The course is initiated by triggers in individuals with a genetic predisposition. The development of the disease is mediated by anti-insulin antibodies (against various β-cell antigens), which can appear months or even years before the onset of diabetic symptoms [2] [3]. During this period, there is a gradual loss of β-cell secretory capacity leading to overt diabetes, which is characterized by absolute insulin

deficiency. It usually manifests itself in children, adolescents and in people under 30 years of age. Once the disease is manifested, the process of β-cell destruction continues for some time and the disappearance of C-peptide (a marker of insulin secretion) from the serum marks their complete destruction. Type 1 diabetes mellitus is the most common chronic endocrine pathology among children. [4] Peaks in presentation occur between 5–7 years of age and at or near puberty. Whereas most autoimmune disorders disproportionately affect women, type 1 diabetes is slightly more common in boys and men. [5] Although most attention has focused on the increase in type 2 diabetes, a parallel rise in type 1 diabetes has occurred. The largest rate of increase is seen in children aged 0-4 years. [6] A noticeable increase in incidence occurred during the COVID-19 pandemic suggesting the impact of infections on morbidity. [7] [8] [9].

Methodology

A variety of scientific papers found using the Pubmed platform and Google Scholar were analysed. The most key information contained in the articles was highlighted and presented in the study in a structured manner, provide a broad overview of the importance of, and challenges to, physical activity among children and adults with type 1 diabetes.

State of knowledge

Methods of treatment

Type 1 diabetes must be treated with insulin. Intensive functional insulin therapy using multiple subcutaneous insulin injections (Multiple daily doses of insulin - MDI) or continuous subcutaneous insulin infusion (CSII) via a personal insulin pump is the recommended treatment model [10]. In MDI case, the choice of rapid-acting or ultra-rapid-acting insulin analogue or long-acting or ultra-long-acting insulin analogue should be based on the individual patient's needs, taking into account the pharmacological differences between the preparations and the registered indications; ultra-long-acting analogues reduce the risk of hypoglycaemia and allow for less restrictive adherence to the time of insulin administration and usually do not require dose reduction during physical activity. In CSII case, the choice of rapid-acting insulin/ ultra-rapid-acting insulin also depends on the individual patient's needs, pace of life, time in the day for meals, etc. The treatment of type 1 diabetes requires a high level of knowledge about the disease. The calculation of carbohydrate exchangers (or, as in the new standards, grams of carbohydrate covered by 1 unit of insulin) requires counting the

weight of the food consumed [11]. Especially for young children, this can be an obstacle to controlling blood glucose levels and, in the long term, contribute to serious complications of the disease. Parents face a big challenge, the disease brings a lot of discomfort in daily life and for this reason, education about the consequences of chronic blood hyperglycaemia is so important. Of course, it is also a huge challenge for older children and adult patients. The level of care in diabetes wards and outpatient clinics has a significant impact on the health behaviour of these patients. [12]

Diabetes treatment goals:

According to the guidelines:

Time in range (TIR) (70-180 mg/dl) should be >70%. (Exceptions are elderly >50%).

Time below range (TBR) (<70 mg/dl) <4%.

Time over range (TAR) (>180 mg/dl) <25%.

Complications of the disease:

Complications of type 1 diabetes are divided into macrovascular and microvascular. Cardiovascular diseases (e.g. myocardial infarction, hypertension, angina (there is also research underway on cardiomyopathy in diabetes. [13] [14]) are becoming an increasingly common complications as people with type 1 diabetes live longer. People with type 1 diabetes aged 30-39 years have a 22-fold higher cardiovascular risk (and 10-fold higher risk of death) than healthy peers. Those aged 40-44 years have a 13-fold higher cardiovascular risk (and a 9-fold higher risk of death) [15] [16]. Intensive diabetes treatment has been shown to reduce the risk of cardiovascular events by 42% [16][17]. The prognosis of patients with type 1 diabetes is less favourable than in patients without diabetes after an acute coronary incident.

The risk of microvascular complications, including retinopathy, nephropathy and neuropathy, decreases with intensive insulin therapy. Disorders of this type most often start around 15-20 years after the onset of diabetes. However, there is a risk that diabetic retinopathy or nephropathy may develop even in childhood, so intensive treatment and education should start as early as possible.

Factors that increase the risk of complications include comorbidities such as overweight, obesity, hypertension, poor glycaemic control and dyslipidaemia, which often result from lack of physical inactivity. [18]

The role of physical activity among type 1 diabetes patients

The health-related quality of life (HRQoL) of people with type 1 diabetes depends on glycaemic control. Regular exercise is strongly recommended for these patients due to its cardiovascular and metabolic benefits. Regular physical exercise is beneficial for diabetes control, at the same time reducing the need for insulin. It also reduces the risk of dangerous late cardiovascular complications [19]. Meta-analyses identified significant effects of physical activity on reductions in HbA1c which is crucial in the management of type 1 diabetes. [18][20]. Also revealed that exercise could improve the lipid profile in patients with type 1 diabetes, the largest effect size was for total cholesterol [21]. However, a large proportion of patients with type 1 diabetes show a sedentary lifestyle due to fear of post-exercise hypoglycaemia, lack of motivation, complex relationships in the context of glycaemic management and insulin dose interactions. [22] [23] Due to 2023 Guidelines on the management of patients with diabetes: A position of Diabetes Poland: Patients with type 1 diabetes without established clinically significant chronic complications of diabetes can undertake any type of exercise, including maximum intensity exercise [24]. It should be emphasised that type 1 diabetes should not be a contraindication to participation in physical education classes at any level of education or in school sport. This fact should be known and repeated by doctors to avoid stigmatisation and fear in educational institutions towards patients with type 1 diabetes. Children and young people with diabetes should be encouraged and supported to achieve daily physical activity of at least 60 minutes, should regularly participate in physical education classes, can participate in sports, including competitive sports, in the same way as children without diabetes [24].

Glucose monitoring during exercise

Continuous glucose monitoring (CGM) systems are recommended for physically active people with type 1 diabetes. The diabetologist should assist in the selection of the CGM. Patients should also be trained to interpret the results and to programme higher hypoglycaemia alarm thresholds individually. Those measuring glucose levels with a glucometer should determine blood glucose up to 15 minutes before, during and after physical activity. It should be added that there is a continuous glucose monitoring system on the Polish market that is implanted subcutaneously and replaced every six months. The sensor is inserted by a doctor and is available for patients >18 years of age. This may be suitable for certain groups of patients e.g. those taking part in contact sports. Severe, symptomatic hypoglycaemia is a contraindication to exercise for 24 hours. In the event of a hypoglycaemia alert ≤ 70 mg/dl, simple carbohydrates should be consumed, preferably in the form of liquid,

after which exercise may be continued if the hypoglycaemia subsides. Late hypoglycaemic events can occur up to 24 hours after exercise. The risk is higher in untrained individuals. If hyperglycaemia > 250 mg/dl is present and, in addition, ketonuria and/or ketonemia ≥ 1.5 mmol/l is found, exercise is contraindicated. If ketonuria and/or ketonemia are not present, light/moderate exercise may be undertaken.

Hypoglycaemia during exercise - how patients should manage concerns

Early symptoms of hypoglycaemia may include trembling, accelerated heart rate, sweating and increased appetite [25]. Unfortunately, these early warning signs are not always present in a person with diabetes who suffers from autonomic nerve dysregulation. Furthermore, evidence suggests that even after a small number of repeated hypoglycaemic episodes or after previous exercise, the autonomic response to hypoglycaemia is reduced in people with T1DM. Symptoms of severe neuroglycaemia usually only occur when blood glucose levels are extremely low (<40mg/dl) or prolonged and can cause acute disorientation and clumsiness, which is a highly unsafe situation. A problematic part in the diagnosis of hypoglycaemia is that many of these symptoms are also associated with intense exercise (increased heart rate, sweating, trembling, fatigue, dehydration, etc.), which is a very important factor in the diagnosis of hypoglycaemia. [26]

Treatment:

In patients on intensive insulin therapy, with insulin analogues or during treatment with a personal insulin pump, the tactic for managing hypoglycaemia usually involves only administering 15 g of glucose orally and checking glucose after 15 minutes. If a low glycaemia persists, the glucose administration should be repeated and the glucose checked after a further 15 minutes. With personal insulin pump therapy, if hypoglycaemia occurs or there is a risk of hypoglycaemia, it is advisable to stop the basal insulin infusion and recheck the glycaemia.

Types of exercise and their effect on glycaemia:

We can divide the types of exercise into aerobic, anaerobic and mixed. Aerobic exercise (e.g. trotting or walking) lowers blood glucose levels. The danger is therefore a high risk of hypoglycaemia. Anaerobic effort (e.g. weightlifting, sprinting), on the other hand, causes hyperglycaemia and patients should be very careful in administering rapid-acting insulin for glycaemic spikes. The hypoglycaemic effect of a bolus in this situation may increase the post-exercise hypoglycaemic risk. In mixed-type exercise, glycaemic levels are hard to predict so

the patient needs to be well trained and make a decision based on the circumstances, initial glycaemia and other factors. He can always discuss his doubts with a diabetologist. Optimal glycaemia at the start and during sport are: for aerobic exercise 126-180 mg/dl (7-10 mmol/l), for anaerobic exercise 90-180 mg/dl (5-10 mmol/l).

Guidelines for undertaking physical activity by people treated with insulin according to Polish Diabetes Association:

If a patient with type 1 diabetes plans to undertake physical activity up to 2 hours after a bolus of rapid-acting insulin, the dose should be reduced by 25-75% depending on the intensity and duration of the activity [24]. The patient should also consume carbohydrates before exercise: 1.0-1.5 g/kg b.w./hour of intense exercise if there was no bolus reduction and 0.2-0.5 g/kg b.w./hour of intense exercise if there was a reduction [27]. For many hours of exercise, a reduction in basal dose of NPH insulin/long-acting insulin/ultra-long-acting insulin should be considered. With an insulin pump, it is recommended to reduce basal insulin flow by 20-80%, depending on the intensity and duration of exercise (optimally 2 hours before exercise). Disconnection of the insulin pump during exercise is recommended for up to 3 hours (only in the presence of active insulin monitored with a bolus calculator). The diabetic should not inject insulin into areas of the body particularly involved in physical exertion, e.g. the thigh in the case of running. This recommendation is due to the fact that exercise causes a faster heartbeat and increased blood flow in the area, so that insulin can be absorbed more quickly, and sudden hypoglycaemia can occur.

Principles of physical exercise by people with diabetes treated with a hybrid closed loop (HCL) according to Polish Diabetes Association:

The use of a hybrid closed-loop system during exercise requires a lot of patient decision-making and therapy modification after careful education. Recommended modifications include: [24]

- an insulin dose reduction of 25-75% for meals consumed up to 2 hours before exercise

- a higher glucose target 90-120 minutes before the start of exercise lasting longer than 30 minutes (especially aerobic exercise)

- additional carbohydrate intake should not be entered into the system, and it is recommended to consume carbohydrate up to 5-10 minutes prior to exercise (smaller amounts than with a traditional insulin pump), consuming carbohydrates earlier than 20 minutes prior to exercise may result in increased insulin delivery through the hybrid closed loop system which may result in hypoglycaemia

- if the insulin pump is detached during exercise, it is necessary to stop operation of the pump, and stopping the pump for longer than 90-120 minutes may require an additional dose of insulin to be administered via a pen or insulin pump.

Recommendations of Diabetes Poland and the Polish Society of Sports Medicine for patients with type 1 diabetes:

A sports medicine specialist can qualify a patient with type 1 diabetes to participate in any sport. This must be preceded by a certificate from a diabetologist. The patient must be treated with intensive functional insulin therapy (penes or personal insulin pump - the preferred and more precise method). The athlete must also monitor blood glucose levels a minimum of six times a day and additionally during exercise or competition (continuous glucose monitoring (CGM) systems are preferred). For an athlete with type 1 diabetes to maintain a high level of physical performance, glycaemia should be maintained > 70% of the time within the target range of 70-180 mg/dl and < 4% below 70 mg/dl, and < 1% on the day of the sporting event. Aquatic, aerial, climbing and motorsports have a high risk of hypoglycaemia. They are contraindicated among patients with type 1 diabetes mellitus. Patients are allowed to participate in them in exceptional cases, very well educated, without a relative risk of severe hypoglycaemia.

Situations that are contraindications to qualify a patient for professional sport: [24]

1. HbA1c value: average of last 12 months > 8.5% or current result ≥ 9%.

2. more than one episode of ketoacidosis in the last 12 months.

3. more than one episode of severe hypoglycaemia in the last 12 months.

4. self-monitoring of glycaemia: number of measurements < 6 per day with a glucometer in athletes not using CGM.

5. diabetes clinic visits: in children < 4/year, in adults < 2/year.

6. unawareness of hypoglycaemia - relative contraindication, can be waived depending on sport and use of CGM.

7. chronic complications of diabetes depending on stage and sport: such as proliferative retinopathy, autonomic neuropathy, proteinuria

If the patient presents any of the points listed below, he should not undertake traning/participate in competitions:

1. severe hypoglycaemia in the past 24 hours.

2. hyperglycaemia greater than 250 mg/dl (13.9 mmol/l) with associated ketonemia/ketonuria due to insulin deficiency rather than carbohydrate deficiency.

3. ketosis ≥ 1.5 mmol/l is an absolute contraindication to the initiation and continuation of exercise.

4. hyperglycaemia > 300 mg/dl (16.7 mmol/l) sustained for more than 2 hours.

5. any acute event requiring medical attention such as visual disturbance, chest pain, fainting, acute infection, etc.

Psychological aspect of disease:

Self-management in type 1 diabetes can be difficult, causing psychological and psychosocial complications for children, adolescents and their families. The main problems are anxiety, depression and eating disorders. Adolescents with type 1 diabetes are 2.3 times more likely to experience mental health problems compared to healthy peers [28]. Many children and adolescents also experience a lack of support in schools or nurseries. Institutions need to educate their staff on how to deal with a child with type 1 diabetes. [4] Caregivers of the youngest patienets (the prevalence of type 1 diabetes in young children aged <6 years is increasing) have a great responsibility to check blood glucose levels, administer insulin, monitor diet and physical activity to maintain goals. Unfortunately, this tight control is necessary during a sensitive developmental period when behaviour is unpredictable, parental stress may be elevated and caregivers are charged with normal childcare routines. [29] Psychological interventions for people with diabetes should include developing a sense of

influence over the course of the disease. It is proven that physical activity is an important factor in reducing stress levels. Cortisol regulation and sleep quality are linked, and physical activity can improve both in several ways [30]. As mentioned earlier, patients with type 1 diabetes are at higher risk of stress and its consequences therefore education on the importance of exercise is even more important in this group.

Conclusion:

It has been proven that regular physical activity has a positive effect on the blood sugar levels of people with type 1 diabetes. This leads directly to a reduced risk of complications of the disease including cardiovascular diseases. Very importantly, patients should be aware that type 1 diabetes is not a contraindication to sport. It should be continually repeated that children with type 1 diabetes can participate in school sports. However, preparation requires certain rules. These depend on the type of exercise, planned exercise time, pre-exercise glycaemia and method of treatment. The insulin dose should be adjusted according to these variables. Professional sport is not contraindicated either but requires good cooperation with a diabetologist and appropriate education.

Disclosures

Funding statement: No external funding was received to perform this review

Conflict of interest: The authors declare no conflict of interest

Authors contribution: Conceptualization Karolina Błaszczak, Adrian Kruszewski; Methodology Natalia Paduszyńska, Paulina Przybysz; Software: Karolina Błaszczak, Adrian Kruszewski; Formal analysis Adrian Kruszewski, Anna Dąbrowska; Investigation Karolina Błaszczak, Anna Dąbrowska; Resources: Natalia Paduszyńska, Monika Szyszka; Data curation: Paulina Przybysz, Maja Kucharska; Writing - rough preparation Natalia Paduszyńska, Monika Szyszka; Writing -review and editing Paulina Przybysz, Maja Kucharska; Supervision: Monika Szyszka, Maja Kucharska; Project administration: Karolina Błaszczak, Anna Dąbrowska

All authors have read and agreed with the final, published version of the manuscript.

Board statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

References:

[1] DiMeglio LA, Evans-Molina C, Oram RA. Type 1 diabetes. Lancet. 2018 Jun 16;391(10138):2449-2462. doi: 10.1016/S0140-6736(18)31320-5. PMID: 29916386; PMCID: PMC6661119.

[2] Gillespie KM. Type 1 diabetes: pathogenesis and prevention. CMAJ. 2006 Jul 18;175(2):165-70. doi: 10.1503/cmaj.060244. PMID: 16847277; PMCID: PMC1489998.

[3] Maahs DM, West NA, Lawrence JM, Mayer-Davis EJ. Epidemiology of type 1 diabetes. Endocrinol Metab Clin North Am. 2010 Sep;39(3):481-97. doi: 10.1016/j.ecl.2010.05.011. PMID: 20723815; PMCID: PMC2925303.

[4] Henríquez-Tejo R, Cartes-Velásquez R. Impacto psicosocial de la diabetes mellitus tipo 1 en niños, adolescentes y sus familias. Revisión de la literatura [Psychosocial impact of type 1 diabetes mellitus in children, adolescents and their families. Literature review]. Rev Chil Pediatr. 2018 Jun;89(3):391-398. Spanish. doi: 10.4067/S0370-41062018005000507. PMID: 29999147.

[5] Atkinson MA, Eisenbarth GS, Michels AW. Type 1 diabetes. Lancet. 2014 Jan 4;383(9911):69-82. doi: 10.1016/S0140-6736(13)60591-7. Epub 2013 Jul 26. PMID: 23890997; PMCID: PMC4380133.

[6] Devendra D, Liu E, Eisenbarth GS. Type 1 diabetes: recent developments. BMJ. 2004 Mar 27;328(7442):750-4. doi: 10.1136/bmj.328.7442.750. PMID: 15044291; PMCID: PMC381328.

[7] Rahmati M, Keshvari M, Mirnasuri S, Yon DK, Lee SW, Il Shin J, Smith L. The global impact of COVID-19 pandemic on the incidence of pediatric new-onset type 1 diabetes and ketoacidosis: A systematic review and meta-analysis. J Med Virol. 2022 Nov;94(11):5112-5127. doi: 10.1002/jmv.27996. Epub 2022 Jul 22. PMID: 35831242; PMCID: PMC9350204.

[8] Karavanaki K, Rodolaki K, Soldatou A, Karanasios S, Kakleas K. Covid-19 infection in children and adolescents and its association with type 1 diabetes mellitus (T1d) presentation and management. Endocrine. 2023 May;80(2):237-252. doi: 10.1007/s12020-022-03266-7. Epub 2022 Dec 3. PMID: 36462147; PMCID: PMC9734866.

[9] Nassar M, Daoud A, Nso N, Medina L, Ghernautan V, Bhangoo H, Nyein A, Mohamed M, Alqassieh A, Soliman K, Alfishawy M, Sachmechi I, Misra A. Diabetes Mellitus and COVID-19: Review Article. Diabetes Metab Syndr. 2021 Nov-Dec;15(6):102268. doi: 10.1016/j.dsx.2021.102268. Epub 2021 Sep 4. PMID: 34562865; PMCID: PMC8416292.

[10] Akil AA, Yassin E, Al-Maraghi A, Aliyev E, Al-Malki K, Fakhro KA. Diagnosis and treatment of type 1 diabetes at the dawn of the personalized medicine era. J Transl Med. 2021 Apr 1;19(1):137. doi: 10.1186/s12967-021-02778-6. PMID: 33794915; PMCID: PMC8017850.

[11] Haak T, Gölz S, Fritsche A, Füchtenbusch M, Siegmund T, Schnellbächer E, Klein HH, Uebel T, Droßel D. Therapy of Type 1 Diabetes. Exp Clin Endocrinol Diabetes. 2019 Dec;127(S 01):S27-S38. doi: 10.1055/a-0984-5696. Epub 2019 Dec 20. PMID: 31860925.

[12] De Beaufort C, Besançon S, Balde N. Management of type 1 diabetes. Med Sante Trop. 2018 Nov 1;28(4):359-362. English. doi: 10.1684/mst.2018.0834. PMID: 30799818.

[13] Cieluch A, Uruska A, Zozulinska-Ziolkiewicz D. Can We Prevent Mitochondrial Dysfunction and Diabetic Cardiomyopathy in Type 1 Diabetes Mellitus? Pathophysiology and Treatment Options. Int J Mol Sci. 2020 Apr 19;21(8):2852. doi: 10.3390/ijms21082852. PMID: 32325880; PMCID: PMC7215501.

[14] Bugger H, Abel ED. Molecular mechanisms of diabetic cardiomyopathy. Diabetologia. 2014 Apr;57(4):660-71. doi: 10.1007/s00125-014-3171-6. Epub 2014 Jan 30. PMID: 24477973; PMCID: PMC3969857.

[15] Miller RG, Mahajan HD, Costacou T, Sekikawa A, Anderson SJ, Orchard TJ. A Contemporary Estimate of Total Mortality and Cardiovascular Disease Risk in Young Adults With Type 1 Diabetes: The Pittsburgh Epidemiology of Diabetes Complications Study. Diabetes Care. 2016 Dec;39(12):2296-2303. doi: 10.2337/dc16-1162. Epub 2016 Sep 21. PMID: 27654986; PMCID: PMC5127232.

[16] Liu Z, Wang H, Yang Z, Lu Y, Zou C. Causal associations between type 1 diabetes mellitus and cardiovascular diseases: a Mendelian randomization study. Cardiovasc Diabetol. 2023 Sep 2;22(1):236. doi: 10.1186/s12933-023-01974-6. PMID: 37659996; PMCID: PMC10475187.

[17] Epidemiology of Diabetes Interventions and Complications (EDIC) Research Group. Epidemiology of Diabetes Interventions and Complications (EDIC). Design, implementation, and preliminary results of a long-term follow-up of the Diabetes Control and Complications Trial cohort. Diabetes Care. 1999 Jan;22(1):99-111. doi: 10.2337/diacare.22.1.99. PMID: 10333910; PMCID: PMC2745938.

[18] Czenczek-Lewandowska E, Grzegorczyk J, Mazur A. Physical activity in children and adolescents with type 1 diabetes and contem-porary methods of its assessment. Pediatr Endocrinol Diabetes Metab. 2018;24(4):179-184. English. doi: 10.5114/pedm.2018.83364. PMID: 30963755.

[19] Cuenca-García M, Jago R, Shield JP, Burren CP. How does physical activity and fitness influence glycaemic control in young people with Type 1 diabetes? Diabet Med. 2012 Oct;29(10):e369-76. doi: 10.1111/j.1464-5491.2012.03740.x. PMID: 22803800.

[20] Quirk H, Blake H, Tennyson R, Randell TL, Glazebrook C. Physical activity interventions in children and young people with Type 1 diabetes mellitus: a systematic review with meta-analysis. Diabet Med. 2014 Oct;31(10):1163-73. doi: 10.1111/dme.12531. PMID: 24965376; PMCID: PMC4232875.

[21] Chang X, Wang Z, Guo H, Xu Y, Ogihara A. Effect of Physical Activity/Exercise on Cardiorespiratory Fitness in Children and Adolescents with Type 1 Diabetes: A Scoping Review. Int J Environ Res Public Health. 2023 Jan 12;20(2):1407. doi: 10.3390/ijerph20021407. PMID: 36674162; PMCID: PMC9860959.

[22] Alarcón-Gómez J, Chulvi-Medrano I, Martin-Rivera F, Calatayud J. Effect of High-Intensity Interval Training on Quality of Life, Sleep Quality, Exercise Motivation and Enjoyment in Sedentary People with Type 1 Diabetes Mellitus. Int J Environ Res Public Health. 2021 Nov 30;18(23):12612. doi: 10.3390/ijerph182312612. PMID: 34886337; PMCID: PMC8656786.

[23] Colberg SR, Laan R, Dassau E, Kerr D. Physical activity and type 1 diabetes: time for a rewire? J Diabetes Sci Technol. 2015 May;9(3):609-18. doi: 10.1177/1932296814566231. Epub 2015 Jan 6. PMID: 25568144; PMCID: PMC4604550.

[24] Araszkiewicz, Aleksandra et al. "2023 Guidelines on the management of patients with diabetes - a position of Diabetes Poland." Current Topics in Diabetes, vol. 3, no. 1, 2023, pp. 1-133. doi:10.5114/ctd/160061.

[25] Jensen MV, Broadley M, Speight J, Chatwin H, Scope A, Cantrell A, Heller S, de Galan BE, Hendrieckx C, Pouwer F; of the Hypo-RESOLVE consortium. The impact of hypoglycaemia in children and adolescents with type 1 diabetes on parental quality of life and related outcomes: A systematic review. Pediatr Diabetes. 2022 May;23(3):390-405. doi: 10.1111/pedi.13308. Epub 2022 Jan 23. PMID: 34981624.

[26] Kelly, Dylan, Jill K. Hamilton, and Michael C. Riddell. "Blood glucose levels and performance in a sports cAMP for adolescents with type 1 diabetes mellitus: a field study." International journal of pediatrics 2010.1 (2010): 216167.

[27] Scott S, Kempf P, Bally L, Stettler C. Carbohydrate Intake in the Context of Exercise in People with Type 1 Diabetes. Nutrients. 2019 Dec 10;11(12):3017. doi: 10.3390/nu11123017. PMID: 31835538; PMCID: PMC6950062.

[28] Mutlu EK, Mutlu C, Taskiran H, Ozgen IT. Association of physical activity level with depression, anxiety, and quality of life in children with type 1 diabetes mellitus. J Pediatr Endocrinol Metab 2015; 28: 1273-1278. doi: 10.1515/jpem-2015-0082

[29] Streisand R, Monaghan M. Young children with type 1 diabetes: challenges, research, and future directions. Curr Diab Rep. 2014;14(9):520. doi: 10.1007/s11892-014-0520-2. PMID: 25009119; PMCID: PMC4113115.

[30] De Nys L, Anderson K, Ofosu EF, Ryde GC, Connelly J, Whittaker AC. The effects of physical activity on cortisol and sleep: A systematic review and meta-analysis. Psychoneuroendocrinology. 2022 Sep;143:105843. doi: 10.1016/j.psyneuen.2022.105843. Epub 2022 Jun 24. PMID: 35777076.