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INSTITUTE FOR PERSONALIZED THERAPEUTIC NUTRITION

THERAPEUTIC CARBOHYDRATE REDUCTION

IN TYPE 1 DIABETES

A GUIDE FOR DIETITIANS & NUTRITIONISTS

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CONTENTS

"The best time to inform patients about a dietary option to manage their disease is at diagnosis. It is up to the patient to decide how they want to manage their diabetes; the skill of the clinician is to work with the patient to secure the best outcome."

Dr. Ian Lake

DEDICATION

While this guide is written for dietitians and nutritionists, it is dedicated to the incredible individuals, devoted caregivers, and families navigating the challenges of type 1 diabetes. To us, your grit is inspiring, and you show the world what true resilience looks like.

We understand the daily journey you must navigate, and we hope others recognize the depth of your strength, your longing for stability, and the constant effort you put into managing type 1 diabetes.

ACKNOWLEDGEMENTS

This project was born from an idea proposed by Adele Hite (PhD, MPH, RDN), whose vision and dedication continue to inspire us. We produce this guide in her memory, and her legacy remains a guiding light in our commitment to supporting choices for individuals and families with type 1 diabetes.

A heartfelt thank you to everyone who volunteered their efforts to make this guide possible.

We extend our gratitude to the healthcare professionals and researchers who generously shared their time and talents during the review process of this guide. Your insights and dedication have greatly enriched this work.

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We also extend our gratitude to Sean McKelvey (BSc (Pharm)), CEO and cofounder of the Institute for Personalized Therapeutic Nutrition (IPTN), and Cecile Seth (BA, MBA) for their invaluable support; to Anne Mullens (BSc, BJ), Director of Communications at IPTN, for her exceptional editorial skills; and to Jessica Turton (RD, PhD) and Caryn Zinn (RD, PhD) and their colleagues for kindly providing their sample meal plans.

Finally, our sincere appreciation to the Institute for Personalized Therapeutic Nutrition (IPTN) in Canada and the Type 1 Diabetes Family Centre in Australia for their support and encouragement in the creation of this publication, as well as for their efforts in promoting the message that therapeutic nutrition is an option that can positively impact diabetes outcomes and improve the quality of life for individuals and families living with type 1 diabetes.

PATIENTS TO WHOM THIS GUIDE REFERS:

- **Adults, adolescents**, and **children diagnosed with type 1 diabetes**, including **those with** Latent Autoimmune Diabetes of Adults **(LADA)**

- **Other individuals who are insulin-dependent**, including individuals diagnosed with type 2 diabetes who have been prescribed insulin medication and individuals whose pancreatic function is compromised due to damage to the pancreas or pancreatectomy and who are insulin-dependent.

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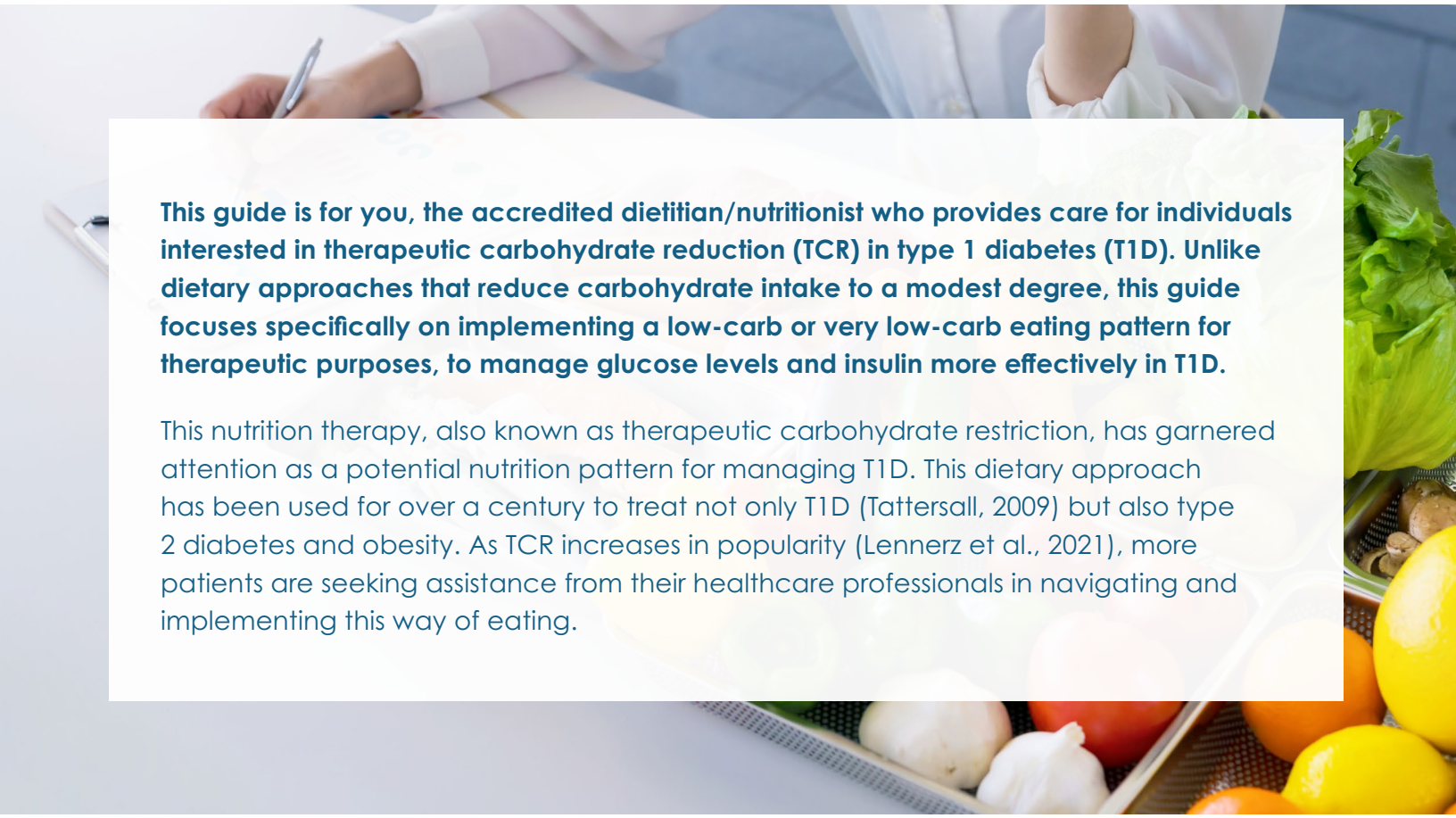
WHY T1D REQUIRES A TAILORED NUTRITION STRATEGY

THE EFFECT OF FOOD CHOICES ON BLOOD GLUCOSE

INTRODUCTION

INTRODUCTION



This guide is for you, the accredited dietitian/nutritionist who provides care for individuals interested in therapeutic carbohydrate reduction (TCR) in type 1 diabetes (T1D). Unlike dietary approaches that reduce carbohydrate intake to a modest degree, this guide focuses specifically on implementing a low-carb or very low-carb eating pattern for therapeutic purposes, to manage glucose levels and insulin more effectively in T1D.

This nutrition therapy, also known as therapeutic carbohydrate restriction, has garnered attention as a potential nutrition pattern for managing T1D. This dietary approach has been used for over a century to treat not only T1D (Tattersall, 2009) but also type 2 diabetes and obesity. As TCR increases in popularity (Lennerz et al., 2021), more patients are seeking assistance from their healthcare professionals in navigating and implementing this way of eating.

Dietitians and nutritionists encounter a unique hurdle when providing care for individuals with T1D who opt to use TCR. This challenge stems from the scarcity of available clinical guidelines and formal training in this specialized area.

Despite recent acknowledgements by Diabetes Canada and The American Diabetes Association regarding the viability of low carbohydrate diets for individuals with T1D, the absence of clinical practice guidelines from medical, dietetics, and diabetes organizations complicates clinical oversight of the implementation of TCR.

Notably, a recent study published in *The European Journal of Clinical Nutrition* highlighted a concerning trend: over two-thirds (67%) of Canadian registered dietitian study respondents reported having "zero or basic level of knowledge" of therapeutic carbohydrate restriction (Kim, Witchell, & Conklin, 2023). The lack of specific training and tailored guidance underscores the gaps in equipping dietitians and nutritionists with the necessary expertise for TCR, especially when tailored for T1D and for insulin titration. You may find that you lack resources and collaborative frameworks to assist patients effectively.

> **This guide strives to bridge these gaps** by providing essential information on using TCR as medical nutrition therapy in T1D. It offers practical guidance on initiating, monitoring, and adapting TCR as part of the nutrition care process.

Your role in supporting individuals who opt for carbohydrate reduction as a therapeutic intervention is significant. It is important to foster flexibility and to seek the necessary support to tailor care for individuals with T1D. By doing so, we can empower those who choose to explore this nutrition therapy and provide personalized nutrition guidance that aligns with their individual needs and preferences.

WHY T1D REQUIRES A TAILORED NUTRITION STRATEGY

Type 1 diabetes is a unique medical and metabolic condition.

Type 1 diabetes (T1D) occurs due to the absence of endogenous insulin production, resulting in impaired blood glucose regulation. Autoimmune destruction of pancreatic beta cells necessitates lifelong insulin replacement therapy.

Despite receiving insulin therapy as part of medical treatment, individuals with T1D often experience fluctuating blood glucose levels, leading to hypoglycemia, hyperglycemia, and elevated hemoglobin A1C (HbA1c) levels, which increase the risk of diabetes complications. According to JDRF Canada, "a person living with T1D has to make over 300 decisions per day regarding their food consumption, activity, and insulin just to manage their blood glucose levels" (JDRF, n.d.). This constant decision-making represents not just a logistical challenge but also a significant mental strain, potentially resulting in diabetes distress and impacting overall well-being. Recognizing this mental load underscores the importance of effective treatment strategies, including dietary interventions, to improve glycemic control and enhance quality of life.

The goals of type 1 diabetes management are to protect health.

The primary objectives in diabetes care are:

- to keep blood glucose as normal[1] as possible without severe hypoglycemia and hyperglycemia, and
- to maintain the health of blood vessels, nerves, and organs and avoid diabetes-related complications.

Individuals with T1D seek support to stabilize their blood glucose and enhance their ability to manage their condition effectively. They benefit from opportunities that intervene early to reduce the burden of disease management and improve their longer-term health outcomes and quality of life.

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1 The generally accepted normal range for blood glucose levels in healthy humans without diabetes in a fasted state is between 3.9 mmol/L (70 mg/dl) and 5.5 mmol/L (99 mg/dl). A normal range for blood glucose levels in healthy humans without diabetes in a fed state is generally between 4.0 mmol/L (72 mg/dl) and 7.8 mmol/L (140 mg/dl) (Diabetes Australia, n.d.).

Dietary choices and mealtime insulin impact glycemic control.

In managing T1D, achieving stable blood glucose levels requires careful attention to both dietary choices and mealtime insulin administration. Variability in daytime blood glucose levels can be largely attributed to the interplay between food intake and insulin inputs. Carbohydrate consumption has the most significant impact on postprandial glucose levels, making dietary choices crucial in managing glycemia. Additionally, while insulin therapy is essential, exogenous insulin often fails to replicate normal physiological function. Unlike endogenous insulin, exogenous insulin is delivered to peripheral circulation rather than portal circulation, and it is subject to absorption delays, which contribute to further blood glucose fluctuations.

By limiting carbohydrate intake and achieving lower postprandial blood glucose levels, individuals can reduce the amount of insulin required. This reduction in insulin dosage helps minimize the variability of its effects. Fewer and smaller swings in glucose and insulin levels reduce the risk of dosing or timing errors, leading to more consistent blood glucose control. This approach can be likened to optimizing an engineered system: by reducing destabilizing factors—such as high carbohydrate intake and excessive mealtime insulin doses—the body's natural management system is relieved of some of its burden. Consequently, this reduction in 'pressure' can lead to a more stable and safer physiological balance, potentially resulting in fewer and less severe hypoglycemic episodes.

> **TCR is a nutrition therapy that limits carbohydrate intake** and requires smaller mealtime insulin doses, effectively contributing to the therapeutic management of glycemic control in T1D.

THE EFFECT OF FOOD CHOICES ON BLOOD GLUCOSE

Dietary Carbohydrate

- Carbohydrate has the greatest and most direct impact on blood glucose levels (Evert et al., 2019, p. 733). It is regarded as the predominant macronutrient influencing postprandial glucose control (Bell et al, 2015, p. 1009).
- Carbohydrate "quality" can alter the rate and peak of glucose changes in the blood. The glycemic index of various carbohydrate sources has been widely studied as an indicator of the rate of glucose change from different nutrient sources (Augustin et al., 2015). In individuals with T1D, this affects the timing of how quickly each carbohydrate source reaches peak glucose levels in the blood, but it does not change the total amount of glucose that enters the bloodstream.
- Dietary fibre is a component of carbohydrates. TCR ways of eating can include fibrous foods, such as vegetables, berries, and nuts. Fibre in foods may slow the digestion and absorption of meals, blunt the glycemic response, and influence the timing and impact on blood glucose levels. Fibre is largely non-digestible and typically does not directly affect blood glucose levels when consumed alone.

Dietary Protein and Dietary Fat

- Both dietary protein and fat can lead to delayed postprandial hyperglycemia in individuals with Type 1 Diabetes (T1D) if not treated with insulin, occurring three to five hours after eating (Paterson et al., 2019).
- Different types of protein foods are digested and absorbed at varying rates.
- The fat content in protein foods also impacts blood glucose levels (Collier & O'Dea, 1983). Dietary fat can delay stomach emptying, therefore delaying the glycemic effects of the carbohydrate in the meal. The effects of a high-fat meal may impair insulin sensitivity and lead to late postprandial hyperglycemia starting at three hours and may extend many hours after eating (Bell et al., 2015; Wolpert et al., 2013). This will be influenced by other meal components.
- Fat consumed alone can lead to dose-dependent increases in glucose levels in individuals with T1D (O'Connell et al., 2021). This effect seems to be unique to T1D, as individuals without the condition do not typically experience glucose or insulin increases from ingested fat after meals.

Sugar Substitutes

- Individuals with T1D may have different responses to sugar substitutes, which include sugar alcohols, artificial sweeteners, and other sugar substitutes.
- Some sugar alcohols can be partially digested and absorbed in the small intestine, impacting blood glucose levels. An example is maltitol, found in various "sugar-free" and "low carb" products. About 40% of maltitol is absorbed, with a glycemic index of 35 (Livesey, 2003). Consequently, individuals with T1D may experience an increase in blood glucose after consuming products containing maltitol. This may also occur with other sugar alcohols, although erythritol appears to have a minimal effect on blood glucose levels (Livesey, 2003).
- Some individuals may opt for naturally occuring sugar alternatives, such as allulose, stevia, and monk fruit (luo han guo), which may have little to no impact on blood glucose and can be enjoyed without the bitter aftertaste some people associate with synthetic sweeteners or sugar alcohols. Allulose has been shown to reduce blood glucose levels in healthy people and those with type 2 diabetes.(Tani et al., 2023; Fukunaga et al., 2023). Allulose has also been demonstrated to reduce postprandial glycemic excursions following mixed-meal tolerance test in an individual with T1D 50%, while reducing total daily glucose and insulin requirements 10% (Koutnik et al., 2024a, unpublished). However, its effects on blood glucose in people with type 1 diabetes have not yet been investigated in randomized clinical trials.

In conclusion, understanding how different macronutrients affect blood glucose levels is crucial for individuals managing T1D. This knowledge allows for a more informed approach to meal planning and insulin management.

For a comprehensive understanding of how dietary choices impact insulin requirements in T1D, we encourage readers to explore the section of this guide entitled "Type 1 diabetes and the impact of TCR on insulin needs", where we offer insights on how a TCR way of eating affects insulin needs and management in T1D.

> **Dietary carbohydrate is not an essential nutrient in the diet because the human body can produce glucose from non-carbohydrate sources if needed.** The liver can either release stored glucose (through glycogenolysis) or create new glucose (through gluconeogenesis) to meet the body's needs, even in the absence of dietary carbohydrate.

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SECTION 01

THERAPEUTIC CARBOHYDRATE REDUCTION (TCR) FOR TYPE 1 DIABETES

DEFINING THERAPEUTIC CARBOHYDRATE REDUCTION (TCR)

TCR FOODS

TCR EATING PATTERNS

CLINICAL AND INVESTIGATIVE APPLICATIONS OF TCR

START SIMPLY WITH TCR

BENEFITS OF TCR IN T1D

Defining Therapeutic Carbohydrate Reduction

In this guide, Therapeutic Carbohydrate Reduction (TCR) refers to lower-carbohydrate dietary interventions that involve consuming fewer than 130 grams of dietary carbohydrates per day.
Lower-carbohydrate dietary patterns have been described by expert consensus (Volek et al., 2024) as follows:

- **Low-carbohydrate diet** (LCD): 50-129 grams of carbohydrate per day (10-25% of energy based on a 2,000 kcal/day eucaloric diet)

- **Very-low carbohydrate**, high-fat ketogenic diet (VLCHFKD): 20-50 grams of carbohydrate per day (<10% of energy based on a 2,000 kcal/day eucaloric diet)

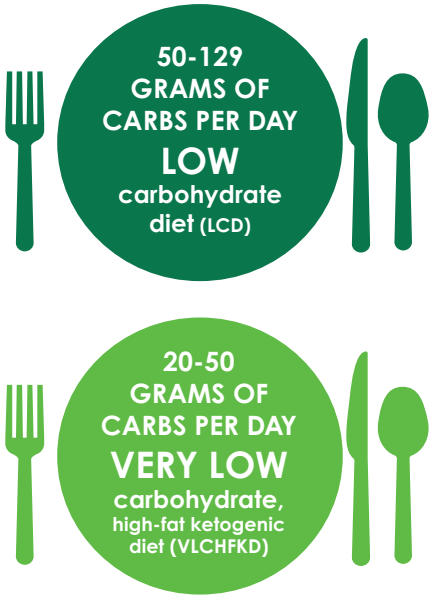
Clinical terms for this way of eating can include:

- Therapeutic Carbohydrate Reduction or Therapeutic Carbohydrate Restriction, both of which are referred to as TCR
- A Low Carbohydrate Diet (LCD)
- A Lower Carbohydrate Diet
- A Very Low Carbohydrate Diet (VLCD)
- A Very-Low Carbohydrate, High-Fat Ketogenic Diet (VLCHFKD)

Note that in the literature, "VLCD" is sometimes used for a "very low calorie diet." In this guide, VLCD refers to a very low-carbohydrate diet.

When a person with T1D follows TCR, they limit their carbohydrate intake for therapeutic purposes, with the goal of reducing postprandial glycemic excursions and experiencing the benefits of more stable blood glucose levels.

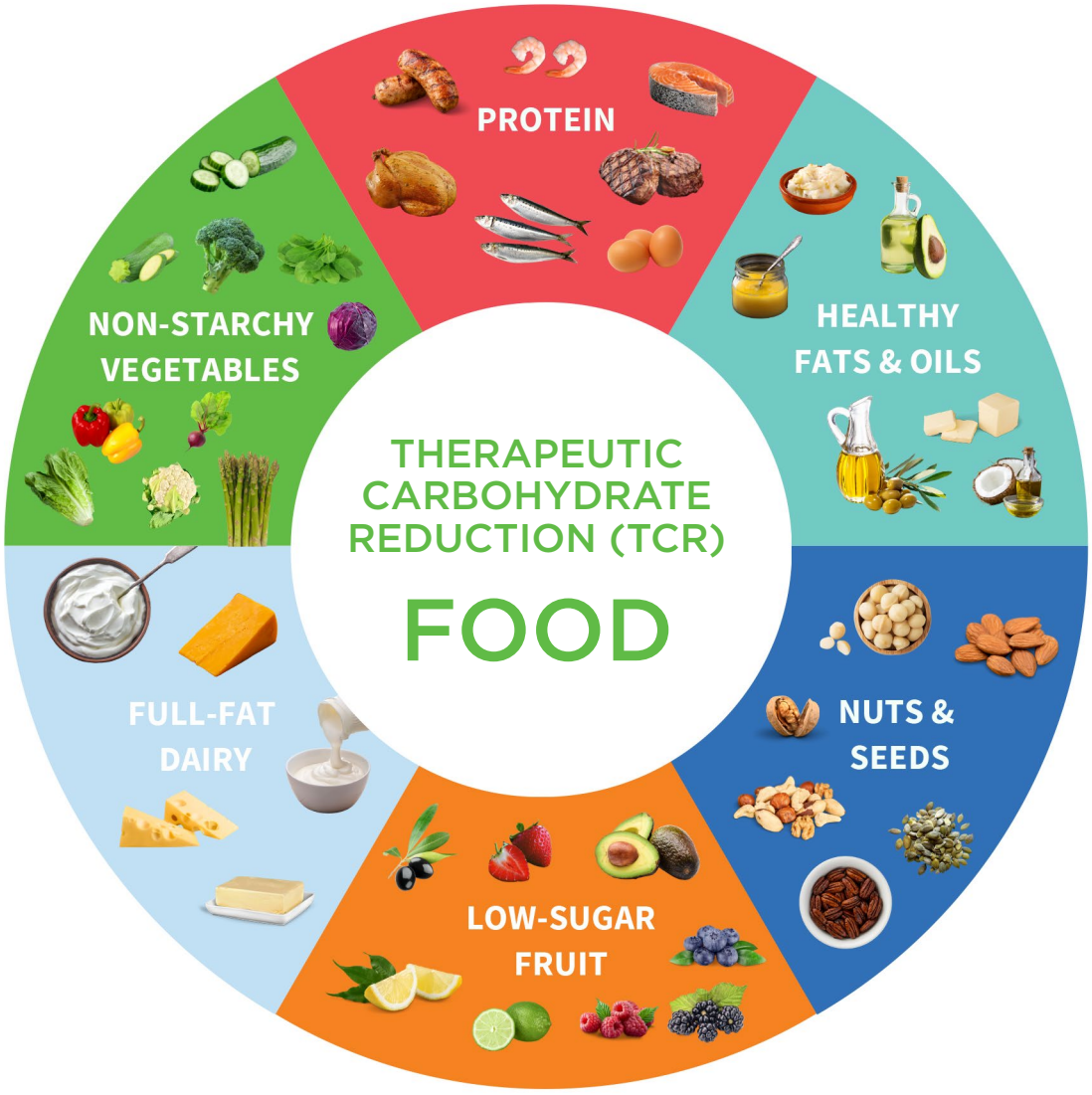
An additional resource historically used to guide patients utilizing a TCR-style approach is *Dr. Bernstein's Diabetes Solution*, by Dr. Richard Bernstein. This protocol has been therapeutically assessed (Lennerz et al., 2017) and is designed to support HbA1c levels below 5.7% in both adults and children. It involves limiting carbohydrate intake to 30 grams daily, distributed as follows: Breakfast: ≤6g, Lunch: ≤12g, Dinner: ≤12g. Familiarity with this protocol can provide additional insights into management of TCR in T1D.



TCR Food

As a way of eating that can comprise whole, nutrient-dense foods, TCR aligns with the American Diabetes Association's nutrition therapy consensus recommendations that healthcare professionals focus on the following key factors:

- emphasize non-starchy vegetables
- minimize added sugars and refined grains
- choose whole foods over highly processed foods to the extent possible (Evert et al., 2019. p. 736)

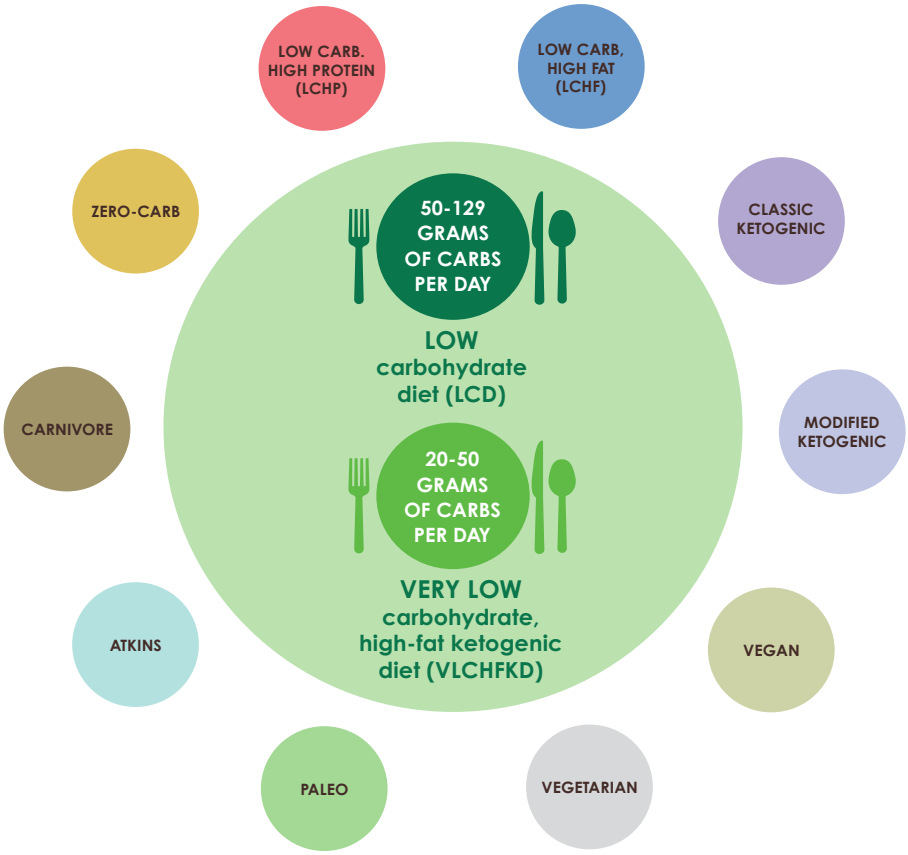


TCR Eating Patterns

TCR can encompass various eating patterns, including vegetarian, Mediterranean, Paleo, food from traditional diets from different cultures, and more. While these plans share a common feature of reduced carbohydrate intake, the TCR umbrella is diverse, reflecting different dietary approaches based on individual needs and preferences.

TCR ways of eating have been applied for a wide range of medical conditions for over a century not just in T1D (Tattersall, 2009), but also for obesity (weight loss), type 2 diabetes, and epilepsy (Wilder, 2021). It's also being explored in other conditions including cancer, mental health, and neurological diseases (Paoli, Rubini, Volek & Grimaldi, 2013; Choi, Kang, Kim, & Nehs, 2024)

CLINICAL AND INVESTIGATIVE APPLICATIONS OF TCR



TCR CAN HELP WITH:

- Diabetes
- Cardiovascular Disease
- Weight Management
- Gastrointestinal Conditions

AND:

- Cancer
- Epilepsy
- Mental Health
- Alzheimer's Disease

The foods among these dietary approaches share similarities, including: protein foods, foods containing fats, and except for the Zero-carb and Carnivore diets, nutrient-dense, low carbohydrate foods, such as non-starchy vegetables and low sugar fruit.

Although any of the eating patterns mentioned above can fall under the umbrella of TCR, it's important to distinguish the 4:1 Classic Ketogenic Diet, mainly used for epilepsy treatment. The 4:1 Classic Ketogenic Diet emphasizes a very high fat intake and limited protein, where 90% of total caloric intake comes from fat where the goal is to minimize insulin and maximize circulating ketone levels for neurological conditions. This limited protein intake is not advisable for managing T1D and has been cited to have lower long-term adherence. In contrast, for managing blood glucose levels in T1D, consuming protein-rich foods can be beneficial, along with a moderate intake of fat. Concerns about the nutritional adequacy of TCR have arisen from experiences with the Classic Ketogenic Diet for epilepsy. However, TCR is a very different diet and approach. TCR approaches for T1D emphasize higher protein, more moderate fat intakes, and healthy, high-fibre green leafy vegetables, aiding individuals, including children, in moving towards meeting their essential amino acid, essential fatty acid, and micronutrient requirements, especially through animal-based protein sources rich in vitamins and minerals.

Start Simply with TCR

Patients and families may seek your support in implementing a TCR approach that suits them best. As with any dietary change and when acquiring a new skill, individuals can feel overwhelmed.

To simplify the process, individuals and caregivers may find it helpful to structure a basic TCR meal as follows:

1. **Choose** a protein source (such as seafood, poultry, eggs, beef, pork, lamb, tofu or tempeh).
2. **Choose a couple** of vegetable side dishes (such as broccoli, green salad, green beans, or cucumbers).
3. **Incorporate** fats to enhance the flavour of the meal and to help meet energy requirements (such as olive oil, butter, ghee, tallow, salad dressing, sour cream, avocado, or the natural fat found in protein sources).

It's worth noting the importance of incorporating enough dietary fat in TCR to meet energy requirements. Sometimes individuals who are familiar with low-fat dietary guidelines do not add in enough fat to meet their body's needs when following TCR. Failing to do so can lead to increased hunger, carbohydrate cravings, or unwanted weight loss, which may undermine the sustainability of this strategy. If the individual experiences undesired weight loss, increasing fat intake may be necessary.

> **As a dietitian/nutritionist,** you can assist individuals with T1D in tailoring their TCR nutrition plan to meet their nutritional needs and health goals. This guide's section on TCR and the Nutrition Care Process offers guidance on this.

Benefits of TCR in T1D

For individuals with T1D aiming to improve their diabetes outcomes and reduce the burden associated with managing chronic disease, TCR may be beneficial. While the research evidence for TCR nutrition therapy in T1D is currently limited and further studies evaluating its effects are needed, recent studies have provided insights into its effects (Lennerz et al., 2021), with recent demonstration of long-term safety, efficacy, and therapeutic benefit in some individuals (Koutnik et al., 2024b). This nutrition therapy shows promise in minimizing postprandial blood glucose fluctuations, improving HbA1c and time in range, lowering insulin needs, and reducing the frequency of adverse events from hypoglycemia or hyperglycemia.

> "Reducing overall carbohydrate intake for individuals with diabetes has demonstrated the most evidence for improving glycemia and may be applied in a variety of eating patterns that meet individual needs and preferences."
>
> ***American Diabetes Association's Nutrition Therapy for Adults With Diabetes and Prediabetes: A Consensus Report, 2019, p. 736***

The largest and most comprehensive systematic review of nutritional intake in T1D, which included 45,972 individuals living with T1D (54% female; 45% pediatric) across 101 studies, demonstrated that reduced carbohydrate intake is associated with better HbA1c levels and lower insulin requirements. This effect was observed in a dose-dependent manner, ranging from 225 grams of daily carbohydrate down to TCR (Koutnik et al., 2024c).

For every 50-gram reduction in carbohydrate intake, there was an associated improvement of 17.8 mmol/mol (0.52% absolute unit) in HbA1c. This means that if an individual had a starting HbA1c of 63.9 mmol/mol (8.0%) and reduced their carbohydrate intake from the average of 225 grams to less than 50 grams per day, they could expect an estimated improvement of 22.7 mmol/mol (2.08% absolute unit), bringing their HbA1c down to 41.2 mmol/mol (5.92%). The data also indicated that the American Diabetes Association (ADA) target of HbA1c <52.5 mmol/mol (<7%) was achieved in 10% of high-carbohydrate (≥45% kcal), 24% of moderate-carbohydrate (26-44% kcal), 78% of low-carbohydrate (10-25% kcal), and 100% of very-low-carbohydrate studies(Koutnik et al., 2024c).

Previously, a systematic review of studies on low carbohydrate diets (LCD) in T1D, 79 articles published up until March 2017 were assessed for eligibility, and 9 studies met the criteria for inclusion (Turton et al., 2018). While the limited data available prevented the authors from determining the overall effect of TCR and drawing conclusions regarding HbA1c results and secondary outcomes—such as severe hypoglycemia and quality of life—they did report that five of the studies demonstrated clinically significant reductions in total daily insulin when subjects adopted an LCD. These reduced insulin needs could explain the anecdotal reduction in hypoglycemic events reported by individuals following a LCD, as correction boluses often precipitate hypoglycemia. Additionally, the systematic review highlighted potential benefits of LCDs, suggesting they may help protect individuals with T1D from hyperinsulinemia and its associated metabolic consequences, including excessive weight gain, inflammation, atherosclerosis, insulin resistance, metabolic syndrome, Alzheimer's, and cancer (Turton et al., 2018, p. 10).

Building on this understanding, another review series by Lennerz, Koutnik and colleagues examined the relationship between dietary carbohydrate intake and glycemic control in reduced-carbohydrate diets for people with T1D (Lennerz et al., 2021). The review of 24 studies—including randomized controlled trials, uncontrolled interventional studies, observational studies, case reports, and case series—demonstrated the following findings:

- LCD (51-130g/d of carbohydrate) and VLCD (≤50g/d of carbohydrate) studies reported mean HbA1C of <7.5%.
- Mean HbA1C results were lower following:
    - a VLCD (14 publications; mean HbA1C range of 4.0-6.2%) compared to
    - a LCD (4 publications; mean HbA1C range of 6.4-7.4%).
- Except for one case report, VLCD studies showed HbA1C levels within or below the non-diabetes range (<6.5%), stable continuous glucose monitoring (CGM) profiles, and low insulin doses.
- Short-term randomized control trials on LCD and VLCD resulted in reductions in various important diabetes outcome parameters, including glycemic variability, HbA1C, insulin doses, and time spent in hypoglycemia (Lennerz et al., 2021, p. 5-6).

An earlier observational study by Lennerz et al., noted "exceptional glycemic control" with low rates of adverse events for more than 300 adults and children with T1D who self-selected to follow a TCR, VLCD approach (mean daily carbohydrate intake of 36g ± 15g) (Lennerz et al., 2018, p. 1). Average diet duration was 2.2 years ± 3.9 years. The study's reported mean HbA1c was <5.67%, mean CGM glucose was 5.8 mmol/L (104 mg/dl), and the mean daily insulin dose was 0.4u/kg. These results are particularly notable because they demonstrate substantial improvements in glycemic control and insulin efficiency, with HbA1c levels and glucose readings significantly better than the typical outcomes reported for T1D patients, where average HbA1c levels often exceed 7.0% and daily insulin doses are generally higher. The lower insulin dose required also suggests enhanced metabolic efficiency, making these outcomes promising for optimizing diabetes management. By achieving better glycemic control with less insulin, people who adopt TCR may help reduce their risk of diabetes-related complications in the future, including "double diabetes." That term is used to describe individuals with T1D who also develop insulin resistance and obesity (Bielka et al., 2024).

As hypoglycemia is a significant concern for individuals with T1D and their healthcare professionals, it is important to highlight that TCR may help reduce risk of hypoglycemia by lowering glycemic variability while appropriately targeting their mean glucose based on glycemic variability to avoid hypoglycemia, particularly for severe episodes. With reduced insulin needs for TCR meals, the margin for dosing or timing errors is minimized. However, further studies on TCR's effects on hypoglycemia are needed as are insulin dosing strategies that align with glycemic responses to TCR foods.

"When compared to eating patterns without carbohydrate restriction, very low-carbohydrate/ketogenic styles of eating produce superior weight loss, greater A1C reductions, immediate reductions in glycemia, and significant reductions in insulin and other diabetes medication requirements."

Association of Diabetes Care & Education Specialists, 2023, p. 356

In a non-randomized, single-arm clinical trial involving adults, the findings suggest following a LCD in T1D may result in enhanced markers of blood glucose control and improved quality of life (Turton et al., 2023). This improvement is accompanied by reduced exogenous insulin requirements and no evidence of increased risk of hypoglycemia or ketoacidosis (Turton et al., 2023).

While these series of recent positive studies can reassure health professionals and patients with T1D that TCR is safe and effective, further research is needed to assess TCR ways of eating and their impact on glycemic control in T1D, as well as secondary outcomes such as quality of life, weight loss, cardiovascular health, psychological well-being, and sustainability.

Healthy low- or very-low-CHO [carbohydrate] diets can be considered as one healthy eating pattern for individuals living with type 1 and type 2 diabetes for weight loss, improved glycemic control and/or to reduce the need for anti-hyperglycemic therapies.

Diabetes Canada's Low Carbohydrate Diets for Adults with Diabetes: Summary

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CLINICAL ROLES IN NUTRITION AND DIABETES MANAGEMENT

SECTION 02

CLINICAL ROLES IN NUTRITION AND DIABETES MANAGEMENT

Navigating the complex landscape of nutrition and diabetes management requires a collaborative and multidisciplinary approach, with key roles assigned to specialized healthcare professionals. Among these roles, dietitians/nutritionists, diabetes educators, endocrinologists, general practitioners, and other diabetes care professionals play distinct yet complementary roles in supporting individuals with diabetes. Understanding these roles is especially important when implementing TCR in T1D as insulin and medication requirements need to be reviewed, adjusted, and monitored to avoid hypoglycemia.

> **Differences in laws, regulations, or professional standards between countries and jurisdictions lead to variations in roles and scopes of practice.** Our goal is to provide a high-level overview of clinical roles in nutrition and diabetes management that accommodates these jurisdictional differences, but be aware that what is presented may differ from your specific regulations, so always refer to your jurisdiction's legislation and policies.

The Role of Dietitians & Nutritionists

Dietitians and nutritionists who assist individuals in adopting TCR in T1D should have a good knowledge base of diabetes. Some clinicians may feel nervous or uncertain about providing care for people with T1D, especially when starting out, given the complexity of the condition, the potential side effects of exogenous insulin, and the fact that each individual manages their diabetes in a unique manner, based on their own understanding, experience and preferences.

Dietitians and nutritionists may be unsure about their role in care provision and the responsibilities involved in overseeing T1D. As with other medical conditions, dietitians and nutritionists leverage their nutritional expertise to help individuals with T1D understand how food and nutrition impact their bodies. This understanding empowers their patients to manage their blood glucose levels and overall health.

An individual's TCR nutrition plan will serve as a crucial component of the overall diabetes care plan. Dietitians and nutritionists work closely with individuals with T1D to develop personalized nutrition care plans aimed at achieving optimal glycemic control. Using the nutrition care process tailored for TCR, they assist in teaching macronutrient counting, explaining the impact of different foods on blood glucose levels, and helping patients select TCR foods based on food preferences and dietary needs. Additionally, they assist with meal planning, label reading, and strategies for addressing weight-related health concerns, and play a vital role in assessing progress related to nutrient intake and glycemic control within the context of a TCR nutrition care plan.

Dietitians and nutritionists can also educate patients about testing for and treating hypoglycemia with fast-acting carbohydrates.

The Role of Credentialled Diabetes Educators

When an individual follows a TCR way of eating, credentialled diabetes educators can provide support through diabetes self-management education, which includes the self-care behaviours of healthy eating, taking medications, and monitoring. If within the legal, ethical and professional standards of their primary discipline (e.g., nursing), a credentialled diabetes educator can support individuals with T1D in making adjustments to and troubleshooting issues related to insulin dosing.

They also might recommend adjustment to other medications and help to coordinate care with the prescribing medical practitioner, as needed.

Facilitating the Implementation of TCR

When assisting individuals in adopting TCR for T1D, it is crucial to delineate the roles of healthcare professionals responsible for insulin and medication adjustments. A dietitian or nutritionist should refrain from providing specific guidance on insulin titration, unless they have the appropriate authorization or credentials in their jurisdiction, or a written order from the prescriber to adjust the prescribed insulin. While dietitians and nutritionists can discuss insulin in general terms and help patients understand how their insulin needs may change during the transition to TCR, the responsibility for making precise adjustments to insulin and medications lies with the prescribing medical practitioners.

It is critical to emphasize that as individuals with T1D make rapid dietary changes that reduce carbohydrate intake, timely medication adjustments are necessary to ensure their safety and prevent the risk of hypoglycemia. This underscores the importance of effective communication among healthcare providers. The prescribing medical practitioner should be kept informed throughout the process to facilitate cohesive insulin management and provide ongoing support for insulin adjustments and monitoring as the TCR nutrition plan is implemented.

> **Dietitians and nutritionists** should collaborate with a credentialled diabetes educator, endocrinologist, or general practitioner who understands the impact of TCR on blood glucose and is confident in assisting patients with adjusting their insulin and medication requirements accordingly.

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TCR & THE NUTRITION CARE PROCESS

KEY POINTS

NUTRITION ASSESSMENT

NUTRITION INTERVENTION

NUTRITION MONITORING & EVALUATION

SECTION 03

TCR & THE NUTRITION CARE PROCESS

Outlined below are key points of TCR to provide an understanding of how this approach works from both a dietetics and diabetes care perspective.

1. Key Considerations for Nutrition Interventions for T1D

For individuals with T1D, effective nutrition interventions should consider the following:

- Foods that help prevent rapid glucose spikes to maintain blood glucose stability
- Foods that do not require large doses of rapid-acting insulin, reducing variability in insulin effects and minimizing the margin for dosing or timing errors
- Foods with enough energy that are high in essential nutrients to support overall health
- Foods that address the specific nutritional needs, preferences, and health goals of the individual
- In addition to these T1D-specific considerations, nutrition interventions should also include foods that are affordable, culturally appropriate, and contribute to the individual's sense of well-being. The role of the dietitian and nutritionist is to educate patients about foods that meet these criteria (Turton et al., 2022).

2. The Impact of TCR on Insulin Needs in T1D

- The initiation of TCR in individuals with T1D brings about rapid physiological changes. These changes affect insulin requirements. Notably, switching to a TCR way of eating changes how much rapid-acting mealtime insulin one needs, often requiring a significant decrease to prevent hypoglycemia. Caution must be exercised.
- It is essential for the prescribing medical practitioner to prepare an insulin dosing plan with the patient as a starting point before dietary changes are made. Follow-up monitoring to assess insulin needs and make adjustments is required.
- The ability for the person to accurately carb count will assist in building their confidence to adjust insulin to match intake.
- Consideration should be given to the different impact protein and fat has on insulin needs compared to carbohydrates.
- Additionally, changes in insulin sensitivity brought about by diet may influence basal insulin needs.
- Patients should be encouraged to use a CGM or to test more frequently using a glucometer, especially in the early days of transition to TCR, to allow close monitoring of glycemic responses and to make adjustments as needed.

3. Nutrition and Energy Requirements

- Following TCR, when carbohydrate is reduced, energy requirements must come from adequate intakes of dietary protein and dietary fat.
- Human essential nutrients include essential amino acids, essential fatty acids, vitamins and minerals. While carbohydrate is not considered essential when sufficient dietary protein and fat are consumed, TCR eating patterns often include fibre-rich carbohydrate foods,

like vegetables, berries, nuts, and seeds. There is no obligatory minimum carbohydrate requirement as long as sufficient energy is obtained from dietary protein and fat.

4. Hypoglycemia

- It has been previously hypothesized that TCR will increase the risk of hypoglycemia. However, the primary risk factor, however, is an excess of insulin, which can lead to hypoglycemia. TCR offers an opportunity to lower HbA1c in T1D without excessive insulin use.
- TCR may reduce glycemic variability and as a result may support more stable blood glucose levels which may assist in mitigating hypoglycemia (Koutnik et al., 2024c).
- Lower HbA1c levels do not necessarily indicate that the individual is experiencing a high rate of hypoglycemic events. Lower HbA1c levels, even those comparable to non-diabetic levels, can be achieved by people with T1D following TCR when insulin doses and timing are appropriately matched, without an increased incidence of hypoglycemia, as evidence suggests TCR can reduce glycemic variability (Koutnik et al., 2024c).
- Being on a TCR "low carb" diet does not change patient treatment for hypoglycemia. Hypoglycemia is still to be treated with fast-acting carbohydrate, with glucose/dextrose as the preferred treatment (American Diabetes Association, 2024), with appropriate care team follow-up to adjust insulin doses, if needed, and to educate the patient on anticipating and preventing lows.

5. Macronutrients' Effects on Blood Glucose

- All three main macronutrients affect glycemic response and insulin requirements (O'Connell et al., 2021; Collier & Dea, 1983; Paterson et al., 2015; Lennerz et al., 2021).
- Although carbohydrate has the greatest impact on blood glucose levels, protein and fat also need to be taken into account when determining the amount of insulin to bolus for a TCR meal.
- Alcohol is a nutrient-void macronutrient that can cause hypoglycemia in people with T1D, regardless of their eating plan. It affects liver function and glucose metabolism, leading to delayed and unpredictable drops in blood glucose levels. To manage these risks,individuals with T1D should be educated about delayed hypoglycemia, careful monitoring, and insulin adjustment when consuming alcohol.

6. Personalized Nutrition Therapy

- You can support individuals in your care to personalize nutrition therapy to meet their needs, preferences, and health goals within the TCR approach. An individual's needs and preferences may be impacted by culturally preferred flavours, how meals are prepared and eaten inside and outside of the home, convenience, as well as disrupting and stabilizing life events.
- It is up to the individual to determine if their eating pattern is sustainable.

TCR in T1D: Nutrition Assessment

Recognizing that all individuals with T1D may benefit from TCR, except those with contraindications as detailed on the following page and in Appendix A, dietitians and nutritionists should approach each patient with an open mind and work collaboratively to create individualized plans. Even in the presence of specific requirements such as advanced diabetes-related complications, exocrine pancreatic insufficiency (EPI), celiac disease (CD), chronic hyperglycemia (HbA1C > 7.0%), or during critical life stages like childhood, adolescence, pregnancy, and breastfeeding, TCR may offer meaningful benefits.

Below, you will find criteria to help you conduct nutrition screening for individuals with T1D who have requested support in implementing TCR. Before you turn the page, two important topics are highlighted as key parts of the TCR screening process.

Contraindications

In most cases, TCR nutrition interventions are not absolutely contraindicated, except for a few rare inborn errors of metabolism and specific situations such as enzymatic defects or porphyria that warrant avoiding this dietary approach. Inborn errors of metabolism primarily involve the transport and metabolism of fatty acids, with these genetic defects typically identified at birth. These conditions should be screened for during the initial evaluation. Appendix A - TCR Contraindications provides a list of absolute contraindications.

Diabetes-related Complications

Most individuals with T1D can transition to TCR as they see fit. However, those with a history of severe, chronic hyperglycemia and/or advanced diabetes-related complications, such as proliferative diabetic retinopathy, should exercise caution when considering dietary changes that lead to substantial and rapid improvements in glycemic control.

Pre-existing Proliferative Diabetic Retinopathy

Evidence suggests that rapid improvements in glucose control- such as those from intensive insulin therapy, GLP-1 receptor agonists, severe dietary restriction (diabetic anorexia), or bariatric surgery- can exacerbate proliferative diabetic retinopathy (Bain et al., 2019). Bain, Klufas, Ho, and Matthews (2019) identify risk factors for early or transient worsening of retinopathy following rapid glucose control improvements, including a significant reduction in HbA1c (<2%) and the severity of pre-existing retinopathy, as well as potentially poorly controlled hypertension. Although there is currently no specific evidence linking the implementation of TCR with worsening retinopathy, caution is advised for those with proliferative diabetic retinopathy due to the potential for rapid glucose control improvements.

Treatment-induced neuropathy of diabetes (TIND)

Reports indicate that individuals with a history of severe, chronic hyperglycemia and very high HbA1C may develop acute, severe neuropathic pain and autonomic dysfunction following rapid improvements in glucose control. This condition, known as treatment-induced neuropathy of diabetes (TIND), or insulin neuritis, has been associated with rapid changes in HbA1C (Gibbons & Freeman, 2015; Hwang & Davis, 2016). In a case series, nine adult subjects with T1D, with reported baseline HbA1C levels ranging from 14.2%-17.8% who developed TIND after intensive glycemic control, reported an improvement in pain after many months of continued glucose control (Gibbons & Freeman, 2010). According to Gibbons and Freeman (2015), the primary risk factor for TIND is the magnitude and rate of HbA1c change, rather than the specific treatment causing the damage. Those with a history of diabetic anorexia or significant weight loss may be at higher risk for TIND. While there is currently no evidence linking the implementation of TCR with TIND, caution is recommended for individuals with severe, chronic hyperglycemia and high HbA1C due to the potential for rapid glucose control improvements.

Refer to the "Diabetes-related complications" section of this guide in Implementing the Nutrition Intervention for guidance tailored to individuals with existing retinopathy or a history of severe, chronic hyperglycemia and a very high HbA1C.

NUTRITION ASSESSMENT: SCREENING

All individuals with T1D wanting to implement TCR should be screened for the following conditions.

☐ Malnutrition

- Energy restrictive eating patterns/behaviours
- Cachexia
- Underweight (<18.5kg/m2)
- Unintended/unexplained weight loss

- If a patient has experienced recent, unintended, or perhaps unexplained weight loss, the cause of that weight loss should be investigated and understood and resolved prior to starting TCR.

☐ Active eating disorder or a history of an eating disorder

- Use of appropriate screening tools specifically for T1D should be used. Refer to the *Clinical Considerations* section of this guide on Eating Disorders for more info.

☐ Food addiction

- Use appropriate screening tools, such as the Yale Food Addiction Scale, to assess signs of addictive-like eating behaviour.

☐ Contraindications for TCR (refer to Appendix A for a full list of contraindications)

- Genetic disorders, including inborn errors of metabolism and enzymatic defects
- Medications: Individuals with T1D using Sodium-Glucose Cotransporter-2 (SGLT2) inhibitors off-label should consider discontinuing them before starting a VLCD. The combination of SGLT2 and very low carbohydrate nutrition has been cited in some case reports to increase the risk of DKA, including euglycemic DKA.
- Other: inherited causes of severe hypercholesterolemia, severe liver disease, states that mimic starvation, including Alcohol Use Disorder or an active eating disorder.
- Use caution with individuals with a history of hypertriglyceridemia-associated acute pancreatitis or severe hypertriglyceridemia.

☐ Consider the nutritional needs of and medical supervision for the following:

- Diabetes-related complications
- History of renal stones or gout
- Exocrine pancreatic insufficiency (EPI)
- Fat maldigestion/malabsorption including active gallbladder disease or known gallstones
- Kidney disease, liver disease, CVD
- Gastroparesis
- Pregnant and breastfeeding women
- Children and adolescents
- Recent dka event
- Underweight (<18.5kg/m2)

NUTRITION ASSESSMENT DATA

The following nutrition assessment data can be collected to support individuals with T1D in creating a personalized TCR nutrition plan.

☐ Listening to the individual

- Personal health goals
- Concerns about diabetes
- Medical and nutrition histories
- Physical activity and limitations
- Knowledge of TCR
- Motivation and mindset for TCR
- Moral support system
- Readiness to change

☐ Factors affecting health and diabetes management

- Glycemic targets and levels.
- Diabetes-related complications.
- Autoimmune comorbidities.
- Social determinant of health (Hill-Briggs et al., 2021):
  - Economic state.
  - Access to food, housing and transportation.
  - Healthcare access & quality.
  - Private or public insurance.
  - Access to diabetes-related technology.
  - Education and understanding diabetes and access to diabetes self-management education and support (DSMES).
  - Neighbourhood and environment.
  - Social and community support.
  - Digital access and literacy.

☐ Patient's core competencies in their T1D management

Diabetes education, self-care skills and behaviours, and daily routines.

- Regular self-monitoring of blood glucose (SMBG)
- Tracking, administering, and adjusting insulin doses
- Identifying the risk of and the ability to treat hypoglycemia
- Identifying food with reduced effects on blood glucose levels

Refer to a diabetes education provider if additional education on the above diabetes education topics is needed.

☐ Medications and supplements

- Review medication regimen and management.
- Work closely with the prescribing medical practitioner who oversees insulin and medication adjustments and medical lab evaluations.
- Consider how any nutritional and herbal supplements may be impacting blood glucose levels

☐ Biochemical data

- Obtain clinical data, which may be from a referral source or client medical record, for: fasting lipid panel, comprehensive metabolic panel (CMP), Vitamin D, and HbA1c for baseline indicators. Also note lab values for CBC, thyroid panel, celiac antibodies, ferritin, hs-CRP, and uric acid.
- Consider testing when signs of a possible nutrient insufficiency are present. If these tests are cost-prohibitive, a pre- and post-TCR food diary analysis, along with a Nutrition-Focused Physical Exam (NFPE), can be conducted first. Afterward, evaluate the need for testing, supplementation, and subsequent re-testing and monitoring.

☐ Anthropometrics, physiological data, and NFPE

- Presenting signs and symptoms
- Height and weight, particularly changes in weight
- Blood pressure.
- Pediatric growth pattern indices/percentile ranks for children and adolescents
- Confirm with patients who are pregnant that they have an obstetrics/maternal fetal medicine team that is monitoring fetal growth patterns.

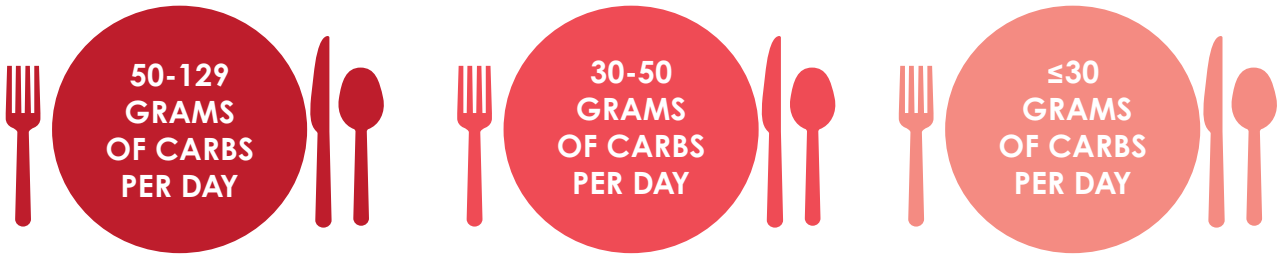
TCR in T1D: Nutrition Intervention

Just as with any dietary intervention, when working with individuals on a TCR nutrition intervention, dietitians and nutritionists will employ the standards of the Nutrition Care Process. This includes focusing on the patient's nutritional needs, providing nutrition education, and offering nutrition counselling. In this section, we will highlight the unique considerations and nuances relevant to implementing a TCR nutrition intervention for individuals with T1D.

Planning the Nutrition Intervention

In a T1D nutrition plan, it's important to consider distributing carbohydrates, protein, and fat evenly across meals rather than 'banking' them or consuming them all at once. This balanced approach may help promote more stable post-prandial blood glucose levels. Additionally, specifying the daily intake of carbohydrate is essential for facilitating insulin dosing decisions based on food consumption, given the demands of this medical condition. This visual outlines possible options for carbohydrate distribution for a personalized nutrition plan.

TCR OPTIONS FOR INDIVIDUALS WITH TYPE 1 DIABETES



SAMPLE BREAKDOWN OF CARBOHYDRATES PER MEAL

BREAKFAST	10-20 grams	**BREAKFAST**	10 grams	**BREAKFAST**	6 grams
LUNCH	10-20 grams	**LUNCH**	10 grams	**LUNCH**	10 grams (12 if no snack)
DINNER	10-20 grams	**DINNER**	10 grams	**DINNER**	10 grams (12 if no snack)
SNACK (optional)	10 grams each	**SNACK** (optional)	5 grams each	**SNACK** (optional)	4 grams

Note that while TCR ways of eating typically involve eating less than 130 grams of carbohydrate per day, research and clinical reports indicate that individuals with T1D observe tighter blood glucose control with greater reductions in carbohydrate intake (Koutnik et al., 2023). In fact, Lennerz, Koutnik and colleagues demonstrated that 14 studies of people with T1D eating less than 50 grams of carbs per day showed better glycemic control with A1C averages between 4.0-6.2% versus 4 studies of people eating 51-130g/d indicating A1C averages between 6.4-7.2%. (Lennerz et al., 2021). Koutnik and colleagues demonstrated that the ADA target of HbA1c <52.5mmol/mol (<7%) was achieved in 10% of high-carbohydrate, 24% of moderate-carbohydrate (26-44%kcal), 78% of low-carbohydrate (10-25%kcal), and 100% of very-low-carbohydrate studies (Koutnik et al., 2024c). Three-quarters of all very-low-CHO studies achieved an average HbA1c <5.7%.

Total Carbohydrate and Net Carbohydrate

Individuals may ask about whether they should count total carbohydrate or net carbohydrate when carb counting and determining insulin doses. The idea behind net carbs is to quantify the amount of carbohydrate that affects blood glucose at each individual meal, aiding in the estimation of insulin requirements.

- When dealing with natural, carb-containing TCR foods such as vegetables and nuts, subtract the estimated grams of fibre from the total carb count to arrive at the net carb count.
- When dealing with processed packaged foods labelled as low-carb or keto products, it's advisable to approach with caution, using the net carb count as a starting point. Depending on individual responses, one might find that more insulin is required.
- While the estimated carbohydrate count on a product label provides a starting point, the actual impact on blood glucose levels depends on the specific ingredients and the amount of protein and fat within the food product. It's important to note that just because a processed food is labelled as low-carb or keto does not guarantee that it won't lead to a spike in blood glucose. For a comprehensive list of ingredients that may impact blood glucose, please refer to Appendix C.

> **Note that nutrition labels vary by country:** Some list "net carbs" directly, while others provide total carbs and fibre separately, requiring calculations to determine net carbs. Nutrition facts labels can have a margin of error of up to 20% per macronutrient, as accepted by the FDA and other regulatory authorities. This variability can lead to unexpected high or low postprandial blood glucose levels when using label information to calculate mealtime insulin boluses.

Selecting a TCR Transition Strategy

For individuals with T1D, selecting a starting approach for the TCR meal plan is crucial, as insulin dosing will depend on the chosen method. Consider two approaches for adopting a TCR meal plan:

1. "All in, 100% from day 1" approach:

This approach involves fully committing to the TCR nutrition intervention for all meals and snacks from a designated start date. It's akin to diving headfirst into the deep end of a pool, fully embracing the TCR plan from the outset.

While some practitioners may believe that a rapid dietary shift is too challenging, consistency in eating patterns is important for individuals with T1D due to the safety implications of insulin use.

Stable and predictable carbohydrate intake helps with effective insulin management. Mixing high-carb and low-carb meals and insulin dosing strategies may lead to confusion, potentially increasing the risk of both hypoglycemia and hyperglycemia, which may compromise safety and overall well-being. For these reasons, some individuals may choose an "all in" approach.

It's important to note that rapid improvements in glucose control - which may occur from very low carb TCR dietary changes - can potentially exacerbate existing diabetes-related complications, such as proliferative diabetic retinopathy, or trigger new complications like treatment-induced neuropathy in patients with chronic hyperglycemia. Therefore, for individuals with existing proliferative diabetic retinopathy and those with a history of severe, chronic hyperglycemia and very high A1C, a phased-in approach to TCR dietary changes is advisable. Refer to the "Diabetes-related Complications" section of this guide in Implementing the Nutrition Intervention for guidance tailored to individuals with existing retinopathy or a history of severe, chronic hyperglycemia and a very high HbA1c.

Rapid onset also may induce reductions in prandial insulin requirements (bolus) from the onset of the first meal. These reductions in insulin can rapidly result in a normal physiologic natriuresis effect resulting in reduction in sodium retention, which may require more immediate mineral supplementation to mitigate symptoms of fatigue and cramping, which can occur in some circumstances (see below).

2. "Phased in" approach:
With this approach, individuals gradually ease into the TCR nutrition intervention, akin to wading into a pool rather than diving in. They may start by incorporating TCR foods into specific meals or for a designated period. Options for this phased-in approach include:

- Starting with one meal at a time (e.g., making all breakfasts TCR) and adding another TCR meal every 3-7 days until all meals and snacks are TCR.
- Swapping out non-TCR foods with TCR alternatives (e.g., replacing white rice with cauliflower rice).
- Implementing a short trial period of TCR, such as 2-4 weeks, to help individuals and families assess readiness for further changes.

- Gradually reducing carbohydrate intake and adjusting glucose targets in incremental steps
    - This approach may be particularly beneficial for individuals with severe diabetes-related complications, such as proliferative diabetic retinopathy, as it allows the body time to adapt to lower carbohydrate intake and helps prevent sudden drops in blood glucose that could exacerbate existing cellular damage.

A phased in approach may minimize the rapid onset of the natriuresis symptoms and the necessity of mineral supplementation.

NUTRITION INTERVENTION CONSIDERATIONS

Consider the following unique considerations and nuances for a TCR Nutrition Care Plan in T1D.

☐ **Nutrition education** Supporting the transition to TCR involves equipping individuals and family members with knowledge and skills to manage food choices and eating behaviour, including providing help with or links to:

- TCR resources or referral to information including food lists, recipes and TCR recipe website and cookbook options, sample meal plans, dining out options, and meal planning tools (refer to *Appendix B - Patient Resources*).
- Information on culturally appropriate TCR foods to help families adapt TCR to their food preferences
- Carbohydrate counting apps and websites
- Techniques to weigh foods and measure macronutrients
- The effect of food choices on blood glucose and TCR mealtime insulin needs
- Understanding nutrition labels (especially for "keto foods"), glucose-spiking ingredients, and sugar alternatives, including sugar alcohols
- Methods for tracking food intake, insulin doses, and blood glucose responses to meals
- Insulin adjustments for TCR (ensuring collaboration with their prescribing medical practitioner) and hypoglycemia treatment
- Potential side effects of TCR initiation, such as the "keto flu"
- Hydration and electrolytes, particularly sodium intake
- Dining out and navigating social events
- TCR food and insulin strategies for different types of physical activity

☐ **Nutritional needs** Dietitians and nutritionist supporting individuals with TCR must recommend intakes for their energy and nutrient needs:

To guide meal planning, see *Appendix B - Patient Resources* for food ideas and sample meal sample meal plans.

- Specify daily net carbohydrate amounts or range of carbs
- Ensure overall energy requirements are met with adequate protein and fat intake when carbohydrates are reduced
- Ensure overall micronutrient requirements are met.
  - Consider recommending a carbohydrate-free daily multivitamin with minerals, especially for pediatric patients, if their nutrition plan does not provide sufficient micronutrients.
- Record estimated macronutrients in absolute terms (i.e. grams) rather than as a percentage of energy consumed
- Ensure adequate sodium, potassium, and magnesium in the diet. Recommended intakes for TCR VLC dietary patterns include: sodium (3000–5000 mg/d), potassium (3000-4000 mg/d), and magnesium (300-500 mg/d) to mitigate fatigue, muscle cramping, and risk for kidney stones.

☐ **Nutrition counselling** Dietitians and nutritionists must also:

- Individualize nutrition therapy within the TCR approach, based on the individual's needs, health goals, and food preferences
- Review the meal-planning approach. Ask the individual whether they plan to start with an "All In, 100% From Day 1" approach or a "Phased In" approach (see "Selecting a TCR Transition Strategy" earlier in this guide)
- Discuss family support and the home environment: How will this work at home? Who grocery shops? Who cooks? Which family members will eat this way? How does the individual feel about this?
- Review meal timing
- Establish health goals and expected outcomes

☐ **Tools and supplies**

Individuals doing TCR may be helped by using the following diabetes management tools:

- Continuous glucose monitoring (CGM)
- Blood glucose meter/glucometer
- Blood ketone meter
- Kitchen scale (grams)
- Macronutrient/food tracking app, diabetes management tracking app, or reference resource

☐ **Coordination of care**

Dietitians and nutritionists supporting individuals in TCR should also:

- Align the Nutrition Care Plan (NCP) with the individual's overall diabetes management strategy, including the use of insulin and other medications, exercise, and an illness/sick day management plan.
- Work closely with the prescribing medical practitioner who oversees insulin and medication adjustments.
- Refer to a diabetes educator for self-management education, including insulin management, monitoring, and other diabetes management methods, if needed.

☐ **Confirm with the individual with T1D and the family**

- Their understanding of adjustments to the insulin regimen and the management of hypoglycemia.
- Their plans for the self-monitoring of blood glucose and CGM use, if applicable.
- Their understanding of the importance of electrolytes, particularly during the transition to TCR, especially an adequate level of sodium intake, which can be up to 5 grams per day for adults.
- Their understanding of ketones and how to monitor ketones, and the difference between nutritional ketosis and diabetic ketoacidosis (DKA). Please refer to the *Clinical Considerations* section in this guide.
- The sick day guidelines their medical practitioner has in place for them to follow during sick days to meet insulin needs and prevent complications.

☐ **Documentation**

In line with other nutrition interventions, documentation should include:

- The TCR start date, details of intervention, established goals, and expected outcomes
- Education materials and resources utilized and provided
- Plans for follow-up and frequency of nutrition monitoring and support throughout the transition
- Referrals made for additional support or specialized care.

For T1D-specific documentation, ensure:

- Verification of the TCR insulin plan, inclusion of sick day guidelines and education on hypoglycemia treatment and ketone testing.
- Inclusion of the nutrition care plan within the broader diabetes care plan.

Implementing the Nutrition Intervention

Dietitians and nutritionists play a vital role in supporting implementation by regularly following up to confirm adherence to the plan, addressing any support needs of the individual or family, collecting data, and adjusting the nutrition intervention as necessary based on the individual's response to TCR. It is crucial to ensure that all members of the individual's diabetes care team are informed about the nutrition plan.

Below are specific considerations to bear in mind during the implementation phase.

Insulin Plan

AN INSULIN PLAN MUST BE IN PLACE PRIOR TO TCR IMPLEMENTATION. Not planning for appropriate adjustment in insulin type and dosage is THE MOST COMMON mistake when attempting to implement TCR in T1D. This should be done in consultation with the individual's prescribing medical practitioner prior to dietary changes being made.

Understanding how different macronutrients affect blood glucose and insulin needs is crucial for individuals managing T1D. This knowledge, combined with a trial-and-error process of keeping records and reviewing outcomes of mealtime insulin amounts and timing, will help individuals with T1D determine their TCR mealtime insulin needs.

Monitoring Blood Glucose and Making Insulin Adjustments

When implementing a TCR nutrition plan in T1D, the primary focus should be on monitoring blood glucose trends and adjusting insulin dosing and timing accordingly. More frequent self-monitoring of glucose levels via CGM or glucometer is essential during the initiation of TCR. Patients are encouraged to use a CGM when feasible and to promptly communicate any significant changes to their diabetes care team. As per standard practice, CGM alarms should be set to alert when glucose levels fall below or rise above target ranges, enabling prompt action through glucose treatment or insulin correction, and the ambulatory glucose profile (AGP) on a 7-to-14-day report can help to identify problematic trends.

Meal Planning for TCR in T1D

Meal planning can be valuable for individuals and families following TCR, as it allows them to plan their meals in advance and makes the dietary change feel more achievable.

1 Starting a TCR meal plan:

- **Select a transition strategy:** either an "All In, 100% Day 1" (fully commit to the TCR nutrition intervention for all meals and snacks from a designated start date) or a "Phased In" Approach (gradually ease into TCR by incorporating TCR foods into specific meals or for a designated period).
- **Specify macronutrients:** Determine daily net carbohydrate amounts (or range), and assess dietary protein and fat needs to meet overall energy requirements and health goals. Macronutrients should be recorded in grams.
- **Distribute nutrients:** Guide individuals or families to meet energy and micronutrient requirements and distribute carbohydrates, protein and fat throughout the day. This helps avoid 'banking' them or consuming them all at once, supporting more stable post-prandial blood glucose levels.

2 Supporting the transition:

- Provide resources for food selection and meal planning, including:
  - TCR food list
  - Recipes and TCR website and cookbook options
  - Sample meal plans
  - Meal planning tools
  - Dining out options

3 Practical Steps:

- Identify foods the individual or family already consumes that fit TCR guidelines.
- Find TCR meals and recipes that the individual may already eat or be interested in trying.
- Provide a list of foods which can be "swapped" for low-carbohydrate ingredient options that fit TCR guidelines.
- Create a grocery list to buy necessary ingredients.
- Determine who in the family will participate in meal planning, grocery shopping, food preparation, and clean-up.
- Talk with the individual or family about how they will track food intake, insulin doses, and glycemic responses to monitor progress and be able to make incremental adjustments, as needed.

See ***Appendix B – Patient Resources*** for a TCR food list and sample menu plans.

Energy Intake

It's essential to ensure that an individual's energy intake aligns with their health goals.

Weight loss can occur unintentionally during TCR due to natriuresis (sodium loss) and unintended caloric restriction, underscoring the importance of consuming nutrient-dense foods and adequate amounts of protein and fat to meet energy needs, if weight stability is a goal. Due to past dietary guidance promoting low fat consumption, many adults transitioning to TCR may harbour apprehensions about consuming fat-containing foods they perceive as unhealthy. However, it's crucial for TCR followers to prioritize adequate intake of fat-containing foods from a TCR list of foods to meet energy requirements and prevent unintended weight loss, especially for those aiming for growth, weight maintenance, or weight gain. There is no need for excess amounts of dietary fat, but adequate amounts of dietary fat are part of a well-formulated TCR eating pattern. Some may find it helpful to initially increase their fat intake when they first initiate TCR to assist with carbohydrate cravings, but can be tapered back once the person is more fat-adapted.

For people living with TID who want to lose weight using TCR, reducing dietary fat and increasing protein intake may help them achieve their goal. This means still eating the fat that comes with protein foods like meat and eggs, but enjoying high-fat foods such as nuts, cheese, butter, and avocado in smaller amounts.

Potential "Keto Flu" Side Effects

One aspect of supporting patients during TCR implementation is helping them manage potential mild side effects, commonly associated with 'keto flu', such as dizziness, lightheadedness, irritability, fatigue, headache, constipation, and muscle cramps. It's particularly important to maintain electrolyte balance and hydration during the transition to TCR; this point cannot be overstated. To help your patients avoid feeling unwell, stress that their hydration and electrolyte balance are crucial, as reduced carbohydrate intake to low and very low amounts leads to increased sodium excretion by the kidneys, resulting in greater loss of water and salt through urine (Tiwari et al., 2007; DeFronzo, 1981). This is a normal physiologic response to reduced carbohydrate intake.

As a dietitian/nutritionist, you can guide individuals to ensure adequate fluid intake, assess nutrient consumption, and incorporate sufficient amounts of sodium, potassium, and magnesium into their diets.This includes advising patients on appropriate water intake, suggesting salting foods or consuming salted broth or a (sugar-free) electrolyte drink, recommending potassium-rich TCR foods such as leafy greens, and considering a magnesium supplement if experiencing muscle cramps or difficulties with bowel movements. Inadequate sodium intake can also contribute to constipation. In general, it is recommended that people who follow TCR consume approximately 3,000 to 5,000 mg of sodium per day. It's important to note that individuals who restrict sodium due to a history of heart failure or salt sensitivity may need to continue to do so, in which case these recommendations would not apply.

Individuals who transition from a processed food diet to a whole foods way of eating may also experience temporary symptoms such as diarrhea, constipation, fatigue, headache, joint pain, skin flare-ups, or flu-like symptoms. This may occur for those with high levels of inflammation and/or impaired liver function. Drinking plenty of water, getting proper rest, light exercise, and reducing stress can support the transition period.

Monitoring Ketone Levels

It is important for all individuals with T1D to have a blood ketone meter and to know their normal ketone levels on TCR. Understanding these levels helps detect abnormal changes that may indicate the onset of diabetic ketoacidosis (DKA). During the implementation phase of TCR, dietitians and nutritionists can advise individuals with T1D to monitor blood ketone levels to establish a baseline and then later, when the individual has adjusted to this way of eating. This baseline serves as a reference for normal levels and helps the individual to assess ketone levels during times of illness or other situations where the risk of DKA is higher.

Dietitians and nutritionists can explain that blood ketone levels represent a snapshot in time and may vary at different times of the day and on different days. To observe baseline levels, individuals might test at the same times each day for a few days, such as upon waking and at bedtime. Blood ketone levels may decrease as the body adapts to using fat as its main fuel, but this varies from person to person.

If an individual with T1D under your care lacks information about ketone testing, when to raise concerns about ketone levels, or what to do if blood ketone levels are rising, refer them to their certified diabetes educator or endocrinologist.

For more information on ketones, nutritional ketosis, and diabetic ketoacidosis (DKA), please refer to the *Clinical Considerations* section in this guide.

Diabetes-related Complications

For individuals with existing retinopathy or at risk of diabetes complications, it is crucial to approach dietary transitions carefully, aiming for gradual and steady improvements over time. Dietitians and nutritionists can collaborate with patients diagnosed with proliferative diabetic retinopathy and those with a history of severe, chronic hyperglycemia to develop individualized, staged TCR plans. These plans should target a controlled HbA1C reduction of <2% over 3 months, as recommended by Gibbons and Freeman (2015) for all treatments that can result in rapid glucose control improvements, to mitigate the risk of worsening or developing microvascular complications.

Patients should be informed about the risks of rapid glycemic changes, and dietitians and nutritionists can work with them to implement gradual dietary adjustments and blood glucose target modifications to ensure steady progress.

When completing a nutrition assessment for individuals with advanced diabetes-related complications, coordinate care with the patient's ophthalmologist for a retinopathy screening. In caring for patients with proliferative diabetic retinopathy, consider adjusting glucose targets and reducing carbohydrate intake incrementally, while explaining the rationale behind incremental changes (refer to the "Phased In" approach explained under the section, *Planning the Nutrition Intervention*, in this guide). Furthermore, emphasize the importance of closely monitoring diabetes-related complications and promoting self-monitoring, with prompt reporting of any changes or symptoms.

TCR in T1D: Nutrition Monitoring and Evaluation

Individuals with T1D who adopt a TCR nutrition plan benefit from weekly, or even daily, clinical monitoring, particularly during the initial transition period due to potential for rapid changes in glucose and insulin. These early days are crucial and require close oversight and patient support. Regular follow-up appointments and communication between patients and their healthcare professionals are vital to fine-tune insulin regimens and optimize glucose management during the transition. Ongoing follow-up is necessary for supporting long-term lifestyle changes, evaluating outcomes, and modifying interventions as needed.

The coordination of care in monitoring a patient following dietary changes is essential, as is clarity regarding the roles of each clinician involved in the patient's care. This ensures the patient knows whom to contact with questions and concerns.

Below is an overview of suggested monitoring and corresponding timelines for individuals with T1D embarking on a TCR nutrition plan.

Initiation of TCR (Week 1)

Because dietary changes warrant immediate insulin adjustments as well as possible changes to diabetic medications in those with T1D, Days 1-7 of a TCR nutrition plan require more frequent contact, monitoring, education, and follow-up from the diabetes care team. This will vary from patient to patient; however, it is wise to have monitoring standards in place in advance. The goal during the initiation phase is to reach stability with glucose levels and insulin needs.

During the first one to two weeks of starting TCR, it is crucial for the prescribing medical practitioner to monitor insulin and glucose levels closely in order to respond to changing insulin needs and to follow-up quickly to confirm that changes were successful. The greatest risk of hypoglycemia occurs in the first few days of starting TCR.

Remote monitoring of CGM and pump data can facilitate rapid follow-up. More frequent self-monitoring of glucose levels via CGM or glucometer is essential when initiating TCR, and the individual's CGM alarms should be set to indicate when glucose levels fall below or rise above target ranges, enabling prompt action through glucose treatment or insulin corrections.

Discuss with the patient and their family whether email, text, or phone will be used in the first week to answer questions and provide guidance and reassurance regarding :

- Troubleshooting issues related to:
    - Insulin dosing and blood glucose control, especially hypoglycemia.
    - Other diabetic medications.
    - Lower blood pressure due to greater sodium excretion.
        - People experiencing lower blood pressure who are on antihypertensives may benefit from ambulatory blood pressure monitoring as they may require reduction in blood pressure medications.
        - People experiencing lower blood pressure who are not on antihypertensives may need to focus on hydration and adequate sodium intake.
- Challenges related to starting TCR, including food choices, meal planning, possible transitional side effects (keto flu and digestive difficulties), and attending social events involving food.
- Questions pertaining to glucose trends, ketone levels, symptoms, hydration and electrolytes.

Short Term (First 2 Months)

As the individual starts to adapt to a TCR nutrition plan, contact may be less frequent, yet consultation visits or follow-up communication should be scheduled more frequently in the short term. Your patient may wish to have weekly visits for the first several weeks as they become accustomed to their new way of eating and as glucose levels and insulin needs stabilize.

Further assessments should be conducted as needed, based on patient observations of insulin sensitivity and/or blood glucose levels affected by TCR meals. Ideally, long-acting/basal insulin should be reviewed within 2 to 4 weeks of implementing TCR, particularly if there has been a significant reduction in carbohydrate load and/or immediate weight loss.

In addition to assessing the insulin regimen, short-term nutrition monitoring may involve:

- Discussing any challenges, barriers, or presenting symptoms when following TCR that the individual may be facing.
- Food recall to review any concerns around energy and micronutrient intake, TCR meal composition, carbohydrate quality and quantity, and carb counting skills.
- Reviewing the foods to focus on to help the individual incorporate essential nutrients that do not meet daily requirements (e.g. total energy, protein, fibre, calcium, iron, a variety of fats)
- Discussing hunger and satiety levels, weight fluctuations, and symptoms such as fatigue, cravings and brain fog. It's also important to consider the impact of not meeting energy, electrolyte, and hydration needs.
- Evaluating glucose trends using glucometer downloads and CGM reports to assess carb counting, reviewing the impact of protein and fat on glucose, discussing food options and substitutes, and advising the patient to see their prescribing medical practitioner for insulin dosing strategies.

> **As individuals adjust to a new way of eating, education and support may focus more on psychosocial aspects of TCR**, such as eating away from home, choosing foods from restaurant menus, attending parties where food is served, and eating at school or work functions.

Medium Term (Month 3-6)

Suggested medium-term nutrition monitoring includes:

- Tracking height and weight, particularly changes in weight.
  - Children and adolescents: track and evaluate pediatric growth pattern indices/ percentile ranks, as appropriate.
- Reviewing food diary for nutritional evaluations.
  - Assessing caloric intake is especially important for the growth of children and adolescents to ensure they get enough energy. Adults following a VLCD using TCR may also unintentionally reduce their energy intake, making caloric adequacy assessments relevant for them as well.
- Reviewing laboratory assessments for: fasting lipid panel, complete blood count (CBC), comprehensive metabolic panel (CMP), HbA1C as well as blood pressure level and any follow-up labs necessitated by results from baseline testing.
- Appropriate follow-up or further laboratory assessment of nutrient values if an analysis of a food diary reveals low intake of certain essential vitamins and trace minerals, especially for growing children.

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T1D & THE IMPACT OF TCR ON INSULIN NEEDS

SECTION 04

T1D & THE IMPACT OF TCR ON INSULIN NEEDS

In T1D, individuals depend on insulin medication to balance blood glucose and to metabolize foods. Changing the diet of a person with T1D will lead to significant alterations in their mealtime insulin requirements. It may also impact their basal insulin and diabetes medication requirements. The total daily insulin dose in individuals who have stably transitioned to TCR may be reduced to as little as 50% of the prior total daily doses, with a range from 25% to 75% (Koutnik et al., 2024c). Any changes in the diet should be discussed with the person's diabetes care team and the prescribing medical practitioner to make informed decisions regarding insulin dosing and diabetes medications.

TCR ways of eating use adequate dietary protein and fat, and limited carbohydrate to meet nutrient and energy needs. Thus, changes in the prandial insulin strategy will be required for metabolizing these foods and maintaining balanced blood glucose levels, including changes in the timing and dosage and possibly even the type of insulin.

> **When a patient transitions to TCR,** it is crucial for them to understand that their insulin needs will likely change, requiring adjustments to their insulin dosing regimen.

The Impact of TCR on Insulin Needs: Key Points

As mentioned in the preceding section, *TCR Nutrition Care Process*, when an individual with T1D begins TCR, it's important to consider the changes in their insulin needs.

- The initiation of TCR in individuals with T1D brings about rapid physiological changes. These changes affect insulin requirements. Notably, switching to a TCR way of eating changes how much rapid-acting mealtime insulin one needs, often requiring a significant decrease to prevent hypoglycemia. Caution must be exercised.
- It is essential for the prescribing medical practitioner to prepare an insulin dosing plan with the patient as a starting point before dietary changes are made. Follow-up monitoring to assess insulin needs and make adjustments is required to ensure patient safety.
    - If a general practitioner (GP) does not have the expertise to adjust insulin dosing effectively, collaboration with a credentialled diabetes educator can provide valuable support to both the dietitian/nutritionist and the GP.
- The ability for the person to accurately carbohydrate count will assist in building their confidence to adjust insulin to match intake.
- Consideration should be given to the impact of protein and fat on insulin needs.
- Additionally, changes in insulin sensitivity may influence basal insulin needs.
- Patients should be encouraged to use a CGM or to test more frequently using a glucometer, especially in the early days of transition to TCR, to allow close monitoring of glycemic responses and to make adjustments as needed.

Common Insulin Patterns in TCR in T1D

Common insulin patterns for those with T1D eating TCR meals and snacks include the following:

- To cover small amounts of dietary carbohydrate, small doses of rapid-acting insulin or regular insulin.
- To cover dietary protein and fat, regular insulin or (split-bolus or extended-bolus) rapid-acting insulin.

See "Common Considerations for the Medical Practitioner Prescribing Insulin During the Transition to TCR" below.

The Role of Dietitians and Nutritionists Related to Insulin Management

Educating individuals with T1D on how TCR foods affect their insulin needs

The role of dietitians and nutritionists in supporting an individual with T1D interested in starting TCR primarily focuses on providing dietary guidance and its possible impact on blood glucose levels.

Most dietitians and nutritionists do not have the responsibility to make insulin adjustments (unless they have the appropriate authorization in their jurisdiction); rather, they collaborate with the medical practitioner in charge of insulin prescriptions. The prescribing medical practitioner, in turn, works with the patient to discuss necessary adjustments to insulin and other medications before the patient implements TCR. Dietitians and nutritionists ensure that a copy of the nutrition care plan is included in the diabetes care plan, and they can provide information to the prescribing medical practitioner about the effect of food choices on blood glucose.

As noted earlier, dietitians and nutritionists provide nutrition education to help individuals with T1D understand how food choices impact their bodies. This nutrition education helps those with T1D understand their insulin needs when following TCR, empowering them to effectively manage their blood glucose and gain confidence in their diabetes management. It is also important that all members of the diabetes care or health team ensure that the individual is aware that an insulin dosing plan must be in place prior to making dietary changes, to reduce the risk of hypoglycemia.

Common Considerations for the Medical Practitioner Prescribing Insulin During the Transition to TCR

It is recommended for the prescribing clinician to:

- Be aware that insulin needs are expected to decrease significantly and that dose reductions should be planned for to reduce the risk of hypoglycemia.
- Review the patient's TCR nutrition plan, current insulin regimen, and all medication.
- Evaluate the patient's ability to self-manage, including regular blood glucose monitoring, knowledge of insulin use, and proficiency in identifying and treating hypoglycemia effectively.

- Collaborate with the patient to establish an initial insulin dosing regimen for a transition to TCR.
  - This plan will be tailored based on whether the TCR nutrition plan follows an "All In, 100% Day 1" approach or a gradual, "Phased In" dietary shift, like introducing TCR meals for breakfast only.
- Assess the suitability of the patient's basal insulin regimen and collaborate with them to make any necessary adjustments.
- Double check if the patient is taking SGLT2 inhibitor medication, which may have been prescribed by another medical specialist as off-label adjunct to insulin for the care of people with T1D.
  - The clinician can educate the patient that taking SGLT2 inhibitors may increase the risk of DKA, including euglycemic DKA, in people with T1D and also in the setting of very low carbohydrate diets.
  - To minimize the risk of DKA, SGLT2 inhibitor medication should be discontinued at least 4 days prior to starting TCR to allow for medication washout.
  - In individuals on SGLT2 inhibitors for cardiorenal indications, resuming these medications a few weeks or months after dietary transition may be warranted, or cautious continuation of dietary changes with increased monitoring for DKA, including ketone monitoring with access to a blood ketone meter.
- Review and adjust any non-insulin diabetic and anti-hypertensive medications to ensure patient safety. Reducing carbohydrate intake can lead to increased water loss and sodium excretion, potentially affecting blood pressure. Self-monitoring of blood pressure may be beneficial for patients on antihypertensives who are at high risk of hypotension.
- Consider other medication classes that may require adjustment as the patient responds to TCR dietary changes include psychiatric medications, reflux medications, statins, warfarin, some anticonvulsant medication, and thyroid hormone.
- Set an initially higher blood glucose target range during the introduction phase of TCR to mitigate the risk of hypoglycemia.

Considerations for Prandial Insulin

TCR ways of eating use adequate dietary protein and fat and limited carbohydrate to meet nutrient and energy needs. Thus, when transitioning to TCR, changes in the prandial insulin strategy will be required for metabolizing these foods and maintaining balanced blood glucose levels.

For dietary protein and fat, meals high in these nutrients can affect individuals with T1D differently. Different types of protein foods are digested and absorbed at varying rates, affecting the required amount and timing of insulin doses. For example, fish might need a smaller insulin dose administered before the meal. In contrast, beef may require a larger dose, which could be administered in several ways: as a split dose before and after the meal, or as a fully delayed dose, given during or after the meal. The fat content in protein foods also impacts blood glucose levels and insulin requirements. Individuals should

exercise caution, particularly for the evening meal to prevent nighttime hypoglycemia, and should carefully monitor food intake, insulin dosage and timing, as well as glycemic responses. Adjustments should be made as necessary.

Regular (short-acting) insulin's action profile has slower onset with a delayed peak (Eli Lilly, Feb. 2015), which is commonly utilized by patients following TCR and also aligns with the timing of the glycemic response from a meal high in dietary protein and/or fat. However, patients may not have access to Regular insulin or want to use Regular insulin injections if using an insulin pump. Thus, when using rapid-acting insulin to cover these nutrients, individuals may require reduced insulin doses and split bolus injections for those using multiple daily injections (MDI), or extended-, split-, or dual-wave bolus options for insulin pump administration.

- During the initial transition to TCR, if an individual consumes around 8 to 10 grams of carbohydrate per meal, it may be beneficial to temporarily halt prandial dosing. Temporarily discontinuing prandial insulin for a VLCD allows for an assessment of its impact, and subsequent dosing can be adjusted based on the individual's insulin-to-carbohydrate (I:C) ratio.
- Monitoring and promptly adjusting insulin in the first 24 to 48 hours after an individual initiates TCR supports a safe and effective transition as changes in glycemic and insulin load occur at the first meal (Hengist et al., 2023). Remote monitoring of CGM and pump data can facilitate rapid follow-up.
- TCR prandial dosing for carbohydrate may consider:
  - small doses of rapid-acting insulin. The timing of a rapid-acting insulin bolus may also change, and individuals may not require a pre-bolus of prandial insulin, or
  - some individuals eating very small amounts of carbohydrate may meet their insulin needs using Regular insulin.

- TCR prandial dosing for protein and fat may consider:
  - Regular (short-acting) insulin via injection,
  - rapid-acting insulin via injection, which may need to be split into two bolus injections and/or given after the meal (e.g. postprandial bolus 1-2 hours after eating), or
  - rapid-acting insulin in a pump via split-bolus, dual wave, or extended bolus options, with extended bolus durations typically over 3-5 hours in duration.
- If the individual is using insulin injections and requires smaller doses at mealtime, utilizing 0.5-unit insulin syringes and pens can be beneficial. Small children may benefit from diluted insulin. Insulin should only be diluted with diluent from the same manufacturer as the insulin itself and should be done under the guidance of an experienced diabetes care provider or clinical pharmacist.
- Some individuals with closed-loop pump systems may experience stable blood glucose following a TCR meal without delivering a mealtime bolus, as their pump may automatically make insulin adjustments to maintain blood glucose in target range.

Considerations for Basal Insulin

The basal to bolus insulin ratio of 50:50 commonly recommended on moderate-high carbohydrate diets in people with T1D not following TCR in the VLCD range will likely be different in someone with T1D who follows a carb-restricted diet. Ratios of 70:30 to 90:10 may provide better glycemic balance for people with T1D following TCR due to the smaller carbohydrate influx. Any individual's basal:bolus ratio is the outcome of careful titration, not a goal of its own.

If insulin resistance is suspected due to high total daily insulin needs, reduce up to 50% for initial diet changes with an "All In, 100% Day 1" approach (see "Selecting a TCR Transition Strategy" earlier in this guide). The reason for this is that the insulin resistance component of the person's physiology may rapidly normalize, leaving them with the underlying insulin deficiency alone. If no insulin resistance is suspected, reduce 25% or so.

The titration process should be tailored to the individual's needs and guided by the assessment of CGM or glucometer data.

"As the principal determinant of postprandial glycemia, dietary carbohydrate offers an attractive therapeutic target."

Lennerz et al., 2021, p.1

TCR Insulin Dosing Principles to Communicate with Patients

Dietitians and nutritionists should clearly communicate the following messages about insulin dosing to their patients:

- Due to the TCR foods you will be eating, your mealtime insulin needs will change when you transition from a high-carb way of eating to a lower-carb way of eating. It is important for you to be aware of this, as rapid-acting insulin typically needs to be reduced (often significantly). Extra caution is needed to avoid the risk of hypoglycemia.
- When following TCR and eating small amounts of carbohydrates, you may notice the following:
    - your blood glucose levels are not likely to rise high immediately after eating.
    - your blood glucose may, however, rise a little right after eating due to the carbohydrate and then gradually rise later on due to the effects of protein and/or fat.
    - If you eat a meal very high in fat, you may observe both a delayed glycemic response from the carbs or protein, plus the possibility of high blood glucose that begins to rise more than 3 hours after eating and into the ensuing hours.
    - Depending on the amount and type of dietary fat consumed, prolonged high blood glucose may occur unless insulin needs are met.
- To help you transition to TCR, your prescribing medical practitioner will help you prepare an insulin dosing plan as a starting point. You are encouraged to use a CGM or to test more frequently using a glucometer, especially in the early days of your transition to TCR, to allow close monitoring of glycemic responses and to make adjustments as needed.
- When you lower your carbohydrate intake, you may find that your blood glucose may become more 'responsive' to carbohydrate, meaning that even small amounts of carbohydrate will cause a blood glucose response. This can result in the need to strengthen bolus calculator carbohydrate ratios (insulin to carb ratio).
- When following TCR, you may find you are more sensitive to insulin, and over time, this will result in the need to weaken correction/sensitivity bolus calculator ratios and reduce basal insulin rates.
- If you experience hypoglycemia on a TCR diet, you treat it the same way you treat hypoglycemia at any other time - with a fast-acting carbohydrate, preferably using glucose or dextrose.

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SECTION 05

CLINICAL CONSIDERATIONS

KETONES, NUTRITIONAL KETOSIS, AND DIABETIC KETOACIDOSIS

PEDIATRIC GROWTH AND NUTRITIONAL ADEQUACY OF TCR

RISK OF HYPOGLYCEMIA

EATING DISORDERS

CHOLESTEROL

PREGNANCY

DIETARY PROTEIN AND KIDNEY HEALTH

CLINICAL CONSIDERATIONS
KETONES, NUTRITIONAL KETOSIS & DIABETIC KETOACIDOSIS (DKA)

Nutritional ketosis and diabetic ketoacidosis (DKA) are different conditions and should not be confused. Understanding the distinction between these two states is vital, especially in T1D management, where confusion can arise and lead to unnecessary anxiety and misunderstanding. The mere mention of 'ketones' can evoke fear among those managing diabetes. Many individuals have been diagnosed with T1D while experiencing DKA, especially among the pediatric population where approximately half of children diagnosed in America present with DKA (American Diabetes Association, 2023, p. S20). This fear can stem from a lack of understanding about why the body produces ketone bodies.

Because reducing carbohydrates is often linked to the ketogenic diet, the word 'ketones' is implicated. Clinicians may worry that even small amounts of ketone bodies in the blood may make a person with T1D more susceptible to developing DKA. With sufficient insulin and blood glucose levels in target range, individuals with T1D can safely follow a very low carb or low carb TCR way of eating. All individuals with T1D are at potential risk of DKA due to endogenous insulin deficiency and the compromised action of exogenous peripheral insulin, and they need to be made aware of this during times of illness and in situations where DKA risk is heightened, such as if there are concerns about their adherence to their insulin regimen. Following a TCR diet may raise ketone level, but it will not increase the risk of DKA as long as they use sufficient insulin.[2]

Individuals with T1D who follow TCR may or may not have ketone production at levels considered to be in a state of nutritional ketosis. Though typically not a primary goal of using TCR nutrition therapy in T1D - which is geared towards reducing mealtime glucose fluctuations and improving glycemic control - nutritional ketosis may have potential therapeutic, metabolic benefits in T1D, similar to those seen in conditions like type 2 diabetes, epilepsy, and obesity. It is crucial for dietitians, nutritionists, and individuals and families living with T1D to understand the metabolic role of ketone bodies and to differentiate between the clinical manifestations of nutritional ketosis and DKA. This knowledge will enable comprehensive support to those living with T1D and to help them understand how the body utilizes energy from different sources to meet its needs. More comprehensive discussion of ketones can be found in these referenced citations (Puchalska & Crawford, 2021; Poff, Koutnik & Ega, 2020)

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2 Note it is currently contraindicated for individuals with T1D to follow TCR while taking a SGLT2 inhibitor medication, as that may increase the risk of DKA, including euglycemic DKA. See the section in this guide on "Common Considerations for the Medical Practitioner Prescribing Insulin During the Transition to TCR" for further information about SGLT2 inhibitor medication.

> **It is crucial for individuals and families living with T1D to understand how to monitor blood glucose and ketone levels, as well as insulin needs during illness (especially dehydrating illnesses), infections, or other acute stressors.** They must also recognize that insulin omission or pump malfunctions can lead to uncontrolled ketone production and DKA. Diabetes education on these topics is essential for preventing complications and reducing the risk of severe events like DKA, regardless of dietary approach. Dietitians and nutritionists should inquire whether individuals have a sick day plan from their diabetes care provider and if they know how to respond if their insulin pump fails.

Ketone Bodies

- Ketone bodies are regulated across numerous metabolic pathways, derived from the breakdown of fatty acids, and utilized by the body as an energy source. Humans, both with type 1 diabetes or without, produce some ketone bodies for energy utilization, particularly in the setting of fasting or of carbohydrate restriction.
- Ketone bodies have been demonstrated to have independent metabolic, signalling, and epigenetic regulator properties in therapeutic ranges (Puchalska & Crawford, 2021; Poff, Koutnik & Ega, 2020).
- Insulin plays a crucial role in regulating ketone production (Dhillon & Gupta, 2023).

THERE ARE 3 DIFFERENT TYPES OF KETONE BODIES

Ketone Body	Acetoacetate	Beta-hydroxybutyrate	Acetone
Measured via	Urine ketone strips	Blood ketone strips	Ketone breath analyzers

Ketone Testing in T1D

There are different ways to test ketone bodies.

In T1D, it is important for all patients, regardless of diet, to have access to a blood ketone meter. Individuals transitioning to TCR should monitor their blood ketone levels to establish a baseline. This baseline serves as a reference point of their normal ketone levels while following TCR, so they will be better able to assess and understand ketone levels during times of illness and in other situations where the risk of DKA is increased.

In T1D, the most important ketone body to measure is beta-hydroxybutyrate (R-BHB) in the blood via blood ketone strips.

Testing urine for ketones might not accurately reflect the severity of ketone levels in the blood (Glaser et al., 2022, p. 838).

Nutritional Ketosis

When an individual metabolizes a sufficient amount of ketone bodies for energy and reaches a specific threshold (established by human standards), this state is referred to as nutritional ketosis.

- Those who consume minimal carbohydrates (typically no more than 20-50 grams/day) may be in nutritional ketosis, or simply, ketosis (Association of Diabetes Care & Education Specialists, 2023). Typically, their blood levels of beta-hydroxybutyrate (BHB) range between 0.3-5.0 mM, with ketone production regulated by sufficient insulin levels.
- Individuals following a high-fat, very low carb TCR diet (LCHF), consuming medium-chain triglycerides such as coconut oil or MCT oil, or undergoing weight loss may experience elevated blood ketone levels consistent with nutritional ketosis.
- Some individuals may initially enter nutritional ketosis as they transition to TCR and may exit this state as their body adapts to reduced carbohydrates and insulin and elevated fat metabolism (i.e., "fat adaptations"; "keto-adaptation").
- Those adhering to a higher-protein TCR approach (LCHP) may not experience nutritional ketosis and may have ketone levels similar to those consuming higher-carb diets.
- In addition to limited carbohydrate, other physiological causes of ketosis include: fasting, pregnancy, parturition, lactation, prolonged exercise, and acute sickness/illness.

Diabetic Ketoacidosis (DKA)

- The reason ketone bodies are an important focus on T1D management is that abnormally high ketone levels can indicate a state of DKA. High ketones, along with uncontrolled hyperglycemia and metabolic acidosis, are characteristic of DKA and accompany symptoms.
- DKA is a life-threatening condition and can occur rapidly in T1D. Clinical presentation includes hyperglycemia, abnormally high ketone levels, acidosis, and various symptoms, including polyuria, polydipsia, weakness, and air hunger (Gougen and Gilbert, 2018).
- In T1D, triggers for DKA may include: insulin omission, inadequate insulin delivery (e.g. insulin pump malfunction), inadequate insulin medication effect (e.g. spoiled insulin), SGLT2 inhibitor medication, infection, and/or illness, particularly when the illness is dehydrating due to vomiting, diarrhea, and/or loss of appetite.
- Individuals with T1D benefit from a solid education in understanding the importance of insulin needs, hydration, electrolyte intake, and close monitoring during times of illness and infection. Frequently monitoring blood ketones during an illness or injection is recommended, and patients should feel knowledgeable about how to manage diabetes during an illness and when to contact their medical provider to report an illness and seek medical assistance.
- Individuals with T1D and their caregivers should have access to medical assistance to help manage sick days.

DIFFERENTIATING NUTRITIONAL KETOSIS FROM DKA

Distinguishing Features of Diabetic Nutritional Ketosis vs Diabetic Ketoacidosis Under Therapeutic Carbohydrate Reduction and Moderate-High Carbohydrate Diets

It would be expected that individuals will have most or all of the features within each category.

	Diabetic Nutritional Ketosis	Diabetic Ketoacidosis	
Dietary Pattern	**Therapeutic Carbohydrate Reduction**	**Therapeutic Carbohydrate Reduction**	**Moderate-High Carbohydrate**
Carbohydrate Intake	<130grams/day (typically <50 grams/day[1])	<130grams/day	<130grams/day
Clinical State	Normal/Physiological	Pathological	Pathological
Key Stimulus	Diet-Induced	Insulin-Deficiency	Insulin-Deficiency
Ketone Production	Regulated	Unregulated	Unregulated
Symptoms[2]	No	Yes	Yes
Blood Ketones (*R-BHB*)[3]	0.3-5.0mmol/L	>10mmol/L	≥5.3mmol/L
Blood Glucose[4]	3.9-10mmol/L	>13.9mmol/L	>13.9mmol/L
	70-180mg/dL	>250mg/dL	>250mg/dL
Urine Ketones	Variable	Variable	Present
Ketone Production	Regulated	Unregulated	Unregulated
Venous pH[5]	>7.3	≤7.3	≤7.3
Serum Bicarbonate[5]	>18mEq/L	≤15-18mEq/L	≤15-18mEq/L

Table outlines the key distinguishing features of diabetic nutritional ketosis and diabetic ketoacidosis. It would be expected that individuals will have most or all of these features within each category. Nutritional ketosis is a physiologic state of elevated ketones which is normal in response to reduced carbohydrate intake and lower insulin levels. This state does not accompany symptoms. Diabetic ketoacidosis (DKA) during TCR and Moderate-High Carbohydrate diet strategy. The key distinguishing factors between TCR DKA and moderate-high carbohydrate diet DKA is the commonly observed serum levels of ketones (R-ßHB). While it is common to present with all key features, there are exceptions as outlined below.

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1 The elevations in blood ketone bodies is a defining feature of nutritional ketosis. Elevations in ketone bodies >0.3mM is not commonly observed unless carbohydrates is <50g/day.

2 Symptoms: excessive urination, dehydration, nausea, vomiting, fatigue, rapid breathing.

3 While nutritional ketosis is often defined as 0.5-5.0mmol/L (Volek et al. 2024; PMID: 38814519), overnight fasting R-ßHB ≥0.3 is uncommon without therapeutic carbohydrate reduction (TCR; Balassee & Fery 1989; PMID: 2656155). Patients with type 1 diabetes (T1D) have observed R-ßHB up to 8mmol/L during extended fasting and exercise without adverse side effects or symptoms (Lake 2021; PMID: 34334612). On a moderate to high-carbohydrate diet and fed state, institutional bodies have previously recommended >3.0mmol/L as the ketone benchmark for DKA (PMID: 32409703). However, ≥5.3mmol/L R-ßHB with hyperglycemia (>13.9mmol/L; >250mg/dL) is the most reliable indicator of DKA (Tremblay et al. 2021; PMID: 32011560) in T1D's on moderate to high carbohydrate diets.

4 Although rare, euglycemic DKA (3.9-7.8mmol/L; 70-140mg/dL) can occur in the absence of elevated glucose levels (Roberts et al. 2024; doi.org/10.2337/db24-1989-LB) and typically occurs alongside acute elevations in energetic demand (e.g., illness/sickness; breastfeeding) or with exogenous glucose lowering medication which reduce insulin levels (i.e., Sodium Glucose Transport 2 Inhibitors; SGLT2i).

5 While venous pH and serum bicarbonate, presented herein are what would be expected to occur alongside other key metrics to establish DKA, DKA has been observed in rare case with people with type 2 diabetes on a very-low carbohydrate diet undergoing caloric restriction (Roberts et al. 2024; doi.org/10.2337/db24-1989-LB).

The Role of Dietitians and Nutritionists Related to Ketone Monitoring

Confirming that patients understand DKA and the importance of ketone monitoring, with referrals to diabetes educators as needed

Regardless of dietary approach, individuals with T1D are susceptible to DKA. When providing nutrition care in T1D, ensure that patients:

- Understand how DKA can occur and the symptoms of DKA.
- Understand that insulin requirements may increase significantly during illness and have a sick day plan from their medical provider and are educated on managing illnesses.
- Have access to a blood ketone meter, and understand how and when to test and interpret their blood ketone levels, especially when transitioning to TCR and during times of illness, infection, and stress.
- Test their blood ketone a few times after starting TCR to establish a baseline ketone level, which will serve as a reference point of their normal ketone levels while following TCR
- Recognize the importance of hydration, fluids and electrolytes during illness.
- Know when and where to seek emergency assistance if DKA concerns arise.

> **If an individual with T1D under your care lacks information about ketone testing,** when to raise concerns about ketone levels, or what to do if blood ketone levels are rising, refer them to a certified diabetes educator or their endocrinologist.

Pediatric Growth and Nutritional Adequacy of TCR

Ensuring optimal growth and nutritional adequacy in children with T1D is paramount for their overall health and development. Pediatric growth serves as a crucial indicator of general well-being and metabolic control. While TCR ways of eating have gained attention for managing T1D, concerns arise regarding their potential impact on growth and nutritional sufficiency. Observational and care studies have reported no negative impact on growth from TCR (McClean et al., 2019; Lennerz et al., 2018) while one case report suggested potential negative outcomes (de Bock et al., 2018). While there is currently no rigorous evidence that TCR is associated with negative growth in T1D (Lennerz, Koutnik et al., 2021), the lack of rigorous evidence necessitates a deeper exploration of the interplay between TCR and pediatric nutrition. In managing the needs of children with T1D, it is essential to prioritize a nutritionally adequate diet that supports growth, minimizes hyperglycemia and hypoglycemia, and safely strives for blood glucose levels as close to normal as possible to mitigate long-term complications and to promote overall health.

When considering the potential impact of TCR on growth and nutritional sufficiency in children with T1D, it is important to distinguish between the macronutrient composition of the 4:1 Classic Ketogenic Diet (CKD), which uses 90% calories from fat for childhood epilepsy, and the variations used in T1D management. Drawing comparisons between these dietary approaches can lead to misconceptions regarding their effects on growth outcomes. For instance, equating the risks associated with a 4:1 or 3:1 CKD for epilepsy with TCR eating patterns for T1D overlooks important nuances. Studies on ketogenic diets for children with epilepsy highlight their design to mimic fasting, providing 90% of energy from dietary fat and generally limiting energy intake to about 75% of the recommended dietary allowance, which has been associated with nutrition-related growth failure (Vining et al., 2002; Groleau et al., 2014). In contrast, TCR for children with T1D does not aim to replicate a fasted state. Its macronutrient composition is designed to achieve optimal glycemic control while meeting energy and growth requirements, with a lower proportion of dietary fat and higher amounts of dietary protein compared to the Classic Ketogenic Diet. The increased intake of dietary protein in TCR in T1D can supply essential amino acids, essential fatty acids, vitamins, minerals, choline, and carnitine needed for proper growth, development, and efficient energy metabolism in children and adolescents.

In light of these considerations regarding the potential impact of TCR on growth and nutritional sufficiency, it's essential to delve deeper into how TCR aligns with the specific dietary needs of children with T1D. In TCR in T1D, children are not restricted in their protein intake and can consume protein to satiety. Insulin remains essential for proper growth and development, and children and adolescents with T1D following TCR require exogenous insulin to cover their basal needs as well as the protein, fat, and carbohydrate components of their meals. Dietary protein specifically increases IGF-1, a critical hormone for developmental bone growth. This balance between protein and insulin availability is crucial for facilitating

normal growth and IGF-1 levels. TCR nutrition patterns are designed to support this balance, while allowing families to pursue normal blood glucose levels more safely. Elevated HbA1cs, which are common among children on standard high-carbohydrate diets, are associated with growth impairment and negative effects on brain development. Of note, elevated HbA1c values are also associated with dysregulation in IGF-1. This highlights the importance of metabolic management from an early age, which TCR as a therapy aims to improve.

When carbohydrate intake is limited for medical reasons, children must consume enough protein and fat to have sufficient energy and allow their bodies to grow, repair, and maintain health. **Thus, pediatric TCR nutrition plans should:**

- Prioritize food high in protein for growth and for essential amino acids, vitamins and minerals
- Include a variety of fat-containing food to meet energy needs and for essential fatty acids, vitamins and minerals
- Include nutrient-dense, fibre-rich food low in carbohydrate like non-starchy vegetables, berries, nuts and seeds, for energy and for vitamins and minerals
- Consume fluids for adequate hydration.

> **Dietitians and nutritionists can offer assistance to families in choosing nutrient- and energy-dense foods,** formulating the diet appropriately, conducting food diary evaluations, and conducting regular follow-up monitoring to ensure children on TCR receive adequate nutrients while managing T1D.

Consider the actions below for follow-up monitoring and evaluation:

- Ensure the child or adolescent consumes sufficient dietary protein and fat to prevent energy deficits and meet their growth-related energy requirements.
- Recommend incorporating a variety of nutrient-rich foods, such as animal-based protein, dairy, non-starchy vegetables, low-glycemic fruits, nuts, and seeds.
- Encourage limiting the consumption of processed foods labelled as keto or low-carb products, as they may lack essential nutrients despite claims of minimal impact on blood glucose. However, these products can help support the transition to TCR, especially for adolescents who are influenced by their peers and prefer foods that resemble what their friends are eating, often opting for convenience foods outside the home.
- Support the transition to this dietary approach, allowing families time to adapt and acquire the skills and knowledge needed for grocery shopping and food preparation.
- Explore strategies to ensure the child has ample time to eat all meals and snacks, particularly during school days.
- Monitor the child's growth to ensure normal development.
- Refer the child to their diabetes care provider if blood glucose levels remain outside the Target range or fail to improve after implementing TCR. They can receive personalized education on insulin management strategies to better address their specific needs.

Two descriptive studies offer valuable insights for dietitians and nutritionists by demonstrating the nutrient adequacy of TCR meal plans for children, adolescents, and adults (Zinn, Rush & Johnson, 2018; Zinn et al., 2022). By providing evidence that well-formulated TCR meal plans can meet energy, protein, and micronutrient requirements, these studies equip dietitians and nutritionists with valuable resources to guide dietary recommendations and address concerns regarding the nutritional adequacy of TCR. In addition, an article by Turton et al., (2022) provides practical guidance in formulating nutritionally adequate low-carbohydrate dietary plans, outlining low-carb food sources and providing a sample meal plan for a VLCD. *Appendix B - Patient Resources* outlines sample TCR meal plans.

Risk Of Hypoglycemia

It has been previously hypothesized that TCR will increase the risk of hypoglycemia. However, the primary risk factor is an excess of insulin, which can lead to hypoglycemia. TCR offers an opportunity to lower HbA1c in T1D without excessive insulin use.

With this in mind, it is crucial to adjust insulin to align with a TCR approach. If the amount, type, and timing of insulin do not match the TCR diet, hypoglycemia (or hyperglycemia) can occur. The greatest risk of hypoglycemia is typically during the initial days of starting TCR. For guidance on making insulin adjustments when transitioning to a TCR diet, refer to the section of this guide titled *T1D and the Impact of TCR on Insulin Needs*.

Note that there isn't a distinct "low carb"/TCR treatment for hypoglycemia. Hypoglycemia should be treated with fast-acting carbohydrate as per general hypoglycemia protocols, preferably using glucose or dextrose (American Diabetes Association Professional Practice Committee, 2024, p. S118). However, individuals following a low-carb (LC) diet may find they require less than the recommended 15 grams of rapid-acting carbohydrate to treat low blood glucose.

Glucagon medication can be used as an emergency treatment for severe hypoglycemia. A concern exists about its reduced effectiveness following a very low carbohydrate diet (VLCD), based on a physiologic study of 10 patients that showed an adequate but blunted response to glucagon after eating a VLCD for one week (Ranjan et al., 2017). Currently, a longer-term study is underway to conduct a glucagon challenge in individuals following a VLCD to further explore this issue (National Library of Medicine, 2023, NCT04200391).

Regardless of an individual's dietary pattern, a sensible approach to manage T1D safely and to minimize the risk of hypoglycemia involves implementing treatment strategies that reduce fluctuations in glucose and insulin levels. This includes regularly monitoring glucose levels, setting CGM alarms to alert when glucose levels fall below target range, and effectively treating hypoglycemia with fast-acting dextrose or glucose.

Eating Disorders

While the etiology of eating disorders (ED) is complex, it is thought that individuals with T1D have increased susceptibility due to factors including:

- Practical aspects of managing the disease - including the hyper attention on blood glucose monitoring to match insulin dose adjustment, meal planning, and carbohydrate counting; and the routine focus on weighing at clinic visits to assess insulin requirements and growth (Queensland Diabetes Clinical Network, Queensland Health, 2022).
- Physiological aspects - including disruption to hunger/satiety signalling, especially in hypoglycemia (Hopkins et al., 2020), and dysglycemia resulting in subtle neuropsychological changes (Queensland Diabetes Clinical Network, Queensland Health, 2022).
- Psychosocial aspects - including the effect on body image following weight regain once insulin is (re)started, social

and peer influences, societal pressures for *thinspiration*, diet culture, and diabetes burden and burnout.

Additional information about the contributing factors to disordered eating and ED in T1D can be found in the document, *Disordered Eating (DE) and Eating Disorders (ED) in Children, Adolescents and Adults with Type 1 Diabetes*, authored by the Queensland Diabetes Clinical Network in Australia.

In T1D, possible signs of an ED include:

- Inattention in diabetes management, such as insulin restriction or omission.
- Less frequent or no blood glucose monitoring, including reduced or ceased use of CGM.
- Frequent hyperglycemia.
- Extreme glucose fluctuations.
- Expressing concerns around weight changes.
- Episodes of DKA.

Patterns of consistent hyperglycemia may suggest challenges with adherence to prescribed management strategies and potential episodes of binge eating (Petitti et al., 2009). Erratic and recurrent hypoglycemia could be related to insulin over-injection to cover binge eating (Royal College of Physicians, 2022) or as a means to justify consuming sweets and high carbohydrate meals (Schober et al., 2011).

Diagnosing ED in individuals with T1D can be challenging because it is difficult to distinguish between a normal preoccupation with eating and weight as part of diabetes management and what may be considered excessive and more indicative of an ED.

Additionally, screening and assessing ED is complicated by the fact that insulin omission - a behaviour used for weight control - is unique to T1D. While some individuals might omit insulin to control their weight, others may limit their dietary intake of carbohydrates thus reducing their need for insulin but use insulin appropriately.

There is currently no conclusive evidence on whether following TCR affects the risk of ED in people with T1D. Currently, a two-year longitudinal study is investigating the effect of the ketogenic diet on eating disorder outcomes in individuals with T1D (Schneider et al., 2022). Preliminary results show no significant increases in ED risk over the two-year period.

On its own, a reduced carbohydrate approach to managing blood glucose does not appear to necessarily increase the risk of developing an ED. In fact, a nutrient-dense, reduced carbohydrate diet may positively impact individuals who exhibit abnormal thoughts around food and insulin use to manage their body shape or those in recovery from an ED. TCR might help reduce the focus on carb counting and alleviate the fear of large insulin doses at mealtimes. One key risk factor associated with ED in T1D is elevated HbA1c (Pinhas-Hamiel, Hamiel, & Levy-Shraga, 2015) and lower carbohydrate intake (i.e., TCR) is associated with improvements in HbA1c (Koutnik et al., 2024c).

Additionally, there is a lack of research examining the reduction of carbohydrates in individuals with an active eating disorder or those recovering from one. Preliminary evidence suggests that TCR may offer

benefits, such as improvements in glucose variability and positive outcomes for binge eating disorder (Al Hourani, 2020), increased satiety (Huda, 2008), and reductions in depression and anxiety (Buchberger, 2016; Hermanns, 2007).

Screening for ED is needed in individuals with T1D. Dietitians and nutritionists should be aware of the risk signals, and ask their patients with T1D about their eating attitudes, thoughts, feelings, and behaviours toward managing their food and insulin to probe for disordered eating. In some jurisdictions, such as the United Kingdom, there is currently no consensus on an appropriate screening tool for ED to use in T1D (Schneider, 2022; Allan, 2019). In other jurisdictions, screening and questionnaires specifically designed for T1D, such as mSCOFF, DPAT, or DEPS-R, can be included in the nutritional assessment for all people living with T1D, including to evaluate the suitability of a TCR approach.

TCR is not advised for individuals with an active, restrictive ED, such as Anorexia Nervosa. A person with co-occurring T1D and an ED should be referred to and supported by an ED specialist team, ideally who specializes in both ED and diabetes.

Cholesterol

Dietitians and nutritionists play an important role in guiding patients through dietary changes, including those related to cholesterol levels. While cardiovascular issues may not be the primary focus of our specialization, understanding the impact of nutrition on lipid profiles and other aspects of metabolic health is essential when working with individuals with diabetes.

TCR ways of eating mobilize fat for energy production, which will be reflected in lipid profiles. Concerns have been raised that TCR - a low carbohydrate diet (LCD) or very low carbohydrate diet (VLCD) - may increase cardiovascular disease (CVD) risk by raising low-density lipoprotein cholesterol (LDL-C). However, a systematic review and meta-regression of 101 studies which included 45,972 patients with T1D showed no significant association between carbohydrate intake and triglycerides, LDL-C or HDL-C (Koutnik et al., 2024c).

In other studies outside of T1D, TCR nutrition therapy has been reported to result in favourable changes in the lipid profile, including higher high-density lipoprotein cholesterol (HDL-C) levels, lower triglyceride levels, and larger LDL particle size, without significantly raising LDL-C (Li et al., 2022). In some people, TCR modestly increases both LDL-C and HDL-C levels, while the total cholesterol/HDL-C ratio remains unchanged or improves. Occasionally, LDL-C increases significantly in response to TCR. While we await definitive clinical evidence on the significance of elevated LDL in people who follow TCR, it's important to consider the beneficial changes to the overall lipid profile

and other metabolic health markers, rather than focusing solely on one biomarker. Of note, HbA1c is the primary risk factor in cardiovascular disease in individuals with T1D (DCCT/EDIC Research Group, 2016). Additionally, it's essential to take into account any other factors that may be contributing to an elevated LDL.

If a patient with T1D and a strong family history of cardiovascular disease experiences a large increase in LDL-C or LDL particles, they may become concerned and ask for advice from their dietitian or nutritionist on how to reduce it. It is important to assess an individual's lifestyle factors that may impact lipid profiles, such as smoking, alcohol consumption, inactivity, and high blood glucose levels, before attributing changes to dietary habits.

Energy intake should also be assessed to determine if the individual may be in an energy intake deficit, which can contribute to raised LDL-C. When an insufficient caloric intake is increased, LDL-C levels may return to normal.

Steps that patients can take to potentially lower LDL without increasing carbohydrate intake include consuming more low-carb sources of fibre and monounsaturated fat, such as fibrous vegetables, nuts and avocados.

> **For individuals with dyslipidemia and other cardiovascular risk factors,** advanced lipoprotein testing may be conducted by the patient's cardiologist or primary care physician.

Pregnancy

Managing type 1 diabetes (T1D) during pregnancy presents unique challenges due to the critical need for meticulous blood glucose control to prevent complications for both mother and baby. This can be particularly stressful due to a care gap in diabetes education regarding pregnancy management. Women may feel overwhelmed and confused by inconsistent information and blood glucose targets that are in or close to the non-diabetic range. TCR nutrition therapy can be a valuable tool to help women with T1D achieve optimal blood glucose control during pregnancy, potentially reducing the risk of complications from uncontrolled diabetes such as birth defects, miscarriage, and macrosomia.

Optimal blood glucose control during pregnancy is crucial for women with T1D. Integrating a TCR nutrition plan into the preconception or pregnancy care regimen can facilitate the achievement of good glycemic control, aiming to maintain an HbA1c ideally at or below 6.0-6.5% (Diabetes Canada Clinical Practice Guidelines Expert Committee, 2021; American Diabetes Association, 1 January 2024, S285). The strict blood glucose targets set for pre-conception and for pregnant women can be difficult to achieve with conventional carbohydrate intake recommendations as evidence demonstrates that only 10% of high-carbohydrate (≥45% kcal) and 24% of moderate-carbohydrate (26-44% kcal) studies in T1D achieve the ADA target of HbA1c <7% (Koutnik et al,, 2024c). A reduced carbohydrate approach offers significant advantages in this regard.

> "Only diabetic ketoacidosis and starvation ketosis have been proven harmful to fetal brain development and pregnancy outcomes, not nutritional ketosis. Pregnancy is naturally a state where women more easily go into nutritional ketosis, particularly between meals or an overnight fast (the same type of ketosis that would be induced by a lower carbohydrate diet in someone with well-managed blood sugar who either produces adequate insulin or in a type 1 diabetic taking sufficient insulin)." ***Lily Nichols, RND, CDCES, in Herschede, 2021, pp. 44-45***

The amount of carbohydrate intake directly impacts blood glucose levels and can contribute to excessive weight gain and macrosomia. Therefore, any nutrition therapy implemented during preconception and pregnancy should focus on minimizing blood glucose excursions, using low-glycemic, nutrient-dense foods while avoiding processed and refined carbohydrates.

Dietitians and nutritionists can support women with T1D who plan to conceive or are pregnant by collaborating with them to develop a personalized TCR nutrition plan. This plan must meet the unique needs of pregnancy, ensuring both maternal health, fetal growth, and glycemic control. For all nutrition therapy, and particularly for TCR, it is essential that the mother understands the importance of consuming adequate amounts of healthy fat, protein and low-glycemic carbohydrates to meet her energy requirements and the energy and growth requirements of the fetus. Close monitoring of food intake and regular consultations with healthcare providers are crucial. Dietitians and nutritionists should confirm with patients that they also have an obstetrics/maternal fetal medicine team that is monitoring fetal growth patterns.

Nutritional Ketosis and Pregnancy

Pregnant women, with or without T1D, may enter ketosis more readily than non-pregnant women. In pregnancy, nutrients from the mother's bloodstream cross the placenta to nourish the developing fetus with various energy sources, including glucose, amino acids, free fatty acids, and ketones (Rudolf & Sherwin, 1983). Pregnancy naturally inclines women towards maternal ketosis, particularly during the third trimester (Herrera, 2002). Ketones are produced by the placenta and are found in the amniotic fluid (Satoh, 2023). The levels of ketones indicated in maternal ketosis don't equate to those indicative of DKA. As long as there's sufficient insulin, good blood glucose control, and proper hydration, ketones levels indicating nutritional ketosis are not a cause for immediate concern.

Collaborative Care to Meet Insulin Needs during Pregnancy

When a pregnant patient is following TCR (or any nutrition plan), as part of the diabetes care plan, the prescribing medical professional helps the woman properly adjust her insulin medication to meet her nutritional and pregnancy-related needs. Sufficient insulin will also ensure that ketone bodies can be regulated effectively. Dietitians and nutritionists should collaborate with the medical team to support this process.

Nutritional Adequacy and Food to Avoid in Pregnancy

Dietitians and nutritionists also play a vital role in ensuring that pregnant women with T1D meet their own and their fetus's energy requirements when following TCR.This is achieved through nutrition education on TCR foods and meal planning, reviewing food diaries, conducting nutritional assessments, and providing personalized guidance.

One of the benefits of TCR nutrition therapy is its emphasis on adequate dietary protein, which is particularly important for pregnant women. Increased amino acid needs are essential for tissue protein synthesis, which is crucial for the healthy growth and development of the fetus. Protein-rich foods also play a vital role in building healthy tissues in the mother, including the breasts, uterus, and placenta, as well as supporting the development of the maternal vascular system, including the heart, arteries and blood volume (Stephens et al., 2015).

TCR meals are typically planned around protein-rich foods, with nutrient-dense, low-glycemic carbohydrates and healthy fats also included. While protein foods do require exogenous insulin in type 1 diabetes, the blood glucose response to a meal higher in protein is gradual and can be matched with the action profile of Regular insulin or using split- and extended-bolus options in insulin pump therapy.

During pregnancy, it is crucial to ensure nutrient needs are met and to be mindful of food that should be avoided due to a higher risk of containing bacteria or toxins, regardless of whether a woman follows TCR or another dietary intervention (for example, listeriosis in unpasteurized dairy products and mercury in fish). Most healthcare professionals recommend incorporating a prenatal multivitamin-mineral supplement into a nutrient-rich diet composed of whole foods. Personalized options are available for those following TCR. Allison Herschede, RN, CDCES, recommends that all pregnant women with T1D following TCR include prenatal multivitamin-mineral, vitamin D3, methylated folate, magnesium, DHA/EPA, and iron (if not contained in the prenatal) supplementation (Herschede, 2021). By tailoring the TCR nutrition plan to the unique needs and preferences of each individual, dietitians and nutritionists can help pregnant women with T1D optimize blood glucose control, promote healthy weight gain, and ensure adequate intake of essential nutrients vital for fetal development.

Dietary Protein And Kidney Health

Concerns have been raised about the potential negative effects of higher protein intake on kidney health. However, recent evidence has found that higher total protein intake was associated with lower mortality among participants with chronic kidney disease (CKD) (Carballo-Casla, 2024). A growing body of research suggests that low carb diets with moderately high protein intake do not jeopardize renal health in people with diabetes who have normal kidney function (Suyoto, 2018). In fact, by improving glycemic control, carbohydrate reduction and increased blood ketone levels may help protect renal health (Unwin et al., 2021; Weimbs, Saville & Kalantar-Zadeh, 2023). When assessing needs for patients with diabetes who have CKD, protein recommendations should be individualized based on the stage of CKD.

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CONCLUSION

This guide has explored the application of TCR as a medical nutrition therapy for individuals with T1D. Recognizing the growing interest in TCR and the challenges dietitians and nutritionists face due to limited clinical resources and training, this guide was created to bridge this gap.

This guide equips dietitians and nutritionists with the essential knowledge and practical tools to initiate, monitor, and adapt TCR within the established Nutrition Care Process framework. This resource is intended to be a valuable asset in clinical practice, empowering effective patient guidance for those patients interested in exploring the potential benefits of TCR and receiving personalized nutrition support. This resource assists dietitians and nutritionists in helping their patients confidently select foods and plan meals that align with TCR principles. The ultimate goal is for individuals with T1D to enjoy a higher quality of life with more stable and predictable blood glucose levels, improved diabetes outcomes, and reduced risk of complications. Additionally, individuals and caregivers living with T1D may experience less mental burden associated with diabetes management, as improved blood glucose stability reduces the constant worry and frequent need to manage highs and lows.

> **We welcome your feedback and suggestions** to improve this guide. If you have any unanswered questions or concerns, please do not hesitate to reach out to us. Your input is invaluable in helping us refine and enhance this resource for everyone's benefit.

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TCR CONTRAINDICATIONS

A contraindication indicates that a particular therapy should not be used for a person, due to a certain condition or circumstance, because it may be harmful to them.

Inborn errors of metabolism are rare genetic (inherited) disorders in which the body cannot properly turn food into energy.

The disorders are usually caused by defects in specific proteins (enzymes) that help break down (metabolize) parts of food. For most people who have these disorders, they are aware of them, and were diagnosed through newborn screening tests. Screen for disorders of fatty acid transport and oxidation if a clinical concern. People with these conditions cannot and should not follow a low carbohydrate diet. Doing so could cause a life-threatening situation.

Genetic Disorders, including Inborn Errors of Metabolism and Enzymatic Defects

Carnitine deficiency conditions:

- Primary carnitine deficiency
- Carnitine palmitoyl transferase I and II deficiencies
- Carnitine translocase deficiency

Fatty acid ß-oxidation disorders:

- Medium-chain acyl dehydrogenase deficiency (MCAD)
- Long-chain acyl dehydrogenase deficiency (LCAD)
- Short-chain acyl dehydrogenase deficiency (SCAD)
- Long-chain 3-hydroxyacyl-CoA deficiency
- Medium-chain 3-hydroxyacyl-CoA deficiency
- Pyruvate carboxylase deficiency
- Succinyl-CoA:3-oxoacid coenzyme A transferase (SCOT) deficiency
- Beta-ketothiolase (T2) deficiency
- Methylmalonyl-coA epimerase deficiency
- Acute intermittent porphyria (a disorder of heme biosynthesis)

(Kossoff et al., 2018; Kirkpatrick et al., 2019; Volek & Hyde, 2018)

Pre-existing Medical Conditions

- Inherited causes of severe hypercholesterolemia
- Liver failure/severe liver disease
- States that mimic starvation, including Alcohol Use Disorder and active eating disorders, including Anorexia Nervosa
- Pancreatitis (a high-fat intake can potentially trigger pancreatitis in susceptible individuals (Choi et al., 2021))
- Acute states of pre-existing medical or psychiatric conditions

Use Caution With

- History of hypertriglyceridemia-associated acute pancreatitis or severe hypertriglyceridemia

Consider the Nutritional Needs of and Medical Supervision For

- Diabetes-related complications
- History of renal stones or gout
- Exocrine pancreatic insufficiency (EPI)
- Fat maldigestion and malabsorption
- Kidney disease, liver disease, and cardiovascular disease
- Gastroparesis
- Pregnant and breastfeeding women
- Children and adolescents
- Recent DKA event: if a patient has experienced a recent DKA event and has depleted nutritional status, it is vital that their diet be properly formulated and that they are closely monitored medically.
- Unintended/unexplained weight loss: if a patient has experienced recent, unintended or perhaps unexplained weight loss, the cause of that weight loss should be investigated and understood and resolved prior to starting TCR.
- Mental health conditions: some symptoms may be exacerbated in early phases of TCR

Medication Use

Patients taking SGLT2 inhibitor medication (risk of ketoacidosis, including euglycemic DKA, which may be accompanied by normal blood levels instead of elevated BG levels and thusharder for patient to detect)

- Patients taking Vitamin K-dependent anticoagulation treatment
- Also consider other medication classes that may require adjustment as the patient responds to TCR dietary changes include psychiatric medications, reflux medications, statins, warfarin, some anticonvulsant medication, and thyroid hormone.

(Kossoff et all, 2018; Kirkpatrick et al., 2019; Volek & Hyde, 2018)

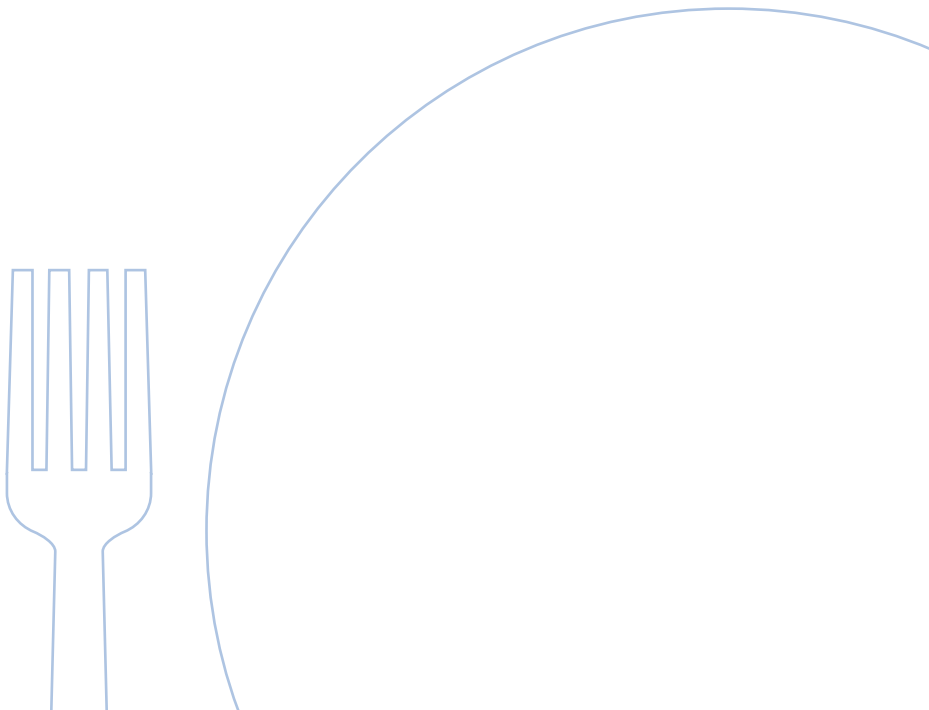
IPTN

PATIENT RESOURCES

TCR FOOD LIST

SAMPLE MEAL PLANS

APPENDIX B



PRESCRIPTION FOR BETTER BLOOD SUGAR
LOW CARB SHOPPING LIST

When you're grocery shopping, stick to the outer rim of the store. Frozen berries and vegetables are great to have on hand and won't go bad. Pick up any of the following items:

Proteins
beef
lamb
pork
poultry
game
fish
seafood
luncheon meats & sausages*
eggs
tofu, tempeh, natto*

Natural fats
avocado oil
bacon
chicken fat (schmaltz)
coconut milk
coconut oil
full-fat salad dressings*
ghee
lard and tallow
mayonnaise
nuts and nut butters
nut oils of all types
olive oil
sesame oil

Vegetables
artichoke
asparagus
avocado
bok choy
broccoli
Brussels sprouts
cabbage
cauliflower
celery
cucumber
eggplant
fennel
garlic
green beans
hearts of palm
jicama
kholrabi
leafy greens
leeks
mushrooms
okra
olives
onion
parsley
peppers
pickles*
pumpkin
radishes
rhubarb
rutabaga
scallions
shallots
snow peas
sprouts
squash
sugar snap peas
tomatillos
tomato
turnip
zucchini

Fruit
blueberries
raspberries
strawberries
blackberries
lemons
limes

Dairy products
butter
cheeses of all kinds
cottage cheese
cream cheese
ghee
cream cream (18%, whipping*)
mascarpone
ricotta
sour cream
yogurt - plain, full-fat

***no added sugar or starches**

Therapeutic carbohydrate reduction/low carb ways of eating have become popular. You can find many cookbooks, websites, and magazines with a wide variety of delicious and nutritious low carb recipes.

SAMPLE TCR MEAL PLANS

Sample Meal Plan (carbs: 25 grams/day)

Day	Breakfast	Lunch	Dinner
A	• 2 large whole eggs • smoked salmon (100 g) • ½ avocado (80 g) • 1 tbs butter (20 g) • 1 small tomato (120 g) • black coffee	• plain yoghurt (120 g) • 2 tbs almond butter^(40g) • ½ mandarin (40 g) • peppermint tea	• beef steak (150 g*) • haloumi cheese (50 g) • 2 tsp olive oil (10 ml) • ¼ cucumber (60 g) • ½ medium red onion • ½ mandarin (40 g)
	carbs: 4 g | proteins: 39 g | fats: 46 g.	carbs: 13 g | proteins: 16 g | fats: 33 g.	carbs: 10 g | proteins: 53 g | fats: 33 g.
B	• 3 whole eggs, large • cheese, fetta (50 g) • 8 olives (30 g) • ¼ cucumber (60 g) • 1 slice watermelon • green tea (75 g)	• chicken breasts (100 g*) • brie cheese (50 g) • mixed nuts (30 g) • 1/3 carrot (40 g) • 3 pcs pickles (20 g)	• 1 medium lamb chop (150g*) • 1 tbs butter (20 g) • ¼ cup green peas (40 g*) • 4 baby carrots (65 g*)
	carbs: 8 g | proteins: 29 g | fats: 31 g.	carbs: 10 g | proteins: 44 g | fats: 36 g.	carbs: 7 g | proteins: 43 g | fats: 47 g.
C	• plain yoghurt (150 g) • mixed nuts (50 g) • 2 tsp cream (10 ml) • 6 strawberries (70 g) • herbal tea	• canned tuna (100 g*) • cream cheese (50 g) • ½ avocado (80 g) • ¼ cucumber (60 g) • 3 sheets dried nori (8 g)	• BBQ chicken (150 g*) • parmesan cheese (15 g) • pine nuts (15 g) • 2 tsp olive oil (10 ml) • ½ avocado (80 g) • 1 cup iceberg lettuce • ¼ capsicum (70 g)
	carbs: 16 g | proteins: 17 g | fats: 48 g.	carbs: 4 g | proteins: 34 g | fats: 31 g.	carbs: 4 g | proteins: 45 g | fats: 60 g.

Abbreviations: carbs, total dietary carbohydrates; g, grams; tsp, teaspoon; tbs, tablespoon.
*Cooked weight; ^natural nut butter (nuts and salt only).
Other instructions: If you want to add snacks to this meal plan and your carbohydrate target is 25 g/day, then your snacks should be proteins and/or fats that do not also contain carbs. If you want to increase your portions of proteins and/or fats at meals to reach satiety, you can.

Reference:

Turton, J. L., Brinkworth, G. D., Parker, H. M., Lim, D., Lee, K., Rush, A., Johnson, R., & Rooney, K. B. (2023). Effects of a low-carbohydrate diet in adults with type 1 diabetes management: A single arm non-randomised clinical trial. PloS one, 18(7), e0288440. https://doi.org/10.1371/journal.pone.0288440

Sample Meal Plan (carbs: 50 grams/day)

Day	Breakfast	Lunch	Dinner
A	• 2 whole large eggs (100 g) • smoked salmon (75 g) • 1 tbs butter (20 g) • 3 spears asparagus (60 g) • ½ cup mushrooms (40 g) • cherry tomatoes, 6 (90 g) • small latte (175 ml)	• plain yoghurt (150 g) • almonds (30 g) • 2 tsp cream (10 ml) • 10 raspberries (20 g) • 15 blueberries (20 g) • 85% dark chocolate (20 g) • peppermint tea	• beef mince (150 g*) • 4 tsp olive oil (20 ml) • 2 tbs tomato paste (40 g) • ½ cup diced tomato (120 g) • 1 medium zucchini, cut into zoodles (150 g) • 8 olives (30 g) • 1 tsp italian herbs • 1 mandarin (75 g)
	carbs: 11 g | proteins: 40 g | fats: 38 g.	carbs: 17 g | proteins: 17 g | fats: 43 g.	carbs: 20 g | proteins: 48 g | fats: 46 g.
B	• plain yoghurt (150 g) • mixed nuts (30 g) • ¼ cup dried coconut (20 g) • 4 tsp rolled oats (7 g) • 6 strawberries (70 g) • herbal tea	• 2 whole eggs, large (100 g) • cheese, haloumi (80 g) • 2 tsp olive oil (10 g) • ½ avocado (80 g) • ½ cup mushrooms (40 g) • 1 tomato (150 g) • small latte (175 ml)	• chicken thighs (120 g*) • cheese, parmesan (30 g) • 1 tbs butter (20 g) • ½ cup broccoli (75 g*) • pumpkin (120 g*) • 3 beetroot slices (60 g)
	carbs: 18 g | proteins: 15 g | fats: 49 g.	carbs: 15 g | proteins: 38 g | fats: 47 g.	carbs: 15 g | proteins: 46 g | fats: 36 g.
C	Smoothie: • plain yoghurt (120 g) • 2 tbs peanut butter^(40 g) • 2 tsp cream (10 ml) • ½ cup berries (80 g) • cow's milk (75 ml) • water + ice (as required)	• canned tuna (100 g*) • cheese, fetta (50 g) • 4 tsp olive oil (20 ml) • 1 cup leafy green • 3 beetroot slices (60 g) • 6 cherry tomatoes (50 g) • sauerkraut (40 g) • 85% dark chocolate (20 g)	• salmon fillet (150 g*) • 1 tbs butter (20 g) • ½ cup broccoli (75 g*) • pumpkin (120 g*) • ¼ cucumber (60 g) • 1 slice watermelon (75 g) • fresh mint leaves (10 g)
	carbs: 19 g | proteins: 19 g | fats: 40 g.	carbs: 12 g | proteins: 38 g | fats: 42 g.	carbs: 16 g | proteins: 49 g | fats: 52 g.

Abbreviations: carbs, total dietary carbohydrates; g, grams; tsp, teaspoon; tbs, tablespoon.
*Cooked weight; ^natural nut butter (nuts and salt only).
Other instructions: If you want to add snacks to this meal plan and your carbohydrate target is 50 g/day, then your snacks should be proteins and/or fats that do not also contain carbs. If you want to increase your portions of proteins and/or fats at meals to reach satiety, you can.

Reference:

Turton, J. L., Brinkworth, G. D., Parker, H. M., Lim, D., Lee, K., Rush, A., Johnson, R., & Rooney, K. B. (2023). Effects of a low-carbohydrate diet in adults with type 1 diabetes management: A single arm non-randomised clinical trial. PloS one, 18(7), e0288440. https://doi.org/10.1371/journal.pone.0288440

Sample Meal Plan (carbs: 60 grams/day)

Day	Breakfast	Lunch	Dinner
A	• 2 large whole eggs (100 g) • smoked salmon (75 g) • 1 tsp olive oil (5 ml) • 3 asparagus spears (60 g) • ⅓ sweet potato (60 g) • small latte (175 ml)	• plain yoghurt (200 g) • almonds (30 g) • 10 raspberries (20 g) • 15 blueberries (20 g) • 85% dark chocolate (20 g) • peppermint tea	• beef mince (150 g*) • 1 tsp olive oil (5 ml) • 2 tbs tomato paste (40 g) • ½ cup diced tomato (120 g) • 1 medium zucchini, cut into zoodles (150 g) • 8 olives (30 g) • 1 tsp italian herbs • mandarin (75 g)
	carbs: 19 g | proteins: 39 g | fats: 26 g.	carbs: 19 g | proteins: 19 g | fats: 44 g.	carbs: 20 g | proteins: 48 g | fats: 33 g.
B	• plain yoghurt (180 g) • mixed nuts (30 g) • ¼ cup dried coconut • 4 tsp rolled oats (7 g) • 6 strawberries (70 g) • herbal tea	• 2 large eggs whole (100 g) • haloumi cheese (80 g) • 1 tsp olive oil (5 ml) • ½ avocado (80 g) • ½ cup spinach (25 g) • pumpkin 120 g • small latte (175 ml)	• chicken thighs (120 g*) • parmesan cheese (30 g) • 1 tsp olive oil (5 ml) • ½ cup broccoli (80 g*) • ⅓ sweet potato (120 g)
	carbs: 20 g | proteins: 17 g | fats: 52 g.	carbs: 20 g | proteins: 40 g | fats: 43 g	carbs: 20 g | proteins: 43 g | fats: 32 g.
C	smoothie: • plain yoghurt (120 g) • 2 tbs peanut butter^ (40 g) • ½ cup berries (80 g) • cow's milk (100 ml) • water + ice (as required)	• canned tuna (100 g*) • feta cheese (50 g) • olive oil 2 tsp (10 ml) • 1 cup leafy greens • beetroot slices 3 (60 g) • ⅓ sweet potato (60 g*) • 2 segments fresh lemon • 85% dark chocolate (20 g)	• salmon fillet (150 g) • 1 tsp olive oil (5 ml) • ½ cup mushrooms (40 g) • pumpkin (120 g) • 1 slice watermelon (75 g) • 6 strawberries (70 g) • herbal tea
	carbs: 20 g | proteins: 20 g | fats: 37 g.	carbs: 19 g | proteins: 39 g | fats: 33 g.	carbs: 18 g | proteins: 47 g | fats: 41 g.

Abbreviations: carbs, total dietary carbohydrates; g, grams; tsp, teaspoon; tbs, tablespoon.
*Cooked weight; ^natural nut butter (nuts and salt only).
Other instructions: If your carbohydrate target is 60-75 g/day of total carbohydrates, you may add 1-2 snacks containing 5-10 g of carbohydrates to this meal plan. If you want to increase your portions of proteins and/or fats at meals to reach satiety, you can.

Reference:

Turton, J. L., Brinkworth, G. D., Parker, H. M., Lim, D., Lee, K., Rush, A., Johnson, R., & Rooney, K. B. (2023). Effects of a low-carbohydrate diet in adults with type 1 diabetes management: A single arm non-randomised clinical trial. PloS one, 18(7), e0288440. https://doi.org/10.1371/journal.pone.0288440

Sample Meal Plan Children and Adolescents (carbs: <80 grams/day)

LCHF Meal Plan 1 (Male; 11 Years)	LCHF Meal Plan 2 (Female; 16 Years)	LCHF Meal Plan 3 (Male; 16 Years)
Breakfast *Eggs on toast*	**Breakfast** *Smoothie*	**Breakfast** *Eggs on toast*
• 1 slice Helga's lower carb five seed bread, 2 tsp salted butter • 2 regular boiled eggs • ½ tsp iodised table salt	• strawberries (80 g) • 1 tbs peanut butter • 5 brazil nuts • ½ cup greek yoghurt • ½ cup tap water	• 1 slice Helga's lower carb five seed bread • 2 tsp salted butter • 2 regular boiled eggs • ¼ cup baked beans • ½ cup cheddar cheese
Morning snack *Vegetable sticks & cream cheese*	**Morning snack** *Vegetable sticks & cream cheese*	**Morning snack** *Fruit and cheese*
• cherry tomatoes (40 g) • telegraph cucumber (40 g) • 6 snow peas • cheddar cheese (49 g)	• telegraph cucumber (50 g) • 10 snow peas • ½ tsp iodised table salt • ½ cup cream cheese	• ½ medium apple • cheese (63 g)
Lunch *Low-carb wrap*	**Lunch** *Frittata*	**Lunch** *Low-carb sandwich*
• 1 Mountain bread natural wrap (20 g) • telegraph cucumber • ½ cup spinach • avocado (45 g) • chicken (100 g) • ¼ cup grated cheddar cheese • 2 tsp mayonnaise	• 2 regular eggs • 50 g grilled chicken breast • 45 g zucchini • ½ cup baby spinach • ¼ cup red capsicum • 1 mushroom • ¼ cup brown onion • 20 g cheddar cheese • 1 tsp olive oil	• salami 5 slices • 2 slices helga's lower carb five • 2 tsp seed bread salted butter (10 g) • 1 tb mayonnaise (15 g) • avocado (40 g) • ½ cup baby spinach (15 g) • telegraph cucumber (20 g) • cheddar cheese (21 g) • tomato (30 g)
Afternoon snack *Fruit, crackers, and peanut butter*	**Afternoon snack** *Mashed avocado and vegetable sticks*	**Afternoon snack** *Seed crackers with peanut butter*
• ½ small apple • 2 Olina's seeded crackers • 1 ¼ tb peanut butter	• avocado (80 g) • 1 cup carrots	• 2 Olina's seeded crackers • 2 tsp peanut butter

Dinner *Steak, cauliflower mash, and vegetables*	**Dinner** *Beef stir fry*	**Dinner** *Pork chops, cauliflower mash, and vegetables*
• steak fillet (150 g) • cauliflower (100 g) • 2 tbs cream • carrots (100 g) • green beans (50 g) • ½ cup peas • 1 tsp mustard • ½ tsp iodised table salt • 2 tsp olive oil	• beef strips (175 g) • 1 cup red cabbage • ½ cup carrots • ½ cup green beans • ¼ cup corn kernels • 1 tb olive oil	• 2 small pork chops • cauliflower (200 g) • 2 tsp cream, • ½ cup carrots • 1 cup green beans
Evening snack *Yoghurt and berries*	**Evening snack** *Yoghurt with nuts and seeds*	**Evening snack** *Yoghurt with nuts*
• greek yoghurt (150 g) • strawberries (80 g)	• greek yoghurt (150 g) • 2 tbs sunflower seeds • 1.5 tbs chia seeds • 1.5 tbs cashews	• greek yoghurt (150 g) • almonds (15 g) • brazil nuts (15 g)

Reference:
Zinn, C., Lenferna De La Motte, K. A., Rush, A., & Johnson, R. (2022). Assessing the Nutrient Status of Low Carbohydrate, High-Fat (LCHF) Meal Plans in Children: A Hypothetical Case Study Design. Nutrients, 14(8), 1598. https://doi.org/10.3390/nu14081598

Sample Meal Plan (carbs: 61-66 grams/day)

LCHF Meal Plan 1 (Females)	LCHF Meal Plan 2 (Males)	LCHF Meal Plan 2 (Males) (Saturated Fat <10%TE)
Breakfast *Yoghurt with nuts and seeds*	**Breakfast** *Omelette*	**Breakfast** *Omelette*
• ¾ cup frozen mixed berries (90 g) • plain, unsweetened, full-fat yoghurt (150 g) • 2 tbs sunflower seeds (20 g) • 2 tbs pumpkin seeds (20 g) • 3 macadamia nuts • 2 brazil nuts • 6 almonds	• 3 eggs • mushrooms (60 g) • tomato (100 g) • 1 cup baby spinach (30 g) • 2 tsp butter (10 g) • coffee made with full-fat milk (200 ml)	• 3 eggs • mushrooms (60 g) • tomato (100 g) • 1 cup baby spinach (30 g) • 3 tsp olive oil (15 g) • coffee with low-fat milk (200 ml)
Lunch *Tuna salad*	**Lunch** *Beef salad*	**Lunch** *Beef salad*
• tin tuna, canned in brine (drained) (95 g) • 1 cup baby spinach leaves (30 g) • english cucumber (60 g) • 5 cherry tomatoes (75 g) • cheddar cheese (30 g) • 2 tbs linseeds (20 g) • 1 tsp basil pesto (5 g) • 3 tsp olive oil (15 g)	• rib eye fillet (120 g) • 1 cup spinach leaves (30 g) • ½ red capsicum (60 g) • english cucumber (60 g) • 5 cherry tomatoes (75 g) • ½ large avocado (100 g) • 5 walnuts • 1 tbs linseeds (10 g) • parmesan cheese (30 g) • 2 tbs olive oil (20 g)	• rib eye fillet (150 g) • 1 cup spinach leaves • ½ red capsicum • english cucumber (60 g) • 5 cherry tomatoes • ½ large avocado • 3 tbs sunflower seeds • 12 green olives • low fat cottage cheese (30 g) • 2 tbs olive oil • 2 tsp avocado oil

Dinner *Steak and vegetable*	**Dinner** *Grilled salmon and vegetable*	**Dinner** *Grilled salmon and vegetable*
• grilled sirloin steak, fat not trimmed (150 g) • 8 cauliflower florets • 1 medium-sized beetroot • 1 medium zucchini • 1 medium carrot • 2 tbs olive oil, for coating	• grilled salmon (130 g) • green beans (100 g) • broccoli (150 g) • grilled pumpkin (200 g) • ½ cup peas • 1 tbs olive oil	• grilled salmon (150 g) • green beans (100 g) • broccoli (150 g) • grilled pumpkin (200 g) • ½ cup peas • 1 tbs olive oil
Snacks	**Snacks**	**Snacks**
• 10 medium strawberries • 3 tbs pistachio nuts • coffee with full-fat milk 200 ml	• 20 macadamia nuts smoothie: • full-fat milk (200 ml) • 10 medium strawberries • crushed nuts (almonds 20 g, linseeds 2 tbs)	• 20 macadamia nuts smoothie: • low-fat milk (200 ml) • 10 medium strawberries • unsweetened low-fat plain yoghurt (100 g) • crushed nuts (almonds 20 g, linseeds 2 tbs)

LCHF, low-carbohydrate, high-fat diet; TE, total energy; tbs, tablespoon; tsp, teaspoon.

Reference:

Zinn, C., Lenferna De La Motte, K. A., Rush, A., & Johnson, R. (2022). Assessing the Nutrient Status of Low Carbohydrate, High-Fat (LCHF) Meal Plans in Children: A Hypothetical Case Study Design. Nutrients, 14(8), 1598. https://doi.org/10.3390/nu14081598

INGREDIENTS THAT CAN IMPACT BLOOD GLUCOSE

THE MANY NAMES OF SUGAR

Agave nectar
Agave syrup
Barbados sugar
Barley malt
Barley syrup
Beet sugar
Blackstrap molasses
Brown rice syrup
Brown sugar
Buttered syrup
Cane juice
Caramel
Carob syrup
Castor sugar
Coconut nectar
Coconut sugar
Coconut palm sugar
Concentrated fruit juice
Confectioner's sugar
Golden syrup
Grape sugar
High fructose corn syrup (HFCS)
High maltose corn syrup
Honey
Icing sugar
Invert sugar
Lactose
Levulose
Maple syrup
Malt
Malt syrup
Maltodextrin
Maltol
Maltose
Maltose sugar
Mannose
Molasses
Palm sugar
Panocha
Powdered sugar
Raw sugar
Rice syrup
Saccharose
Sorghum
Sucanat
Sucrose
Sugar
Syrup
Treacle
Trehalose
Turbinado sugar
Xylose
Yacon syrup
Yellow sugar
Corn syrup
Date sugar
Dates
Dehydrated cane juice
Dextrin
Dextrose
Disaccharides
Dulcitol
Evaporated cane juice
Fructooligosaccharides
Fructose
Fructose syrup
Fruit juice
Fruit juice concentrate
Galactose
Glucitol
Glucose
Glucose solids
Granulated sugar

SUGAR SUBSTITUTES

SugarAlternatives
(best of the options)

allulose*
monk fruit extract
stevia

Sugar Alcohols
(some cause BG spikes)

erythritol
isomalt
lactitol
maltitol
mannitol
sorbitol
xylitol**
hydrogenated starch hydrolysates

Artificial Sweeteners
(best to avoid for overall health)

aspartame (Nutrasweet, Equal, Sugar Twin)
saccharin (Sweet 'n low)
sucralose (Splenda)
neotame (Newtame)
acesulfameK (Sunett, Sweet One)

OTHER INGREDIENTS THAT MAY RAISE BLOOD GLUCOSE

Best to Avoid

carrageenan
corn starch
isomalto-oligosaccharide
oat flour
rice starch
pea protein
quinoa flour
tapioca starch

Okay

agar agar
chicory root/inulin
gelatin
guar gum
gum arabic
oat fibre***
pectin
soluble corn fiber (resistant maltodextrin)
xanthan gum

Watch for Added Sugars In

coffee drinks
condiments:
BBQ sauce, hot sauce, ketchup, mustard, relish, salad dressings, teriyaki sauce
energy/protein bars
non-dairy milks (eg. almond)
pasta sauce
soups
yogurt
jams
peanut butter
shredded coconut
vinegars (flavoured)

*Allulose: When counting carbs for insulin dosing, check U.S. nutrition facts labels for allulose. Allulose is counted towards total carbohydrates on the nutrition label, yet allulose has a minimal effect on blood glucose and insulin levels in people without diabetes and in people with diabetes, and in some cases, it can lower blood glucose and insulin when added to beverages (U.S. Food and Drug Administration, April 23, 2019). Individuals with T1D should be instructed to subtract allulose from the total carbs. Including allulose in a carbohydrate calculation could increase the risk of hypoglycemia. **Xylitol: Toxic for dogs ***Oat fibre: For people with a Celiac Disease diagnosis, oat fibre is naturally gluten-free; however, these products must use processing equipment separated from gluten to avoid cross contamination, so please check the product is deemed "gluten-free".

IPTN

THERAPEUTIC CARBOHYDRATE REDUCTION

IN TYPE 1 DIABETES

A GUIDE FOR DIETITIANS & NUTRITIONISTS