

PHYSIOPROPHYLAXIS OF TYPE 1 DIABETES IN CHILDREN USING PHYSICAL EXERCISE

FIZJOPROFILAKTYKA CUKRZYCY TYPU 1 U DZIECI Z WYKORZYSTANIEM AKTYWNOŚCI FIZYCZNEJ

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- C. Data analysis/statistics
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Summary

According to the Physiotherapist Act, physioprophylaxis is an important component of physiotherapy and of the physiotherapist's professional activities. Physioprophylaxis can be oriented towards practicing healthy lifestyle behaviours, minimizing disease risk factors, or attenuating the consequences of the disease, surgery, and/or disability. Type 1 diabetes is a chronic metabolic disease characterized by hyperglycaemia, i.e. high blood glucose levels. It is caused by the dysfunction or destruction of β cells of pancreatic islets of Langerhans, which are responsible for the production and secretion of insulin. Type 1 diabetes is most common in children and adolescents. According to the 2018 report, 6,400 children aged 0-14 years and about 180,000 people over 14 years old suffer from type 1 diabetes in Poland alone. Physical activity is an important stimulus for optimal physiological development of children and adolescents, and is an important factor in reducing the risk of cardiovascular diseases, cancer, and mortality. Physical exercise reduces the need for insulin and increases the sensitivity of cells to insulin, so that the daily dose of insulin can be reduced. The Polish Diabetes Association recommends that children with type 1 diabetes should exercise for more than one hour a day in order to reduce the risk of vascular complications associated with the disease. The aim of this paper is to examine the effects of type 1 diabetes physioprophylaxis in children in the form of physical exercise, based on previous literature. The majority of research indicates physical activity has a positive effect on physiological function in children with type 1 diabetes, specifically reducing the risk of hypoglycaemia, high blood glucose level, insulin demand, and premature death.

Keywords: physioprophylaxis, type 1 diabetes, physical exercise, children

Streszczenie

Fizjoprofilaktyka, zgodnie z Ustawą o zawodzie fizjoterapeuty, jest składową fizjoterapii i czynnością zawodową fizjoterapeuty. Może być ukierunkowana na praktykowanie zachowań zdrowotnych, zapobieganie czynnikom ryzyka choroby lub zapobieganie konsekwencjom choroby (operacji) i niepełnosprawności. Cukrzyca typu 1 to przewlekła choroba metaboliczna cechująca się występowaniem hiperglikemii, czyli podwyższonego poziomu glukozy w osoczu krwi. Jej przyczyną jest zaburzenie funkcji lub zniszczenie komórek β wysp Langerhansa trzustki. Cukrzyca typu 1 występuje najczęściej u dzieci i młodzieży. Według raportu z 2018 roku w Polsce na cukrzycę typu 1 choruje 6 400 dzieci w wieku 0-14 lat oraz ok. 180 000 osób powyżej 14 roku życia. Aktywność fizyczna jest ważnym stymulatorem prawidłowego rozwoju dzieci i młodzieży w ujęciu holistycznym, a także istotnym czynnikiem zmniejszenia ryzyka chorób układu sercowo-naczyniowego, nowotworów oraz śmiertelności. Wysiłek fizyczny powoduje zmniejszone zapotrzebowanie na insulinę oraz zwiększanie wrażliwości komórek na insulinę, dzięki czemu dawka dobowej insuliny może być zmniejszona. Polskie Towarzystwo Diabetologiczne zaleca podejmowanie wysiłku fizycznego przez dzieci chorujące na cukrzycę typu 1 w wymiarze powyżej jednej godziny dziennie celem redukcji ryzyka powikłań naczyniowych. Celem artykułu jest przedstawienie wyników fizjoprofilaktyki cukrzycy typu 1 u dzieci w formie aktywności fizycznej na podstawie literatury. Większość badań wskazuje pozytywne działanie aktywności fizycznej na stan funkcjonowania dziecka z cukrzycą typu 1 zmniejszając: ryzyko hipoglikemii, stężenie glukozy we krwi, zapotrzebowanie na insulinę i ryzyko śmierci.

Słowa kluczowe: fizjoprofilaktyka, cukrzyca typu 1, aktywność fizyczna, dzieci

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Introduction

Physioprophyllaxis is one of the health services provided within the framework of physiotherapeutic activity [1]. The goal of physioprophyllaxis is to advocate pro-health behaviours and to improve fitness of people of different ages in order to prevent disability. In the literature we distinguish three levels of physioprophyllaxis – primary, secondary, and tertiary. Primary physioprophyllaxis is targeted at the general population and vulnerable groups. Its purpose is to provide knowledge and skills for maintaining health through appropriately-oriented physical activity. Secondary physioprophyllaxis includes actions taken when the first symptoms of the disease appear. Its aim is to prevent the consequences of the disease or to slow down the development of symptoms that are not yet visible but predictable. Tertiary physioprophyllaxis is action taken with developed diseases or dysfunctions, which cannot be cured; its task is to prevent the possible accumulation of symptoms and to create optimal compensation mechanisms [2].

Type 1 diabetes is a chronic metabolic disease characterized by hyperglycaemia, i.e. high blood glucose levels. It is caused by the dysfunction or destruction of β cells of pancreatic islets of Langerhans, which are responsible for the production and secretion of insulin [3, 4].

According to data from 2014, 387 million people worldwide suffer from diabetes, of which 46.3% are undiagnosed; in other words, approximately 1 in 12 people suffer from the disease. This number is expected to increase by 205 million people by the year 2035 [5].

Type 1 diabetes develops rapidly, and its first symptoms, such as increased thirst, weight loss, and general fatigue, appear suddenly. No effective method of preventing type 1 diabetes exists, and the aetiology of type 1 diabetes is still not fully understood [3-5]. Vitamin D1 deficiency and excess body fat have been suggested as modulating factors. Further, excessive inflammatory responses to various external factors can be induced by polygenic hereditary factors. Such factors may increase the risk of autoimmune dysfunction [6].

Prophyllaxis in the prevention and treatment of diabetes is inadequate, but attention should be also drawn to the lack of diabetes education of various social groups, especially parents and teachers of children. As a result, individuals with diabetes have little social and familial support in coping with the disease. This is particularly disturbing given that type 1 diabetes is most common in children and adolescents [3, 4]. In Poland, 6,400 children aged 0-14 years and 180,000 people over 14 years old suffer from type 1 diabetes [7, 8].

Type 1 diabetes generates high treatment costs for diabetic patients. According to data from the World Bank, diabetes is the second largest economic burden on society after ischemic heart disease, and it constitutes between 5-10% of the total health care budget [7]. Further, according to the data obtained from the Social Insurance Institution, the National Health Fund, and Statistics Poland, it was estimated that the total costs due to diabetes and related complications were at least PLN 7 billion in 2013 [9]. Evidence suggests an active lifestyle, including moderate and frequent physical activity, has a positive impact on glycaemia, better disease control, and improvement of patient quality of life [3-5].

This paper aims to outline the impacts of preventive physical therapy in treatment of childhood type 1 diabetes through physical exercise, taking into account the location, role, and form of the physioprophyllaxis within the available literature. PubMed, EBSCO, and Google Scholar databases were used to find qualifying papers; specifically, to identify the proper publications, a search was performed with combinations of the following keywords: Diabetes Mellitus, Type 1, children, adolescent, and exercise (according to Medical Subject Headings, MeSH), with publication dates from 2009-2019.

Physical activity (PA) in physioprophyllaxis of type 1 diabetes in children

For many years, physical exercise was considered dangerous for people with type 1 diabetes. It was not until 1986 that results of a scientific study indicated physical activity does not have a negative impact on patient health, and may, in fact, also have a pro-health effect [10].

Physical activity is one of the most important factors holistically influencing the proper physical and mental development of children and adolescents. The musculoskeletal, circulatory, respiratory, and neurohormonal systems are particularly important for development – all of which are impacted by PA [11-13]. PA also prevents many metabolic diseases such as obesity, cardiovascular diseases, and cancer [14-16].

The rapid development of civilization causes systematic reduction of physical activity in every age group [16-18]. As more nation-states become developed, this inactivity epidemic is likely to increase. Currently, only 30% of adolescents and 10% of adults participate in regular physical activity satisfying their health needs [19, 20]. Studies by Chabros et al., conducted on a group of 1054 primary and secondary school students, showed that physical activity of children and adolescents is insufficient and far from recommended – 18.4% of boys and 11.9% of girls were overweight [12]. Ridell et al. indicated that children with type 1 diabetes, in particular, often

have problems with maintaining proper body weight and do not reach the minimum dose of daily PA [17].

There is no evidence to suggest that physical exercise can prevent the development of type 1 diabetes. Therefore, PA may not be effective as a primary preventive physical therapy; however, it is possible to use exercise as an effective means of secondary and tertiary preventive physical therapy.

Physical exercise influence on the organism of patients with type 1 diabetes

During physical activity, the demand for oxygen increases, which results in increased muscle consumption of glycogen, triglycerides, free fatty acids, and glucose from the liver. In healthy individuals, the hormonal system is largely responsible for maintaining normoglycaemia. In the initial phases of exercise, dropping insulin levels and the presence of glucagon cause an increase in liver glucose production. However, during long-term exercise, the increases in glucagon and catecholamine levels play a more substantial role in the response. In patients with type 1 diabetes with insulin deficiency, this control mechanism is disturbed – there is not enough insulin in the blood, and the resultant hormones cause an increase in hyperglycaemia and ketone concentration. In contrast, high insulin levels as a result of insulin treatment may result in weakening or even inhibition of glucose release during physical activity, thus causing hypoglycaemia [13, 14].

A common symptom of type 1 diabetes is myopathy, characterized by decreases in muscle mass and function [21]. The mechanisms responsible for muscle atrophy in this population are complex. It is believed that hyperglycaemia contributes to muscle tissue atrophy through the formation and accumulation of glycolysis end-products in skeletal muscles and increased oxidative stress, which results in increased expression of genes responsible for atrophy and normal protein metabolism [3].

Physical activity also influences the growth of muscle mass by stimulating morphological tissue changes, i.e. improving blood supply to the tissue, improving elasticity and, consequently, maintaining correct joint range of motion. Physical exercise also speeds up the conversion of cartilage into bone, thus supporting the growth process [11, 13, 22, 23, 24]. Importantly for type 1 diabetics, regular training reduces the need for insulin after physical exercise and increases the sensitivity of cells to insulin, so that the daily dose of insulin may be reduced. This is an important factor in reducing the risk of cardiovascular diseases, cancer, and mortality [25-31].

Wu et al. conducted a meta-analysis of 24 articles on the impact of aerobic physical activity on patients with type 1 diabetes. The results show that physical exercise improves physical fitness, muscle strength and lipid profile and reduces the risk of cardiovascular diseases [27]. Similar conclusions were reached by Chimen et al., who analysed 48 studies on the influence of aerobic physical activity on patients with type 1 diabetes. A reduced need for insulin was noted; however, the influence of physical activity on the control of glucose levels, function of β cells of pancreatic islets, and the risk of cancer was not established. The authors recognise the need for further research on the intensity, duration, and types of physical activity that may bring the greatest health benefits to patients with type 1 diabetes [30].

Ostman et al. prepared a meta-analysis of 15 publications on the influence of physical exercise on major health parameters of patients with type 1 diabetes. In adults, body mass index (BMI) and low-density lipoproteins (LDL) decreased, and maximal oxygen capacity (VO_{2max}) increased, while in children, the body weight, insulin dose, and lipid profile improved [29].

Meta-analyses by Absil et al., Aljawarneh et al., and Tonoli et al. confirmed the positive effects of aerobic training, while emphasizing the ambiguous influence of strength training on glycaemia of patients with type 1 diabetes [32-34]. Yardley et al. indicated a smaller initial decrease in blood glucose levels during strength training compared to aerobic training [35]. The same authors in their previous studies point to a more effective influence of physical activity on glycaemic control in the case of using first strength and then aerobic exercises in one training session. Additionally, this sequence of exercise attenuates hypoglycaemia and its duration after the training [36].

Wójcik et al. examined the level of physical activity of 95 children with type 1 diabetes. Most (75%) of the respondents subjectively stated that physical activity had a positive effect on glycaemia control. They noted, however, that physical activity had no significant effect on metabolic control as assessed by glycated haemoglobin (HbA1c) [37].

Similar conclusions were reached by Kennedy et al., who performed a meta-analysis examining 14 publications. The authors did not report any statistically significant influence of physical activity on glycaemic control, however, they point to other positive effects accompanying the training, such as improved quality of life [38].

The impact of physical exercise on mental health is worth emphasizing. Regular physical activity reduces symptoms of depression and anxiety and improves mental fitness and mental well-being through an increase

in blood endorphins levels [39-41]. Aman et al. surveyed 2269 adolescents (average age 14.5 years old) from 21 paediatric diabetes departments in 19 countries. The results confirmed a significant correlation between physical activity and mental well-being in patients, but an influence on metabolic control was not observed [42].

In their research, Ridell et al. stressed the impact of emotional barriers limiting physical activity in patients with type 1 diabetes, including fear of hypoglycaemia, loss of control over glycaemia, and a lack of knowledge about physical activity [17].

Treatment of type 1 diabetes includes insulin therapy, a properly chosen diet, and physical exercise. Regular training is especially important because it leads to a reduced need for exogenous insulin by raising insulin sensitivity of cells, improves the lipid profile, and reinforces the muscle strength and physical efficiency of patients. In addition, physical exercise reduces the risk of cardiovascular complications and decreases rates of mortality, though the effect of exercise on glycaemic control remains unclear. The most significant conclusions drawn from the discussed systematic reviews are presented in Table 1.

Table 1. Search results

| Study (Author, year, title) | Number of studies included in the meta-analysis | Conclusions |
|--|--|---|
| Absil et al., 2019 Benefits of physical activity in children and adolescents with type 1 diabetes: a systematic review. | n=7 | <ul style="list-style-type: none"> – Physical effort has a positive effect on metabolism (i.e. total cholesterol reduction, physical fitness improvement etc.) and mental health in children with type 1 diabetes. – The effect of exercise on glycaemic control is unclear. |
| Aljawarneh et al., 2019 A systematic review of physical activity and exercise on physiological and biochemical outcomes in children and adolescents with type 1 diabetes. | n=27 | <ul style="list-style-type: none"> – Supervised regular moderate to vigorous physical activity is more effective on adiposity and cardiorespiratory fitness than habitual physical activity. – Physical activity of different intensities improves insulin sensitivity and decreases daily insulin dosage requirements. – The effect of exercise on glycaemic control is unclear. |
| Wu et al., 2019 Cardiovascular health benefits of exercise training in persons living with type 1 diabetes: a systematic review and meta-analysis. | n=24 | <ul style="list-style-type: none"> – Exercise training increases maximal aerobic capacity and reduces glycated haemoglobin and total cholesterol. – Exercise training does not lead to consistent changes in body mass index, blood pressure, triglycerides, high-density lipoprotein cholesterol, or low-density lipoprotein cholesterol. – Exercise training is associated with a beneficial cardiovascular profile, including improvements in lipid profile, glycaemic control (decreased daily insulin dosage and HbA1c), and aerobic fitness. |
| Ostman et al., 2018 Clinical outcomes to exercise training in type 1 diabetes: a systematic review and meta-analysis. | n=15 | <ul style="list-style-type: none"> – Exercise training improves some markers of type 1 diabetes severity, particularly insulin dose, waist circumference, LDL-C, and triglycerides in children. |
| Quirk et al., 2014 Physical activity interventions in children and young people with type 1 diabetes mellitus: a systematic review with meta-analysis. | n=26 | <ul style="list-style-type: none"> – Physical activity is important for diabetes management and has the potential to delay cardiovascular disease. – There is a lack of studies underpinned by psychological behaviour change theory that promote sustained physical activity and explore psychological outcomes. – There remains a lack of knowledge of how to successfully promote physical activity in people with type 1 diabetes. |
| Kennedy et al., 2013 Does exercise improve glycaemic control in type 1 diabetes? A systematic review and meta-analysis. | n=13 | <ul style="list-style-type: none"> – This meta-analysis does not reveal evidence for a glycaemic benefit of exercise as measured by HbA1c. |

| | | |
|---|-------|--|
| Tonoli et al., 2012 Effects of different types of acute and chronic (training) exercise on glycaemic control in type 1 diabetes mellitus: a meta-analysis. | n=33 | <ul style="list-style-type: none"> - The addition of brief bouts of high-intensity, sprint-type exercise to aerobic exercise can minimize the risk of sustaining a hypoglycaemic episode. - Only regular aerobic training improves HbA1c levels of patients with type 1 diabetes. |
| Chimen et al., 2012 What are the health benefits of physical activity in type 1 diabetes mellitus? A literature review. | n=48 | <ul style="list-style-type: none"> - There is little evidence for a beneficial effect of physical activity on glycaemic control or microvascular complications. - Further, there is little evidence indicating significant risk of harm from physical activity via hypoglycaemia. - While there is sufficient evidence to recommend physical activity in the management of type 1 diabetes, it is still unclear as to what form, duration, and intensity should be recommended and what specific beneficial outcomes are supported. |
| Sluik et al., 2012 Physical activity and mortality in individuals with diabetes mellitus: a prospective study and meta-analysis. | n= 12 | <ul style="list-style-type: none"> - Higher levels of physical activity are associated with lower mortality risk in individuals with diabetes. - Even those undertaking moderate amounts of activity were at appreciably lower risk for early death compared with inactive persons. |

Recommended dose and types of physical training for individuals with type 1 diabetes

According to the recommendations of the American Diabetes Association and the Polish Diabetes Association (2019), young patients with stabilized type 1 diabetes can undertake most types of physical exercises. Before training, the patients should be examined by a physician for risk of complications [43].

In order to best support children with diabetes, experts recommend that parents, teachers, physiotherapists, and trainers should receive appropriate training on the basics of physical activity in diabetic patients [7, 39, 44]. Chmiel-Perzyńska et al. indicated that the main source of information about diabetes among teachers is mass media. Only 4.5% of the responding teachers received knowledge from physicians, and 24.8% were not interested in this subject [45]. An important problem concerning the use of physical activity in physioprophyllaxis of type 1 diabetes is access to physiotherapy specialists, as evidence suggests nearly half (48%) of diabetic patients report no access to physiotherapist services [47].

Due to the interindividual variability in glycaemic responses to physical activity, it is difficult to create uniform carbohydrate consumption recommendations, for both before and after training. In order to prevent hypoglycaemia during prolonged exercise (over 30 minutes) of moderate intensity, additional carbohydrate doses of 10-15 grams are recommended. Those with type 1 diabetes should measure blood glucose level before, during, and a few hours after training. As an alternative to additional carbohydrate portions or as a supplement to prevent hypoglycaemia, the dose of insulin may be reduced. In order to avoid hypoglycaemia during and after a physical activity, patients should have knowledge of the typical metabolic and hormonal responses to the physical activity, as well as the skills necessary for self-control and prevention of adverse events. Patients should also take care of proper hydration both before and after physical exercise [14, 17, 18, 29, 43, 46, 47].

Type 1 diabetes should not be a contraindication to participation in physical education classes or in school sports. Diabetics should simply be aware of blood sugar levels at the beginning and during sports activities, and monitor levels and symptoms accordingly. Recommended blood sugar levels are as follows: for aerobic exercise 126-180 mg/dl (7-10 mmol/l); for anaerobic exercise 90-180 mg/dl (5-10 mmol/l) [43].

Current recommendations are that children should exercise for more than one hour a day to reduce the risk of vascular complications. The reduced risk is achieved as physical exercise induces an increase in adiponectin secretion, increases HDL levels and glucose uptake by muscle cells, and reduces the level of proinflammatory cytokines, including C-reactive protein and IL-6 [47]. To maximize the therapeutic effect, physical activity should be performed regularly, at least 2-3 times a week. The standard training session for a type 1 diabetic patient should consist of a warm-up (10 minutes) with low intensity aerobic exercises, a main part (10-15 minutes), and a cool-down (10 minutes) [14]. Moderate exercise in the range of 40-56% VO_2 max or 55-69% of maximum heart rate is recommended. The development of individual insulin therapy schemes is also important [47].

According to the guidelines (2019) of the American Diabetes Association and the Polish Diabetes Association, patients with type 1 diabetes can practice any sport following clinical examination, specifically after receiving a positive medical opinion from a diabetologist. However, particular caution should be exercised when choosing

disciplines such as paragliding, gliding, motor and car racing, scuba diving, horse racing, extreme mountain climbing, and parachute jumping due to the overall greater risks involved [48].

Undesirable consequences of exercise and contraindications to training

Contraindications to physical training in children with type 1 diabetes include hyperglycaemia (>250 mg/dl), hypoglycaemia (<70 mg/dl), acute complications such as ketoacidosis, lack of glycaemic control, and lack of medical consent [14].

The highest risk of hypoglycaemia occurs during prolonged moderate-intensity training or during high-intensity exercises [47, 49]. Fear of hypoglycaemia is a significant obstacle to physical activity in both children and adults with diabetes, and reduced blood glucose levels may occur during or after exercise. Late post-workout hypoglycaemia usually develops after 6-15 hours, but may appear the following day. The delayed hypoglycaemia is caused by a prolonged increase in insulin sensitivity of tissues and resynthesis of glycogen in the liver and muscles. In individuals who exercise, meal composition and inadequate insulin dosing are also important factors contributing to the development of hypoglycaemia. Major symptoms include fatigue, tachycardia, and increased sweating [47-49]. In contrast, high glucose levels, i.e. hyperglycaemia, can arise from anaerobic exercises and/or very intensive endurance training. The causes of hyperglycaemia include insufficient insulin dose, excessive carbohydrate intake, high stress level, and less physical activity than planned. Symptoms of hyperglycaemia include drowsiness, weakness, frequent urination, headaches and increased thirst [47-49]. People with uncontrolled diabetes, who tend to experience a greater influence of sympathetic nervous system activity, adrenaline and glucagon secretion with increased blood glucose levels, are particularly at risk of hyperglycaemia [47].

Conclusions

Diabetics face numerous daily challenges, including learning about the disease, developing self-control skills, and addressing emotional issues related to the disease and necessary lifestyle changes. The main task of healthcare professionals is to prepare patients for life with the disease and to prevent its secondary consequences [50]. Physioprophyllaxis in the form of physical activity not only has a positive impact on the physical health of patients, but also on their mental well-being and self-esteem, and thus, improves the quality of life. Exercise increases the chance of entering a period of partial remission of the disease, while also reducing the duration of episodes. Finally, regular physical activity reduces the risk of cardiovascular complications and related mortality.

The presented studies illustrate a positive influence of physical activity in diabetic patients. Specifically, regular physical activity increases measures of strength and efficiency in diabetic patients, reduces the need for insulin, and reduces the risk of cardiovascular diseases, which significantly improves the quality and lifespan of patients. Given the absence of consistent evidence regarding physical activity's effects on glycaemic control, there is a need to individually adjust the intensity and type of physical activity to the patient's abilities. Further research on the impact of physical activity on the overall health of patients with type 1 diabetes, especially children, is also necessary.

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