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Dietary treatment of type 1 diabetes – once upon a time versus today

Leczenie dietetyczne cukrzycy typu 1 – kiedyś a dziś

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Abstract
Type 1 diabetes is a disease in which nutrition is an integral part of treatment. The type of recommended diets for therapeutic purposes has changed over the years. Proper metabolic equalization of the disease is an enormous challenge and problem for patients at the same time. This review paper discusses the history of dietary treatment of type 1 diabetes and refers to current dietary recommendations and their impact on the patient's health. The important roles of glycaemic index and glycaemic load are pointed out for proper treatment and slowing of the development of complications. Attention is also paid to the role of dietary education as an integral part of therapeutic management. Continuous progress in the development of technology is of great help to the patient.
Key words: type 1 diabetes, children, diet, nutrition, history.

Streszczenie
Cukrzyca typu 1 jest chorobą, w której żywienie stanowi integralną część leczenia. Rodzaj rekomendowanych diet w celach terapeutycznych zmieniał się na przestrzeni lat. Prawidłowe wyrównanie metaboliczne choroby to dla pacjentów bardzo duże wyzwanie i jednocześnie problem. W niniejszej pracy przeglądowej omówiono historię leczenia dietetycznego cukrzycy typu 1, odniesiono się do aktualnych zaleceń dietetycznych i ich wpływu na zdrowie pacjenta. W trosce o prawidłowe leczenie oraz spowolnienie rozwoju powikłań wskazuje się na istotną rolę indeksu i ładunku glikemicznego. Zwrócono również uwagę na rolę edukacji dietetycznej jako nieodłącznego elementu postępowania terapeutycznego. Ciągły postęp w rozwoju technologii jest bardzo pomocny dla pacjenta.
Słowa kluczowe: cukrzyca typu 1, dzieci, dieta, żywienie, historia.

Introduction

Over the past decades, the incidence of type 1 diabetes mellitus (DMT1) has steadily increased worldwide [1]. An estimated 8.4 million people were living with DMT1 across the globe in 2021, and this number may rise to 17.4 million by 2040 according to “The Type 1 Diabetes Index” study [2]. Stress, genetics, or diet are examples of factors that can contribute to the development of diabetes. The detailed aetiology and pathogenesis of DMT1 is still not fully recognized.

The origins of diabetes

Diabetes is a disease that has been known of for at least 5000 years. An Egyptian papyrus from around 1550 BC, found by Georg Ebers, contains the oldest full description of DM1. It is believed to have been written by Imhotep – an architect, physician, and priest in the court of Pharaoh Zosser in 3000 BC. The most commonly cited characterization of diabetes comes from ancient times from “Acute and Chronic Diseases” by Areteus of Cappadocia in Asia Minor from around 150 AD. Areteus is considered the first physician to use the word “diabetes” meaning: “melting”, “leaking”, or “passing through”. These words reflect the typical clinical symptoms of diabetes: polyuria, increased thirst, and progressive weight loss [3].

History of dietary treatment

Dietary treatment is one of the main components of behavioural therapy (the influence of environment, stimuli, and experiences on a person’s behaviour, conduct, and thinking) in diabetes [4]. Over the years, the diet has changed. The initial low-carbohydrate diet was replaced by a high-carbohydrate one, and eventually by a diet without specific restrictions. Rapid advancement of diabetes therapeutics and technologies have enhanced diabetes monitoring and insulin delivery capabilities that permit more flexibility in the dietary regimen [5].

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Before the era of insulin therapy, the lack of proper treatment for DMT1 had forced people to control the disease by nutritional management. Two schools of nutritional treatment emerged. The first proclaimed that sugar lost through urine had to be replenished through the diet, while the other recommended limiting carbohydrates to reduce adverse effects due to excessive glucose. In 1675 the physician Willis, a promoter of the former school of thought, recommended a diet consisting of bread, milk, and a drink of boiled barley. The diet was rich in carbohydrates but provided little energy.

John Rollo, a Royal Artillery surgeon in the English Army, was a proponent of the latter school. In 1797, he initiated a long period of carbohydrate avoidance in the dietary treatment of diabetes. He advocated a high-fat, high-protein, and low-carbohydrate diet. It was based on animal products to the exclusion of all plant products. A typical morning meal consisted of blood and tallow served in the form of pudding. For lunch, venison or other old, rancid, fatty meats such as pork were served. Then, this diet was characterized by a low carbohydrate content, high fat content, and moderate protein content [6–8]. The reduction in carbohydrate leads to increased formation of ketone bodies (such as -hydroxybutyrate, acetoacetate, and acetone) in the body. Its main goal is to mimic the state of starvation, but without the negative consequences of starvation. It causes to a change in the body's preference for its main source of energy supply. In other diets the main source of energy is glucose, in which case the body's preference is changed, and then ketone bodies are used as an alternative source of energy. It puts the body into a metabolic state called nutritional ketosis. A beneficial effect of the ketogenic diet on the values of glycated haemoglobin, glucose, insulin, or other metabolic parameters in patients with diabetes is observed [9].

The 19th century is considered the period of dietary treatment. The credit goes to Rollo, who prepared the ground for the treatment of diabetes through dietary changes. Dietary recommendations evolved from a high-carbohydrate diet to a low-carbohydrate diet. The basic premise of the high-carbohydrate diet was to replenish large amounts of sugar lost through urine. Chevalier in 1829 and Priorry in 1857 suggested the use of sugar as a form of supplementation for diabetics. In turn, other researchers advocated carbohydrate supplementation using rice (Von During – During's diet) or potatoes (Dujardin, Beaumetz, or Mosse). Naunyn also counted himself among those promoting a diet rich in carbohydrates. He claimed that "fat burns in the fire of carbohydrates". By consuming the right amount of carbohydrates, the fat-burning process and the secretion of ketone bodies in the urine were supposed to occur properly [10].In addition to Rollo's recommendations for limiting carbohydrates and supplementing energy through the consumption of fish and meat, other dietary recommendations emerged. The aforementioned restrictions were repeatedly supported by other researchers in the late 19th century. L. Traube (1816–1876) believed that both the consumption and digestion of carbohydrates contribute to the complete removal of glucose from the urine. In the mid-19th century (1860–1870), Bouchardat modified Rollo's diet. He noted that the effect of limited access to food in Paris during the Franco-Prussian War (1870–1871) caused a significant decrease in urinary glucose excretion in diabetics. He recommended eating meat and fat products with the addition of green vegetables, which had to be cooked to remove starch. The addition of vegetables made that diet somewhat tastier and more acceptable. Milk was not advisable due to its high lactose content, while alcohol was considered a good source of calories. The diet had to be supplemented with gluten-containing bread. Bouchardat found that proteins also could cause glycosuria, and for this reason he advocated carbohydrate restriction and would frequently eliminate proteins in the diet. He advised diabetic patients to eat as little as possible, maintain a state of moderate malnutrition, and recommended intermittent fasting to control glucosuria [7].

Before insulin therapy was introduced, Elliott Proctor Joslin had treated DM1 by promoting a sizable reduction in sugar-containing foods (the tenets of low-carbohydrate diets recommended 70% of energy coming from fat, up to 10% from carbohydrates, and the rest from protein). That is how he treated his mother who had diabetes. He reduced the amount of carbohydrates until no sugar precipitated in the urine. Eventually the woman took in 40–75 grams of carbohydrates a day with her food. Italian physician Professor Arnoldo Cantini (1837–1893) implemented similar dietary recommendations. He recommended consumption of diluted alcohol, lean meat, and fats supplemented by days of starvation and exercise. He isolated patients to enforce compliance with his dietary recommendations [10, 11]. The above diets were expected to lead to a moderate state of malnutrition and produce similar effects to the use of the ketogenic diet. Subsequently, other dietary recommendations were introduced, including that of Arthur Scott Donkin, in 1871, who proposed a diet based on skimmed milk [12]. In 1902, Carl von Noorden introduced the oatmeal diet in the hope that diabetes can be cured by using oatmeal as a source of carbohydrate in the diet. The main premise of this diet was to limit the amount of protein, and it proposed a daily intake of about 230 grams of oatmeal mixed to a mush with an identical amount of butter, served every 2 hours [13].

Frederick Allen, historically known as a diabetes researcher physician, also advocated a low-energy diet, the so-called "therapeutic starvation diet". He proved that a sizable reduction in total energy requirements prolongs the life of animals with established diabetes. According to him, the recommendations could be applied to people with diabetes because diabetes was not an ordinary metabolic disturbance but a disorder caused by insufficient pancreatic activity. "Allen's diet" assumed energy coverage of only basic functions in the body, thus the amount of carbohydrates was minimal, i.e. 10 g/day [14]. The result of this diet was malnutrition, which, according to Allen, could illogically benefit the patient more than covering carbohydrate requirements. Allen's very strict and deficient diet contributed to the death of one of his diabetes patients, a 12-year-old boy. The immediate cause was starvation. The doctor was banned from doing any further research in this area [10].

It seems to be a good moment to observe that the presented concepts of diet in diabetes originated from observations that did not distinguish types of diabetes and arose without knowledge of insulin action or the effects of insulin treatment.

The next stage of working on the diabetic diet was more precise in its description, or even calculation, to consider the effects of both diet as well as insulin treatment.

Over the years, nutrient ratios have changed. In 1926, after the discovery of insulin, William Sansum recommended a higher amount of carbohydrates per day, up to 40% (about 250 g). In the mid-1930s, Izarel Rabinovich, a Canadian physician, in his diet containing more than 2000 kcal, recommended an intake of 50 g of fats, 400 g of carbohydrates, and 70 g of protein. Thus, carbohydrates accounted for nearly 70% of total energy content. The discovery of insulin significantly reduced dietary restrictions in diabetes and enabled diabetic patients to implement the principles of the so-called "healthy diet". In 1929, Karl Stolte pointed out that the use of an appropriate insulin therapy regimen could reduce the obligation of children diagnosed with DMT1 to follow onerous dietary recommendations. He promoted taking a few general rules, without specific restrictions, regarding the type and amount of food consumed, with the only condition being the application of an adequate dose of insulin. As a result, patients' quality of life, nutritional status, and overall immunity improved. The number of hypoglycaemia cases was also successfully reduced [15]. In 1983, Michael Berger adopted an identical approach [16].

Carbohydrate exchangers

Several hundred years of observations have proven that in people with DM1, the amount of carbohydrates included in a meal plays a very important role and affects postprandial glycaemia. Young people with DM1 usually have an active lifestyle, so acquiescence to a more flexible diet obliges variable doses of insulin.

In the 1990s, a German nutritionist introduced a bread unit (or carbohydrate unit) to estimate the carbohydrate content of a particular food product. One bread unit corresponds to a quantity of food containing 12–15 g of digestible blood-sugar-effective carbohydrates present in different forms of sugar or starch. In Central Europe, bread was consumed by most people for breakfast, lunch, or dinner. For this reason, through the use of bread units, it was easy for the patient to visualize the amount of food he or she could consume and how it would affect blood glucose levels [17]. However, with the further development of science, this method was abandoned because it was not precise enough.

The mid-20th century is considered the beginning of intensive insulin therapy. At that time, Karl Stolte, a paediatrician, taught his patients about monitoring urine glucose levels before each main meal, the amount of carbohydrates they should consume, and how to regulate insulin doses conditional on the result [18].

At the beginning of the 1980s, Jean-Phillippe Assal of Geneva and Michael Berger of Dusseldorf developed a 5-day training regimen for people with DM1, aiming to involve them in therapy themselves [18, 19]. At the same time, Kinga Howorka created the NIS (near-normoglycaemic insulin substitution) program, which became the basis for functional intensive insulin therapy. This method relied on counting carbohydrate exchangers as the fundamental unit needed to calculate the post-dose of insulin [19]. It made it possible to match the appropriate insulin dose to the meal consumed, the exercise undertaken, and the individual's needs. In determining the meal insulin dose, the amount of carbohydrates (g) contained in the planned meal plays a fundamental role, as well as the insulin sensitivity index, adjusted by a correction dose that depends on the level of glucose before the meal. In Poland, the carbohydrate exchange (CE, wymiennik węglowodanowy, carbohydrate exchange) determine the amount of carbohydrates consumed, where 1 CE is 10 g of assimilable carbohydrates, in the United States 1 CS (carbohydrate serving) is 15 g of carbohydrates, in German-speaking countries 1 KE (Kohlenhydrateinheit) is 12 g of carbohydrates, and in the United Kingdom 1 CP (carbohydrate portion) is 10 g of carbohydrates [20, 21]. Nowadays, according to the trend proposed by manufacturers of modern technology, carbohydrates are counted in grams only. After prior education, the patient can independently adjust the dose of insulin according to their individual response to the number of carbohydrate exchangers taken. This type of therapy is considered safe for maintaining proper energy balance and avoiding both hyperglycaemia and hypoglycaemia, with a beneficial effect on controlling body mass index (BMI), waist circumference, and significantly improving the comfort of life [22].

Glycaemic index and glycaemic load

Insulin output is associated not only with the amount of carbohydrates consumed but also with the quality of the carbohydrates. The concept of the glycaemic index (GI) was implemented in the 1980s. It shows the differences in postprandial glycaemia after taking the same amount of carbohydrates contained in a variety of products with divergent properties [23, 24]. The term glycaemic index is defined as the percentage increase in blood glucose concentration after ingestion of a product containing 50 g of assimilable carbohydrates compared to the standard glycaemia after ingestion of 50 g of pure glucose (a value of 100%). Tables with GI of carbohydrate products are available for patients. They allow them to choose products after consumption of which both the increase in glycaemia and the need for insulin will decrease [25, 26]. The glycaemic load (GL), on the other hand, is defined as the product of the GI and the amount of carbohydrate consumed divided by 100. Following a diet with a low GI and GL contributes to a slow, uniform distribution of glucose absorption over time and thus reduces the risk of postprandial hyperglycaemia [27].

Modern diet

The cornerstones of DMT1 treatment are self-monitoring of blood glucose levels, insulin, and adequate nutrition [28–30]. Nowadays, dietary recommendations for adolescents with DMT1 are based on healthy eating principles to ensure adequate growth, development, improved glycaemic control, and prevention of acute and chronic complications [28]. The daily diet of adolescents with DMT1 should meet the criteria of current guidelines (Table I) [28]. Analysis of the diet of children and adolescents with DMT1 now includes not only the amount of carbohydrates but also the amount of protein and fat. Macronutrients, such as fat and protein, are often overlooked in the standard carbohydrate-focused method used for prandial insulin dosing. However, both have been shown to cause delayed postprandial hyperglycaemia. High-fat meals delay gastric emptying, and circulating free fatty acids impair insulin sensitivity and promote hepatic gluconeogenesis. Dietary proteins increase glucagon concentrations and gluconeogenesis from amino acids [31, 32].

Several methods have been established to incorporate those meal components into insulin dose calculations; for example, Pańkowska *et al.* introduced a system of protein and fat exchanges (PFE) that estimate insulin requirements based on ingested fat and protein. An PFE is defined as 100 kilocalories ingested from fat or protein, and it is thought to roughly approximate an insulin requirement equivalent to that of 10 g of ingested carbohydrate [33].

Diet in DMT1 should be properly balanced, containing adequate amounts of both macronutrients and micronutrients. The Mediterranean diet, rich vegetables, fruits, whole grains, and unsaturated fatty acids, is a good example of diet meeting those criteria. Many studies have demonstrated that such a diet is associated with an improved lipid profile in the general population. Similarly, implementing the Mediterranean diet in children with DMT1 has caused reduction in the ratio of low-density lipoprotein cholesterol, non-high-density lipoprotein (non-HDL) cholesterol, and total cholesterol to HDL cholesterol [34, 35].

Despite diabetes education some patients have difficulties following the given recommendations on diet. For example, Mayer-Davis *et al.* showed that only 6.5% of patients met the American Diabetes Association and International Society of Paediatric and Adolescent Diabetes (ISPAD) recommendations of < 10% energy intake from saturated fat. Less than 50% of subjects met their daily requirements for fat, vitamin E, fibre, fruit, vegetables, and whole-grain products [36].

Non-nutritive sweeteners (NNS) have been used since the 19th century as a substitute for nutritional sweeteners in DM1 to keep both carbohydrate and energy intake under control [37]. Non-nutritive sweeteners, due to their negligible amount of energy and induction of a sweet taste without affecting glycaemia or insulinaemia, are considered safe within the limits of the US Drug and Food Administration's (FDA) acceptable daily intake (ADI) (Table II) [28]. However, the patients should still be wary of possible side effects.

Nutrition education

For years nutrition education has been an indispensable part of diabetes therapy throughout the world [38]. It should be conducted by professional dietitians who have experience in diabetes and (in the case of children and adolescents) additionally in paediatrics. Meal planning requires an individual approach to each patient, taking into account their dietary, occupational, family, or cultural preferences. Proper training of both the patient and their relatives allows them to understand the relationship between the consumed meals and blood glucose levels. Typically, patients learn the rules in theory and then have to apply them in everyday life, where they encounter numerous difficulties.

The child as a paediatric patient presents a challenge for doctors, dietitians, and educators. As the child grows, everything changes: the body matures, and every change must be taken into account in the management. Diabetes technology when coupled with nutrition education can improve the lives and health of children with DMT1. A continuous glycaemic monitoring (CGM) system can be helpful in controlling the effectiveness of a patient's diet by making changes based on real-time glucose control. Moreover, CGM is a useful tool for educating people with diabetes on food-related behaviours and the impact of

Table I. Nutritional recommendations for children and adolescents with DMT1 from the International Society of Paediatric and Adolescent Diabetes [27]

Recommendation for type 1 diabetes	
Carbohydrate	40–50% TE
Protein	15–20% TE
Fat	30–40% TE
Saturated fat + trans fatty acids	< 10% TE
Moderate sucrose intake	Up to 10% TE As recommendation for general population
Sodium	As recommendation for general population

%TE – percentage of total energy

Table II. Acceptable daily intake of non-nutritive sweeteners [28]

Non-nutritive sweetener	Acceptable daily intake (ADI)*
Sucralose	0–15 mg/kg body weight
Saccharin	0–5 mg/kg body weight
Acesulfame K	0–15 mg/kg body weight
Aspartame	0–40 mg/kg body weight

*https://apps.who.int/food-additives-contaminants-jecfadatabase/

specific meals on glucose levels. Also, continuous subcutaneous insulin infusion (CSII) and recently introduced automated insulin delivery (AID) systems give the ability to tailor prandial insulin delivery to the meal composition. This enables the meal bolus to match the glycaemic effect of the meal (low GI, high fat, or high protein content). These systems could lead to alleviation or simplification of CHO counting; however, this benefit should not be detrimental to overall glucose control. The optimal meal strategy for insulin boluses is yet to be determined, and several challenges still need to be tackled. However, such solutions would be helpful for both the patient and the dietitian [39].

Summary

Dietary management has been a key point of DM1 management for over 3000 years, and the discovery of insulin has been a real breakthrough in diabetes treatment, as well as the introduction of formal dietary education. Recent nutrition recommendations for children and adolescents with DMT1 are in line with those for the general population. Individualized meal plans should emphasize a wide variety of healthy food choices to meet the recommended nutrient intakes for essential vitamins and minerals, energy, and fibre and to provide for normal growth and development. Current diabetes technologies, such as new insulin analogues, continuous glucose monitoring systems, continuous subcutaneous insulin infusion, as well as automated insulin delivery systems that integrate readings from monitoring systems and insulin pump technology with mathematical algorithms that automatically adjust insulin delivery, help in improving glycaemic outcomes and following eating guidelines. However, carbohydrate counting remains a key strategy in dietary management.

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