LITERATURE REVIEW Open Access

Manfaat Carbohydrate Counting pada Diabetes Melitus Tipe 1: Scoping Review

The Benefits of Carbohydrate Counting in Type 1 Diabetes Mellitus : A Scoping Review

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ABSTRAK

Latar Belakang*: Asupan karbohidrat merupakan penentu utama kestabilan kadar glukosa pasien dengan DM tipe 1. Carbohydrate counting sebagai teknik pengaturan diet pasien dengan DM tipe 1 diketahui memiliki fleksibilitas dalam kontrol glukosa darah melalui pengaturan jumlah asupan karbohidrat dan dosis insulin, namun tetap dibutuhkan pemahaman yang baik terkait praktik carbohydrate counting agar tercapai target kontrol glukosa darah.*
Tujuan*: Artikel ini bertujuan mereview hasil penelitian sebelumnya terkait manfaat terhadap kontrol metabolik dan ukuran tubuh, serta bagaimana praktik pemberian edukasi terkait carbohydrate counting pada pasien Diabetes Melitus tipe 1.*
Diskusi: *Carbohydrate counting memberikan dampak terhadap HbA1c, indeks massa tubuh, lingkar pinggang, kualitas hidup, dan kepuasan terhadap terapi yang diterima pada pasien Diabetes Melitus tipe 1. Pengaruh carbohydrate counting bergantung pada usia, pengaturan makanan yang dilakukan, kemampuan menghitung kebutuhan ideal insulin, pemberian edukasi dan kesiapan pasien dalam melakukan carbohydrate counting, dukungan keluarga serta intervensi tambahan yang diberikan untuk mendukung perbaikan kontrol metabolik. Penggunaan Automated Bolus Calculator (ABC) bersamaan dengan carbohydrate counting dan Food Insulin Index (FII) diperkirakan mampu mendukung efektivitas terapi Diabetes Melitus tipe 1.*
Kesimpulan: *Carbohydrate counting dapat meningkatkan kontrol metabolik pasien Diabetes Melitus tipe 1 pada anak-anak, remaja maupun dewasa dan dapat memfasilitasi penurunan berat badan. Dibutuhkan penekanan edukasi berkelanjutan oleh registered dietisien menggunakan media dalam menentukan jumlah porsi, dosis insulin dan melibatkan orang tua untuk meningkatkan akurasi carbohydrate counting pada anak dan remaja. Kombinasi penggunaan Automated Bolus Calculator (ABC) dan Flexible Intensive Insulin Therapy (FIIT) dapat meningkatkan efektivitas penerapan carbohydrate counting pada terapi DM tipe 1.*

Kata kunci: *Carbohydrate Counting, DM Tipe 1, Kontrol Metabolik, Antropometri, Edukasi*

ABSTRACT

Backgrounds: Carbohydrate intake is a major determinant of blood glucose stability in patients with type 1 diabetes. Carbohydrate counting as a meal planning approach for patients with type 1 diabetes is known to have flexibility in controlling blood glucose by regulating the amount of carbohydrate intake and insulin dose, yet a good understanding about carbohydrate counting practices is still needed in order to achieve blood glucose control targeted blood glucose control.
Objectives: this article aimed to review the result of previous studies relating to effect, impact and benefits in metabolic control, anthropometry, also impact and practices of education relating to carbohydrate counting in type 1 diabetes.
Discussion: Carbohydrate counting has an impact on HbA1c, body mass index, waist circumference, diabetes-related quality of life and type 1 diabetes therapy satisfaction. Effects of carbohydrate counting depends on age, diet management, ability to calculate ideal insulin requirements, provided education, patient readiness to apply carbohydrate counting, family support, and additional interventions provided to support improved metabolic control. The use of Automated Bolus Calculator (ABC) with carbohydrate counting and FIIT simultaneously was thought to be able to support the effectiveness of type 1 diabetes mellitus therapy.
Conclusions: Carbohydrate counting can improve metabolic control in children, adolescents and adults with type 1 diabetes. It is necessary to emphasize continuous education by registered dietitian using media in estimating the portion of food and insulin doses, also involving parents to improve the accuracy of carbohydrate counting in children and adolescents. The combination of Automated Bolus Calculator (ABC) and Flexible Intensive Insulin Therapy (FIIT) is known to increase carbohydrate counting effectiveness in type 1 DM therapy.

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Keywords: Carbohydrate Counting, Type 1 Diabetes Mellitus, Metabolic Control, Anthropometry, Education

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INTRODUCTION

Diabetes Mellitus (DM) is a chronic disease whose prevalence continues to increase globally. In 2017, the number of people with type 1 DM in children and adolescents in the world reached more than one million sufferers and annually reached 132,600 people[1]. The registered data for type 1 DM cases in children in Indonesia based on the Central Board of the Indonesian Pediatrician Association (PP IDAI) until 2014 showed the number of 1021 cases. The incidence of type 1 diabetes in children has two peaks of incidence, namely at the age of 5 to 6 years and also at 11 years[2]. Diabetes Mellitus is characterized by high blood glucose levels which are the result of impaired insulin secretion, impaired insulin action, or a combination of both[3]. Type 1 Diabetes Mellitusmany occurs in children, adolescents and adults[4].

An important condition for type 1 DM patients is that they must get insulin immediately when insulin reserves are depleted, if they do not get insulin immediately, the patient can experience a state of ketoacidosis with all the consequences. So that type 1 DM patients are very dependent on insulin for their survival. The insulin commonly used for children and adolescents is basal-bolus insulin with a basal component ranging from 40 to 60% of the total insulin requirement, and a bolus component injected 20-30 minutes before meals if using regular insulin, or immediately after or before meals if using fast-acting insulin[2].Despite many recent advances in pharmacology for DM patients, the provision of medical nutrition therapy that is appropriate to the patient's medical condition still remains an important intervention to achieve optimal blood glucose monitoring[4,5]. The management of type 1 DM consists of 5 pillars that must be integrated, namely proper insulin administration, diet management, physical activity, education, and supported by independent monitoring[6]. In an effort to achieve good metabolic control, the management of type 1 diabetes should be carried out in an integrated manner by a team consisting of endocrinologists, dietitians or nutritionists, psychologists, and educators[2,7].

Diabetes cannot be cured but can be controlled in order to prevent complications of diabetes that occur[1]. Dietary regulation, especially monitoring of carbohydrate intake, is the main determinant of post-meal blood glucose in type 1 DM patients[2]. Carbohydrate counting is one of the techniques in diet management that can provide flexibility in choosing food and can help patients to identify blood glucose patterns.[2]. The stages in simple carbohydrate counting suggested by dietitians or nutritionists include: 1. Determining or choosing healthy foods with various types of vegetables, limiting fat and paying attention to food portion sizes, 2. Focusing on the number of servings of carbohydrates from the food consumed, 3. Determine the target number of carbohydrates in grams to be consumed by monitoring and consulting with a dietitian or nutritionist, 4. Recording portion sizes of food and drinks consumed throughout the day, 5. Monitoring blood glucose levels regularly and periodically[3]. However, this method really requires great adherence to food regulation of the large variety of foods, so that it can determine the amount of carbohydrates in food in order to maintain blood glucose monitoring.[2].

Carbohydrate counting has become popular in the last two decades and has begun to be widely applied by the public[4,2]. Further dissemination of information related to carbohydrate counting needs to be given to patients with type 1 diabetes so that patients can manage food intake in relation to the insulin dose given. This strategy while scientifically proven to be an effective strategy in reducing HbA1c . levels[5]. However, there are still not many reports of literature studies related to carbohydrate counting as a single intervention or in conjunction with other blood glucose regulation interventions in type 1 DM patients.benefits on metabolic control, anthropometric measures, educational and practice outcomes in type 1 DM patients undergoing carbohydrate counting with or without other adjuvant therapy. Type 1 DM patients include children, adolescents, and adults.

METHODS

Scoping review It was developed based on the methodological framework proposed by Arksey and O'Malley regarding scoping review[6,7] to align and define research objectives and questions[8]. Researchers used the PICOS approach (Population, Intervention, Comparison, Outcome, Study Design) in compiling questions as a reference to identify key concepts that match the objectives and review questions and determine inclusion and exclusion criteria. Inclusion criteria in this scoping review include: (1) study population in patients with type 1 DM; (2) research reports on carbohydrate counting; (3) provide information on the comparison of carbohydrate counting with other interventions; (4) providing output information in the form of metabolic control, anthropometry, educational outcomes and carbohydrate

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counting practices; (5) study design in the form of RCT; (6) published in the last 10 years. While the research exclusion criteria if: (1) cannot be accessed in full text;

Researchers identified several relevant studies using the Pubmed database related to carbohydrate counting and type 1 diabetes mellitus. used to obtain the literature to be studied. Literature search on the latest research in the last ten years, namely in the period 2011 to 2020. The first keyword or keyword used in the search was "Type 1 Diabetes AND Carbohydrate counting" and the second keyword was "Type 1 Diabetes Mellitus AND Carbohydrate counting". In the search for articles using both keywords, 690 articles were identified. After filtering by year, full text availability, and study design found 51 articles. Further screening based on the title and abstract obtained 16 articles and after the researcher conducted a review using the inclusion criteria, 9 articles were obtained for the final review. An explanation related to the literature search flow can be explained in Figure 1.

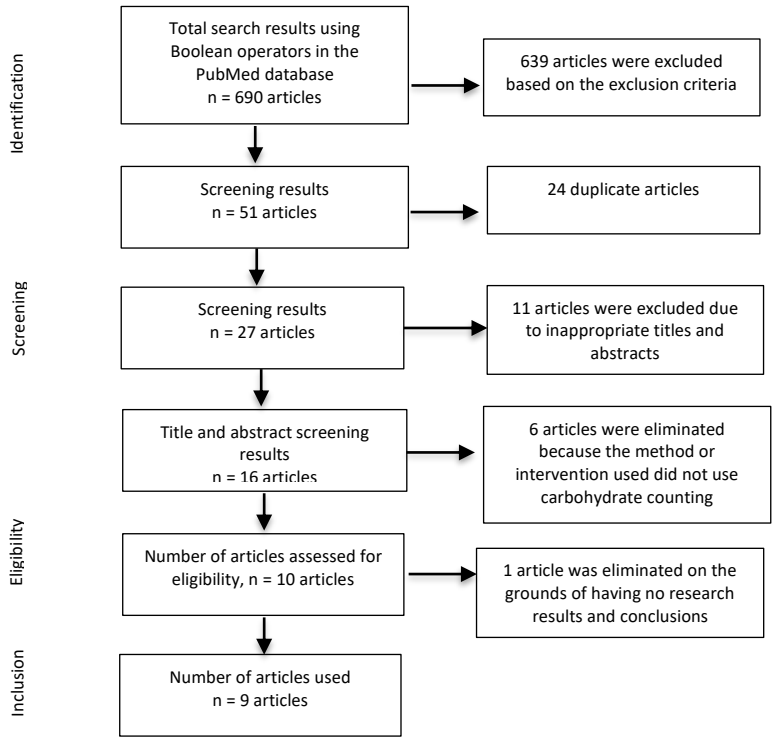

Figure 1. Search Method based on PRISMA Flowchart

DISCUSSIONS

Table 1 presents information related to the characteristics of the articles used in this literature study. Seven of the nine articles used adult type 1 DM patients with an age range of 21-61 years, one article used adolescent patients (12-18 years) and one article used pediatric and adolescent patients (17 ± 5 years). The research in this review article was conducted in several countries such as New Zealand, Turkey, Italy, the Netherlands, Switzerland, Australia, Colorado and Denmark. Most of the intervention activities were in the form of carbohydrate counting education sessions by dietitians, diabetes nurses or other diabetes educators with a duration of 30-90 minutes per session. Based on the inclusion criteria that have been set, the study design in the article used RCTs that were carried out with varying durations of time, from 1 to 96 weeks.

This article not only discusses the education provided regarding the necessary understanding of carbohydrate counting, but also discusses the calculation, application and benefits provided by carbohydrate counting. The data extracted from this scoping review article was organized into several themes, including: carbohydrate counting calculations, carbohydrate counting and specific diet settings, carbohydrate counting and metabolic control, carbohydrate counting and anthropometry, carbohydrate counting education, carbohydrate counting practices in children and adolescents , comparison of carbohydrate counting with other DM therapies.

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Table 1. Table of Article Characteristics in Scoping Review

No	Author, Year	Outside	Subject	Study Design	Intervention Form	Conclusion
1	Krebs, JD et al, 2016	HbA1c, continuous monitoring of glucose, body weight, blood pressure, food diary, daily total insulin, DM-related quality of life	10 adults (45 ± 10 years) with type 1 DM taking MDI	Parallel design RCT, 12 Weeks	Education class by dietitian and diabetes nurse on carbohydrate counting 1-1.5 hours per session weekly for 4 weeks, evaluation after 12 weeks	Provides the effect of reducing daily insulin requirements and improving glycemic control
2	Gökşen D. et al, 2014	Demographic characteristics, BMI, insulin requirement, HbA1c, total cholesterol, HDL, LDL, TG	32 children and adolescents (17 ± 5 years) with type 1 DM	Parallel design RCT, 96 Weeks	Training by trained dietitians, nurses and diabetologists on carbohydrate counting for two weeks, evaluation through visits at 12-week intervals	Provides the effect of increasing HDL levels and improving glycemic control without increasing body weight and insulin requirements
3	Laurenzi A. et al, 2011	Changes in HbA1c, diabetes-related quality of life, BMI, waist circumference, incidence of hypoglycemia, blood pressure, TDD, and fasting blood glucose	61 adult patients (40 ± 10 years) with type 1 DM and taking CSII > 3 months	Parallel design RCT, 24 Weeks	Training by dietitian and diabetologist 4-5 sessions per individual on carbohydrate counting and bolus calculations for the first 12 weeks	Has an impact on improving the quality of life related to diabetes, decreasing BMI and waist circumference, significantly decreasing HbA1c without increasing the incidence of hypoglycemia, improving metabolic control
4	van Meijel, et al, 2018	Changes in glucose variability, HbA1c, low blood glucose index (LBGI), high blood glucose index (HBGI), hypoglycemia, diabetes-related quality of life	32 adult patients (45 ± 15 years) with type 1 diabetes who underwent CSII	Parallel design RCT, 16 Weeks	Advising by a dietitian on carbohydrate counting and insulin bolus calculations, consultation sessions with diabetes coaches to receive information regarding the use of bolus calculators	Provides the impact of increasing blood glucose variations. Automatic bolus calculation was more suitable to be given as an individual treatment strategy with sufficient motivation
5	Campbell MD et al, 2017	HbA1c, triglycerides, plasma glucagon, TNF-, plasma fibrinogen	10 adult patients (26 ± 4 years) with type 1 DM over five years and familiar with carbohydrate counting and use of ICR	Parallel design RCT, 21 weeks	Three laboratory-based visits with a difference of 7 days, giving food with the same carbohydrate and protein content but different fat and insulin depending on each individual's carbohydrate counting calculation	The addition of an insulin bolus 3 hours after eating a high-KH and high-fat diet can prevent a delayed increase in postprandial triglycerides and TNF-, thereby improving the cardiovascular risk profile.

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No.	Author, Year	Outside	Subject	Study Design	Intervention Form	Conclusion
6	Hegar K et al, 2011	HbA1c, blood glucose, BMI, frequency of hypoglycemia, quality of consultation with dietitians, diabetes-related quality of life	134 adult patients (40 ± 15 years) with type 1 diabetes who had received basal-bolus insulin therapy and had the ability to calculate carbohydrate counting	Parallel design RCT, 9 weeks	Three 1-hour visits with three-week intervals related to the use of the Nutri-Learn Buffet (NLB)	Nutri-Learn Buffet (new tool) has the effect of increasing metabolic control, can improve the teaching and learning process about carbohydrate counting, make it easier for nutritionists to assess patients' carbohydrate counting skills, so this tool was suggested to be useful in nutritional counseling of patients with diabetes mellitus including carbohydrate counting
7	Bao J et al, 2011	Fasting blood glucose, blood glucose before meals, blood glucose after meals, blood glucose monitoring results during the observation period	28 adult patients (21-62 years) with type 1 diabetes on insulin pump therapy and already undergoing self-monitoring of blood glucose and ICR calculations	Parallel design RCT, 1 week	Discussion session about personal needs and carbohydrate counting skills + three food consumption test sessions with diet settings and food portion counting tools	Physiologically insulin-based insulin algorithms can be useful for estimating mealtime insulin doses in type 1 DM patients and replace carbohydrate counting if patients have basic knowledge of insulin and carbohydrate calculations in food.
8	Schmidt S et al, 2012	Changes in HbA1c, treatment satisfaction and frequency of occurrence of hyper and hypoglycemia, quality of life regarding diabetes, changes in TDD, and changes in body weight	51 adult patients (42 ± 10 years) with type 1 DM on long-acting and rapid-acting insulin injection therapy	Three-group parallel design RCT, 16 weeks	Three hour group structured teaching session by diabetes nurse and registered dietitian on diabetes and carbohydrate counting	FIIT and carbing can be successfully taught for 3 hours to research subjects and can improve metabolic control and treatment satisfaction. Concurrent use of ABC can increase satisfaction further.
9	Spiegel, G et al. (2012)	Applicability accuracy (duration, kin support, and carbohydrate counting pattern), HbA1c, BMI	66 adolescent patients (12-18 years) with type 1 . DM	Parallel design RCT, 16 weeks	90-minute educational class session with registered dietitian and diabetes educator on carbohydrate counting and two three-day sets of food recordings	Increasing the accuracy of adolescent DM patients in performing carbohydrate counting was difficult to achieve with just one session and two sets of filling food records, other approaches and developments need to be done

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Information :
BMI : Body Mass Index
MDI: Multiple Daily Injection (Using daily insulin injections)
RCT : *Randomized Controlled Trial*
HDL : *High Density Lipoprotein* (HDL Cholesterol)
LDL: Low Density Lipoprotein (LDL cholesterol)
TG: Triglycerides (Cholesterol Triglycerides)
TDD : *Total Daily Dose* (Total daily dose)
LBGI: Low Blood Glucose Index (Low Blood Glucose Index)
HBGI : High Blood Glucose Index (High Blood Glucose Index)
CSII : Continuous Subcutaneous Insulin Infusion (Using continuous insulin)
ICR: Insulin Carbohydrate Ratio (ratio of the amount of insulin to carbohydrates)
ISF: Insulin Sensitivity Factor (a correction factor for lowering blood glucose that can be reduced by 1 unit of insulin)

Carbohydrate counting

Carbohydrate counting was not a dietary regulation but rather a method that emphasizes metabolic control based on the use of multiple doses of insulin depending on the intake of carbohydrates in the diet[9]. Carbohydrates have the greatest effect on blood glucose levels after meals compared to fat and protein, so carbohydrate counting has become a mainstay in the management and education of DM patients.[16.17]. Basic carbohydrate counting was used to keep blood glucose levels consistent based on a structured approach that emphasizes time consistency with the amount of carbohydrates consumed. The calculation was based on the principle that 15 grams of carbohydrates was equal to one serving or one serving of carbohydrates. Advanced carbohydrate counting, also known as advanced carbohydrate counting, was used to help calculate insulin doses using calculations*Insulin Carbohydrate Ratio* (ICR) and Insulin Sensitivity Factor (ISF)[11]. There were several formulas or calculation of insulin dose requirements using ICR and ISF which depend on various conditions of application of carbohydrate counting.

Calculation of the ideal insulin requirement based on measurement of blood glucose before and after meals and at night[2,12,13]. Determination was calculated individually on target blood glucose, ICR and ISF[14]. ICR or insulin-carbohydrate ratio was calculated with a coefficient of 500[2,11,14,15] divided by the total daily dose (TDD) or the total daily amount of insulin, while the ISF or insulin sensitivity factor with a coefficient of 1800[2,4,15]also divided by the total daily amount of insulin. These calculations were performed in patients with normal or near normal blood glucose. In patients receiving carbohydrate counting education with bolus calculator calculations, ICR and ISF calculations based on total daily insulin doses and their ratios were programmed into the bolus calculator. The calculation uses the same ICR calculation as before but ISF with a coefficient of 100 divided by the total daily amount of insulin[14]. Based on the results of previous studies, the ISF calculation coefficient can also be based on the type of insulin used by the patient, a summary of the calculation was listed in table 2.

Table 2. Table of Calculation of Insulin-Carbohydrate Ratio (ICR) and Insulin Sensitivity Factor (ISF)

No.	Information	ICR/ISF	Calculations Used	Reference
1	Based on blood glucose that reaches normal or near normal	ICR	Rule 500, ie by calculating 500 divided by TDD (500 : TDD) . So the ICR can be used to determine the number of grams of carbohydrates that can be neutralized by 1 unit of fast-acting or short-acting insulin	2,11,14,15
2	Based on the type of insulin used	ISF	Rule 1800 or 1500, namely by calculating the correction factor using 1800 or 1500 divided by TDD (1800 : TDD or 1500 : TDD). Correction of hyperglycemia with regulation 1800 for fast-acting insulin, regulation 1500 for short-acting insulin. So that ISF can be used to determine the amount of blood glucose in mg/dL that can be lowered by 1 unit of insulin	12,2,4,15
3	Based on the education of carbohydrate counting + bolus calculator calculation	ISF	Rule 100, correction factor used 100 : TDD	14

Patients can estimate the insulin dose before meals by considering blood glucose before meals and the planned amount of carbohydrates to be consumed by combining ICR and ISF[4]. The insulin-to-carbohydrate ratio shows how much insulin was needed to "cover" the amount of carbohydrates you have consumed and restore

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blood glucose levels to their pre-meal target. The ratio was calculated based on individual daily recorded data by dividing the total carbohydrate in grams in one meal by the number of units of short-acting insulin capable of holding post-meal blood glucose within 28.8 mg/dL. While the insulin sensitivity factor adjusts the decrease in blood glucose obtained by one unit of short-acting or fast-acting insulin[4].

Carbohydrate Counting and Certain Dietary Settings

Carbohydrate restriction in type 1 DM patients who apply carbohydrate counting can reduce body weight in patients. They lost an average of 5 kg over 12 weeks and an average BMI of 27 - 25 kg/m2. This decrease was likely due to a reduction in energy. The recommended glucose requirement for a low-glucose diet in Nielsen et al's study was 50-75 grams23, while in Krebs et al's carbohydrate restriction, the glucose requirement used was 100 grams/day21. Based on statistical calculations, carbohydrate restriction can also help patients reduce their total daily insulin requirements significantly. However, the insulin requirement for postprandial blood glucose control required in the pre-study did not match the estimated targeted carbohydrate intake, i.e. 1 unit of insulin for 15 grams of glucose. So that initially the patient was expected to only need 2 units of insulin for 30 grams of glucose in one meal, to 10 units of insulin to arrive at the targeted postprandial blood glucose level. This happens because there was a tendency for some patients to fail to estimate carbohydrates in one meal. Errors in estimating carbohydrates can occur in adults about 15.4 ± 7.8 grams per meal. These errors generally occur in foods that have a variety of food groups in one food serving. Mentioned that the patient found it difficult to follow the advice of a low-carb diet and estimate the daily carbohydrate intake. Even if the desired amount was not achieved, 100 grams per day can still be considered a low-carb diet. Dietary regulation with carbohydrate restriction also reduces HbA1C levels, but can increase the risk of hypoglycemia because patients may have difficulty estimating the amount of carbohydrate intake in their food so that the calculation becomes inaccurate. In other literature it was mentioned that carbohydrate restriction can increase LDL-cholesterol levels in the blood. In addition, carbohydrate restriction did not show any change in quality of life, had side effects of being irritable and easy to experience pain and difficulty regulating insulin requirements, but it can increase the risk of hypoglycaemia because patients may have difficulty estimating the amount of carbohydrate intake in their food so that the calculation becomes inaccurate. In other literature it was mentioned that carbohydrate restriction can increase LDL-cholesterol levels in the blood. In addition, carbohydrate restriction did not show any change in quality of life, had side effects of being irritable and easy to experience pain and difficulty regulating insulin requirement, but it can increase the risk of hypoglycaemia because patients may have difficulty estimating the amount of carbohydrate intake in their food so that the calculation becomes inaccurate. In other literature it was mentioned that carbohydrate restriction can increase LDL-cholesterol levels in the blood. In addition, carbohydrate restriction did not show any change in quality of life, had side effects of being irritable and easy to experience pain and difficulty regulating insulin requirements.

Carbohydrate restriction was very beneficial for weight loss and was appropriate for people with type 1 diabetes when combined with the use of insulin that follows the recommendations and carbohydrate counting. In addition, carbohydrate restriction can be an option to reduce daily insulin requirements, but further research was needed to determine whether there were non-glucose factors that confound insulin estimates for carbohydrates when carbohydrate intake was low. This allows for a reduced total daily insulin requirement and was associated with improved glycemic control.

Carbohydrate Counting and Metabolic Control

Research by Goksen et al9 showed that carbohydrate counting has a positive effect on metabolic control in children and adolescents by increasing HDL levels, which can reduce the risk of heart disease. The results also showed that HbA1c levels decreased more sharply in the carbohydrate counting group, although there was no statistically significant difference in the mean HbA1c levels between the control group and the carbohydrate counting group. use of insulin between meals. In another study showed that there was a significant decrease in HbA1c levels in both the exchange meal plan and carbohydrate counting groups given insulin glargine,

The addition of fat to carbohydrate-based foods has been shown to cause postprandial hyperglycemia and increase insulin requirements in the postprandial end. This is because people with type 1 diabetes were often reluctant to give additional insulin bolus injections between main meals or at the end of the prandial period for fear of experiencing hypoglycemia due to increased injection frequency. Based on the results of research by Campbell et al[5], when consuming foods that were high in carbohydrates and high in fat, type 1 diabetes mellitus needs to be given an additional dose of insulin given 3 hours after eating because it can reduce the concentration of triglycerides and Tumor Necrosis Factor Alpha (TNF-α), which is a marker of inflammation in the blood. TNF- was one of the first cytokines to be identified and is involved in the systemic inflammatory response which is also frequently associated with the development of insulin resistance, obesity and diabetes. TNF- is produced by monocytes, lymphocytes, adipose tissue and muscle and plays a role in the pathogenesis of the obesity-associated metabolic syndrome. In the case of insulin resistance, TNF- increases the release of free fatty acids in adipose tissue blocks the synthesis of adiponectin which has insulin-sensitizing activity in high concentrations in adipose tissue and interferes with the phosphorylation activity of tyrosine residues in the first substrate of the insulin receptor, which was required for the development of intracellular hormone signaling. TNF-α activates NF-B

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(Nuclear Factor Kappa B), resulting in increased expression of adhesion molecules on the surface of endothelial cells and vascular smooth muscle cells, resulting in inflammation in adipose tissue, endothelial dysfunction and ultimately atherogenesis.[17]. Patients with type 1 diabetes were also required to understand the importance of calculating the carbohydrates contained in food and giving additional insulin units three hours after eating when consuming high-carbohydrate foods and to know the importance of using long-acting insulin from the start of eating which was not only beneficial for controlling blood glucose, but also for controlling blood glucose levels. normalize other markers that affect vascular health[5].

Carbohydrate Counting and Anthropometry

Studies with children and adolescents with type 1 diabetes to see the effect of carbohydrate counting on anthropometric measures can be done by looking at changes in body weight, height, and Body Mass Index (BMI). However, it should be noted that the increase in BMI in children and adolescents was associated with puberty, not with the use of carbohydrate counting[2,18]. Children with higher BMI show earlier pubertal development and slower linear growth during adolescence, growth factors such as IGF-I and fasting insulin were predicted to have an important role in linear growth and their positive correlation with BMI.[19]. Carbohydrate counting was known to provide good metabolic control in type 1 DM patients in children, adolescents and adults without causing an increase in body weight, waist circumference or insulin requirements.[4,2]. Adult patients with type 1 diabetes can experience a significant reduction in BMI and waist circumference in the carbohydrate counting group compared to the control group, so that in patients with type 1 diabetes, carbohydrate counting can be suggested to facilitate weight loss through improved nutrient intake and increased physical exercise.[4].

Carbohydrate counting education in Diabetes Mellitus Type 1

In looking at the effectiveness of carbohydrate counting, accurate knowledge of this method and its application by patients and families is very important[2]. Several studies that provide intervention with carbohydrate counting use educational programs involving diabetes experts (diabetologists) and certified dietitians who have been trained to provide education related to carbohydrate counting.[9.10,15,20,16]. Other studies also involve nurses who have been trained to provide education[2,15,20]. The training sessions provided contained biological and nutritional content related to food groups (carbohydrates, fats, proteins, fiber and micronutrients), their impact on blood glucose, and taught how to estimate the amount of carbohydrates in food.[2]. The provision of education accompanied by information regarding the introduction of the amount of daily carbohydrates equivalent to 50-55% of the total calorie intake and also the distribution of carbohydrates in the daily diet also needs to be given to improve patient understanding. Some things that can be given in education include learning how to regulate simple carbohydrates and snacks in adjusting insulin doses related to carbohydrates in food, physical exercise, and blood glucose values before eating. Patients who have sufficient knowledge and can apply the procedure correctly can start nutritional calculations according to the calculation model[2].

Studies that provide education to adult type 1 DM patients who use insulin therapy include: *carbohydrate counting* and bolus counting can provide education using a combination of ICR and ISF over four to five individual sessions [4]. As an educational topic about carbohydrate counting, various material topics can be given in stages. The topics include maintaining the completeness of the contents of the food diary which consists of completing the food record in the form of meal times, number of days in a week, number of meals, total carbohydrates in grams of each food, total carbohydrates in grams in snacks and meals. mainstay, blood glucose before and after meals, doses of short-acting insulin, and physical activity[4]. Understanding carbohydrates, how to estimate the quantity of carbohydrates, the duration of insulin action, the ratio of insulin and carbohydrates, correction factors, and setting the day when you were sick also topics that can be given depending on the patient's condition and the purpose of the study to be carried out.[20]. Other education can also be provided by simply providing advice on diet and physical exercise settings from the visits made, as well as providing information regarding carbohydrate counting and getting consultations from diabetes educators about the use of bolus insulin calculations using certain tools.[14]. The intervention in the form of a short meeting can be given to patients who were accustomed and comfortable using carbohydrate counting so that education only focuses on the additional interventions provided. An example of a food record format in a diary that can be used for patients using carbohydrate counting is shown in Figure 2[21,22].

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Buku Harian Carbohydrate Counting

Nama : Dokter/Dietisien :

Hari/Tanggal : No. Pasien :

Waktu Makan	Makanan dan Minuman yang dikonsumsi		Jumlah Sajian Karbohidrat	Dosis Insulin	Glukosa Darah		Latihan Fisik (Durasi dan Jenis)	Komentar
	Nama	Jumlah (gram)			Kadar	Waktu Mengukur		

Figure 2. Example of a Food Record Format in a Diary for Carbohydrate Counting

A brief education can also be carried out using a diabetes team consisting of trusted diabetes educators and clinical dietitians through a brief presentation or explanation of the need for detailed studies, assessing the ability to apply carbohydrate counting methods, and reviewing the regulation of bolus insulin in blood glucose self-regulation.[23]. While in another study, structured educational intervention consisted of various aspects such as food recommendations for diabetes, insulin profiles, appropriate settings related to hypo and hyperglycemia and their relation to stress, infection, menstrual periods, and physical exercise.[15]. Education on carbohydrate counting that teaches theory as well as practical exercises using ICR and ISF calculations, as well as providing instructions for the use of automated bolus calculators can show good and successful results in improving metabolic control and treatment satisfaction.[15]. So that providing education to patients needs to involve patients to do exercises and practice on the theory presented.

In testing the educational accuracy of carbohydrate counting in adolescents with type 1 diabetes, adolescents were asked to estimate the size of the serving or portion of food consumed. The results show that foods such as milk, syrup, orange juice, carrots, broccoli were examples of foods that teenagers overestimate[16]. While foods such as cereals, bananas, sauces and sodas were foods that teenagers estimate is too low. Most of the teenagers claimed to be assisted by their mothers in doing calculations, especially at dinner. This shows that the emphasis on continuing education by registered dietitians in estimating portions, involving parents, and using the media is something that can be suggested in increasing the accuracy of education for adolescents with type 1 diabetes[16].

Good blood glucose control will be achieved if knowledge of food, insulin dose adjustment, and skills in estimating food portions. Accuracy in estimating food portions can also be achieved using Nutri Learn Buffet (NLB), which is a computer application that was run using a plastic doll equipped with a microchip containing food content data and can provide more precise food calculations. Research shows that patients who use carbohydrate counting with the help of NLB have a significant reduction in HbA1c levels compared to those who do not perform accurate food counting estimates.[24]. Patients with Type 1 DM must calculate carbohydrate requirements correctly to calculate the correct insulin dose.21 To calculate carbohydrates correctly, it was necessary to know the exact weight of food, but in everyday life, the scale is rarely used. The use of NLB in counseling has proven to be preferred by patients and nutritionists because this tool is direct and interactive, besides that it can be used without knowledge of certain languages, making it easier for patients to calculate glucose needs accurately.[24].

Carbohydrate Counting Practices for Children and Adolescents

The practice of carbohydrate counting in type 1 DM in children and adolescents is relatively different from that in adults. The accuracy of carbohydrate counting practices in adolescents aged 12-18 years with type 1 diabetes is classified as inaccurate, which tends to estimate the carbohydrate content above or below the actual carbohydrate content.[16,25]. Another age group (8-18 years) in Australia and the UK showed that adolescents were able to estimate the carbohydrate content of ± 10-15 grams from the actual carbohydrate content of 73% of foods, so it was concluded that they could calculate carbohydrates accurately[26]. The accuracy of the calculation of carbohydrate content is expected to be high in labeled packaged foods. However, in reality, individuals who consume labeled packaged foods actually calculate the carbohydrate content of their food more inaccurately than individuals who do not consume labeled packaged foods.[16]. This condition is motivated by the difficulties encountered when estimating the portion of food consumed. Therefore, the role of the Registered Dietitian is needed to help adolescents estimate the portion of food through props in the form of food models and real food.

A positive influence on DM therapy in children and adolescents is also obtained through parental involvement. Parental support measured through a collaborative scale is known to be associated with

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achieving better HbA1c scores. HbA1c is a standard parameter to identify metabolic control in DM patients. Achieving a good HbA1c value indicates an increase in metabolic control[27]. This phenomenon supports the idea that the adoption of carbohydrate counting in adolescents is better when parents were involved in diabetes therapy[16]. There was an idea that carbohydrate counting in children and adolescents can increase daily insulin requirements. Studies on children aged 7-18 years found an increase in daily insulin requirements in the carbohydrate counting intervention group, but this increase also occurred in the control group[2]. The increased insulin requirement in this condition was associated more with growth and development and the entry of puberty in adolescents than with the adoption of carbohydrate counting. In line with this explanation, an increase in BMI was also found in the carbohydrate counting intervention group[2]. These two findings show that increased insulin requirements and increased BMI in children aged 7-18 years were not associated with the adoption of carbohydrate counting.

Comparison of Carbohydrate Counting with Other DM Therapy

Although not many have been found, several research publications have collected that compare or combine the use of carbohydrate counting with other methods in patients with type 1 diabetes. The most common insulin therapy for type 1 DM patients is Multiple daily injection (MDI) or Continuous Subcutaneous Insulin Infusion (CSII). The application of carbohydrate counting is generally accompanied by determination of insulin dosage or Flexible Intensive Insulin Therapy. However, not all type 1 DM patients apply carbohydrate counting and FIIT as their daily therapy.

a. Flexible Intensive Insulin Therapy (FIIT) and Carbohydrate counting

Flexible Intensive Insulin Therapy (FIIT) is a method of administering insulin in the form of daily injections of several types of insulin with doses adjusting to blood glucose levels, carbohydrate intake, and physical activity.[15]. In a Danish study, FIIT combined with carbohydrate counting has become a therapeutic recommendation for patients with type 1 diabetes, according to national guidelines published in 2010. One of the goals of therapy in type 1 diabetes is to improve metabolic control of patients.[13]. Good metabolic control can be achieved by maintaining blood glucose levels in the normal range or near normal values, but still not causing hypoglycemia[27]. HbA1c is a standard parameter used to identify how the metabolic control of DM patients. The combination of the application of FIIT and carbohydrate counting is known to be able to provide a significant change in the HbA1c value of type 1 DM subjects with Multiple daily injection (MDI) therapy who have poor metabolic control. Monitoring the effect of applying FIIT and carbohydrate counting was carried out for 16 weeks on 21 subjects in the intervention group, with the results showing that at week 16, the mean HbA1c value decreased by 0.8%.[15]. The combination of carbohydrate counting and FIIT is a therapy that can be recommended to patients with type 1 diabetes to improve metabolic control.

b. Combination of Automated Bolus Calculator (ABC), FIIT and Carbohydrate Counting

Automated Bolus Calculator (A B C)is a blood glucose meter, equipped with an integrated bolus calculator function that offers patients using MDI the same benefits as patients using insulin pumps. Insulin pump therapy or also known as Continuous Subcutaneous Insulin Infusion (CSII), is a method of insulin therapy that involves the use of a device (insulin pump) that provides a steady flow of insulin into the patient's body. The advantage of using an insulin pump is that it allows the wearer to adjust the dose of insulin that is put into the body to increase or decrease blood glucose levels[12,28]. The use of ABC together with carbohydrate counting and FIIT is estimated to be able to support the effectiveness of type 1 DM therapy. The combination of the application of the FIIT method, carbohydrate counting, and the use of ABC is known to be able to reduce the HbA1c value of type 1 DM subjects with MDI users who have poor glycemic control, with a decrease in the mean HbA1c of 0.7%. These results were obtained through monitoring of 22 subjects in the intervention group for 16 weeks[15]. Therefore, the use of ABC together with carbohydrate counting and FIIT can also be recommended to support the effectiveness of type 1 diabetes therapy.

In addition to influencing the HbA1c value, the use of FIIT, carbohydrate counting, and ABC also has an effect on the satisfaction score of type 1 DM patients with the therapy they receive. The therapy satisfaction score was assessed through the Diabetes Treatment Satisfaction Questionnaires (DTSQ) to type 1 DM subjects using MDI with poor metabolic control. DTSQ is an instrument that is officially approved by the World Health Organization (WHO) and the International Diabetes Federation (IDF) and has been widely used in various countries to assess the therapeutic satisfaction of DM patients.[29,30]. In the FIIT and carbohydrate counting intervention groups, it was found that there was an increase in satisfaction scores until week 2, but then decreased again until week 16 of monitoring. Increased satisfaction scores were also seen in the combination intervention group ABC, FIIT, and carbohydrate counting, continuously from the start of the intervention until the end of the monitoring period. Enthusiasm for the introduction of new types of therapy methods for type 1 Diabetes Mellitus patients was the reason for the satisfaction scores in both intervention groups increasing until the 2nd week of monitoring. The application of the method that is considered complicated causes a decrease in satisfaction scores in the FIIT and carbohydrate counting intervention groups. In contrast to the combination intervention group ABC, FIIT, and carbohydrate counting,[15].

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Another benefit of the combined use of ABC, FIIT, and carbohydrate counting is to provide improvements in the distribution of blood glucose levels. Blood glucose levels were often in the range of expected values, which were 70-140 mg/dL, hypoglycemia and hyperglycemia were rare. The use of FIIT and carbohydrate counting also has an effect on increasing the frequency of blood glucose levels on target, but on the other hand when the frequency of hyperglycemia decreases, the frequency of hypoglycemia tends to increase.[15]. Overall, the combination of using ABC, FIIT, and carbohydrate counting was more beneficial for type 1 DM patients using MDI than using FIIT and carbohydrate counting alone. However, large-scale, long-term studies were needed to further explore the benefits of using ABC in combination with FIIT and carbohydrate counting in MDI therapy.

***c. Continuous Subcutaneous Insulin Infusion* (CSII) and Carbohydrate Counting**

Insulin therapy in type 1 DM can not only be given by MDI, but can also be given through an insulin pump or CSII. The application of carbohydrate counting in type 1 DM with CSII therapy is known to improve the quality of life of patients. Quality of life is important to pay attention to in DM patients because improving quality of life is one of the goals of DM therapy[31]. A study examined how carbohydrate counting affects patients' quality of life, as measured using the Diabetes-Specific-Quality-of-Life-Scale (DSQOLS) questionnaire for 24 weeks. The questionnaire used consisted of several components, one of which was related to dietary restrictions, in which an increase in scores was seen.[4] Increased scores on the components of the DSQOLS questionnaire indicate that the application of carbohydrate counting in type 1 DM with CSII therapy can improve the quality of life of patients[10.41].

d. Food Insulin Index (FII) counting

Balancing the insulin dose with the amount of carbohydrates in the diet is a proven strategy for achieving glycemic control. Despite many recommendations for the use of carbohydrate counting in daily practice, not a few individuals with type 1 diabetes report increased postprandial blood glucose levels and remained high for 2-3 hours afterward, especially after consuming foods high in protein and/or fat. tall like pizza[42.43] and other fast food[35]. Therefore, it is important to consider other nutrients in the diet that affect insulin secretion in the body. Theoretically, the use of carbohydrate counting is considered to be more suitable for foods that contain high carbohydrates but contain little protein and fat[23]. Food Insulin Index (FII) counting is a new algorithm to determine preprandial insulin dose through the insulin index of food to be consumed. The use of the FII algorithm in controlled type 1 diabetes who received insulin pump therapy is known to improve postprandial acute blood glucose better than the use of carbohydrate counting. The FII algorithm is able to keep the patient in a normoglycemic condition for a longer period of time, reduce insulin incremental area under the curve (iAUC) significantly, flatten the blood glucose rise curve, and reduce the time to restore fasting blood glucose levels. Taken together, these findings provide first-stage clinical evidence that the use of FII can be an effective method for estimating preprandial insulin dose in Type 1 DM.[23]. The obstacle faced in using the FII counting algorithm compared to carbohydrate counting is that the FII information on food is not written on the food packaging label, while the carbohydrate content is written. Although the results of the study show that FII counting has a better effect than carbohydrate counting, this result cannot be used as a basis for the application of FII counting because it is the result of studying the effect of FII counting in one meal. Identification of the effect of using FII at every meal in one full day has not been carried out and further analysis is still needed. The dose-response relationship (insulin requirement-insulin ratio) also needs to be demonstrated before the FII algorithm can be applied in clinical practice for the management of type 1 diabetes.[23].

CONCLUSION

Carbohydrate counting can improve metabolic control of type 1 DM patients in children, adolescents and adults and can facilitate weight loss. In increasing the effectiveness of carbohydrate counting, needed Emphasis on continuing education by registered dietitians for the application of carbohydrate counting such as using the media in determining the number of servings, insulin doses and involving parents in children and adolescents. The combination of the use of Automated Bolus Calculator (ABC) and Flexible Intensive Insulin Therapy (FIIT) is known to increase the effectiveness of the application of carbohydrate counting in type 1 diabetes therapy. idea FII counting instead carbohydrate counting on Type 1 diabetes requires further long-term and large-scale studies. This review uses only one database, so comparisons with other databases are needed to understand the wider application of carbohydrate counting.

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