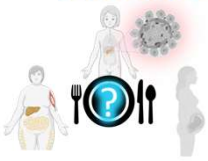
In-Depth Analysis of Carbohydrate Modification in Diabetes



Dr. Andrew P. Koutnik, Ph.D.

Institute for Sports Science & Medicine
Florida State University
Healthspan, Resilience and Performance
Institute for Human and Machine Cognition
Patient Living with Type 1 Diabetes

ISSM Florida State University Institute of Sports Sciences and Medicine

ihmc

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Table of Contents

- History
- Very-Low Carbohydrate/Ketogenic Diet
  - Types/Definitions
  - Foods
- Type 1 Diabetes
  - Outcomes
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  - Resources
- Type 2 Diabetes
  - Outcomes
  - Risks
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- Gestational Diabetes
  - Outcomes
  - Risks
  - Resources
- Resources
  - Predictable & Preventable Pitfalls
  - Gaps
  - Resources



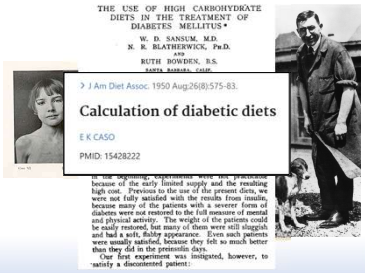
Biorender

2

History: Very-Low Carb in Diabetes

- **1796 – Type 2 Diabetes/LADA**
  - Animal-only diet ("carnivore")
  - LADA/T2D resolved:
    - **Weight regain**
    - **Eliminate glucose in urine**
- **1863 – Obesity**
  - Cut starch and sugar (NO bread, milk, sugar, beer and potatoes)
  - **Obesity resolved** (203lb (34 kg/m2) -> 156lbs (26 kg/m2))
- **1916 – Type 1 Diabetes**
  - 5% Carbohydrate (often extreme caloric restriction)
  - **Prolonged life ~1-2 years.**
- **1916 – Gestational Diabetes**
  - 45–125 g/day, with fat restricted to prevent acidosis.
  - **Glucosuria resolved; 9/11 mothers and children well.**
- **1922 – Insulin Discovery**

- **1923 to 1935 – High Carb Re-Introduction**
  - All forms of diabetes (not distinguished)
- **1971 to Present - ADA Official Guidelines**
  - 1950: 40% Carb
  - 1971: 45% Carb
  - 1979: 50-60% Carb
  - 1986: 60% Carb (30% Fat limit)
- **1994: Reversal towards individualization**



THE USE OF HIGH CARBOHYDRATE DIETS IN THE TREATMENT OF DIABETES MELLITUS*

W. D. SANSUM, M.D.
N. R. BLATHERWICK, Ph.D.
AND
RUTH BOWDEN, B.S.
SANTA BARBARA, CALIF.

J Am Diet Assoc. 1950 Aug;26(8):575-83.

Calculation of diabetic diets

E K CASO

PMID: 15428222

3

Carbohydrate Categories: Definition, Types, Foods

Diets	Carbohydrates	Defining Features
High Carbohydrate Diet	≥45%kcal; ≥225g/day	• Typical Carbohydrate Intake of General Population; • Previous ADA, USDA, and HHS Dietary Guidelines Recommended Carbohydrate Intake
Moderate Carbohydrate Diet	26-45%kcal; 130-224g/day	• Lower Carbohydrate Intake than General Population; • Below Previous ADA, UDSA, and HHS Dietary Guidelines Recommended Carbohydrate Intake; • Above Previous ADA Recommended Carbohydrate Minimums; • Uncertain Changes in Metabolite Oxidation
Low-Carbohydrate Diet	10-25%kcal; <130g/day	• Lower Carbohydrate Intake than General Population; • Below Previous ADA, UDSA, and HHS Dietary Guidelines Recommended Carbohydrate Intake and Minimums; • Uncertain Changes in Metabolite Oxidation
Very Low-Carbohydrate Diet	<10%kcal; ≤50g/day	• Lower Carbohydrate Intake than General Population; • Below Previous ADA Recommended Carbohydrate Minimums; • Altered Lipid Metabolism;Reduced Insulin (Threshold)
Very Low-Carbohydrate Ketogenic Diet	<10%kcal; ≤50g/day	• Lower Carbohydrate Intake than General Population; • Below Previous ADA Recommended Carbohydrate Minimums; • Reduced Insulin (Threshold); • Altered Lipid Metabolism; • Elevated R-βHB ≥0.5mmol/L (<8.0mmol/L)

- Based on Intake Norms & General Pop (**not T1D/T2D**)
- **Objectively Undefined**
- Based on Define Physiologic State
- **Objective Metabolic Adaptation**
- Popularity

*ADA now recommends individualized carbohydrate targets and therapy

Lennerz. *et al.* (2021)

4

Carbohydrate Categories: Definition, Types, Foods

Table 4 Quick reference conversion of percent calories from carbohydrate shown in grams per day as reported in the research reviewed for this report

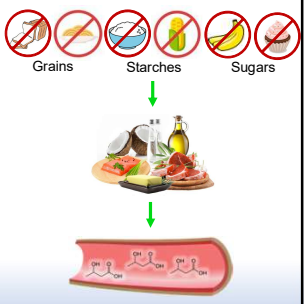
Calories	10%	20%	30%	40%	50%	60%	70%
1,200	30 g	60 g	90 g	120 g	150 g	180 g	210 g
1,500	38 g	75 g	113 g	150 g	188 g	225 g	263 g
2,000	50 g	100 g	150 g	200 g	250 g	300 g	350 g
2,500	63 g	125 g	188 g	250 g	313 g	375 g	438 g

Evert. *et al.* (2019)

5

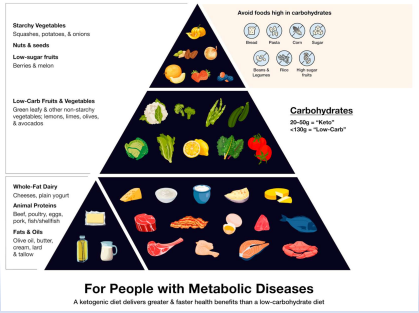
Low Carbohydrate Diets: Definition, Types, Foods

- Defined:
  1. No sugary, starchy carbohydrates
  2. <50g carbohydrates/day fibrous carbs
  3. Food plan that can promote "ketone(s)" production



6

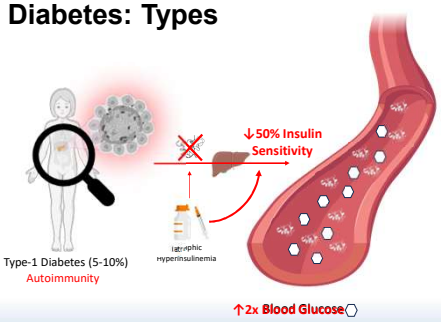
Low Carbohydrate Diets: Definition, Types, Foods



Teicholz. *et al.* (2025)

7

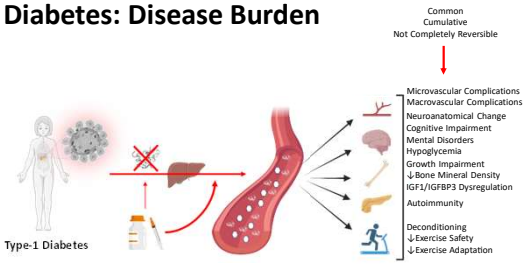
Diabetes: Types



Biorender; DeFronza et al. 1982; Gregory et al. 2019 & 2020

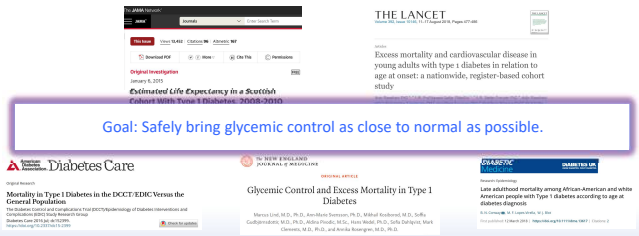
8

Type 1 Diabetes: Disease Burden



9

Type-1 Diabetes: Increased Risk & Outcomes



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Type 1 Diabetes: Disease Management

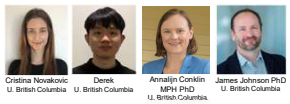


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Therapeutic Options: Current & Limited Access/Exploratory	Outcomes (HbA1c):
Intensive Treated Therapy (≥3 injections/day)	**DCCT/EDIC: Δ-1.5%** AU **8.9** ± 1.6 (n=711) → **7.4** ± 1.1 (n=620)
Carbohydrate Counting (Carb : Insulin Ratio)	**Meta-Analyses: n.s.**
Insulin Pumps (Continuous Spot Infusion)	**Meta-Analyses: Δ-0.2 to -0.4%** AU
Continuous Glucose Monitor (24-hour Glucose Estimations)	**Meta-Analyses: Δ-0.2 to -0.8%** AU
Augmented Pump (Manual: Pump + CGM)	**Meta-Analyses: Δ-0.7%** AU
Closed Loop System (Computer Algorithm: Pump + CGM)	**Meta-Analyses: Δ-0.3 to -1.0%** AU
Islet-Cell Transplantation (β-Cell Replacement)	**Meta-Analyses: Δ-1.7 to -2.2%** AU (pre to post)
Stem Cells (β-Cell Regeneration)	**Meta-Analyses: Δ-1.5 to -4.1%** AU (pre to post)

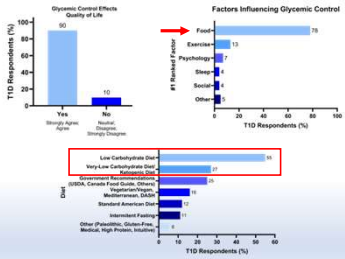
12

Type 1 Diabetes: Patient Perspective



T1D International Survey (n>1000)

- 90%: Glycemic control affects quality of life
- 78%: Food #1 factor influencing disease management
- ¾ were following a specific diet strategy
- Therapeutic carbohydrate restriction (LCD, VLCKD) were the most commonly utilized diet strategy.



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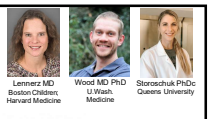
Type 1 Diabetes: Impact of Food

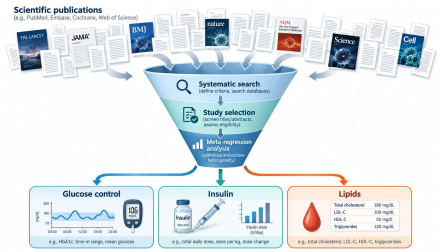


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Systematic Review & Meta-Analysis

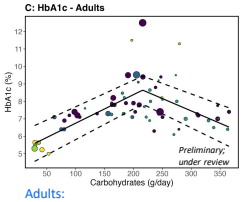
-T1D: 47,699
-Studies: 129
-Diet Duration: 3 months [0.9,9.3]

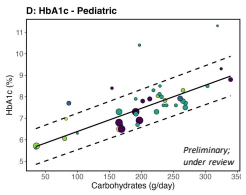




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Results: Glycemic Control





Adults:

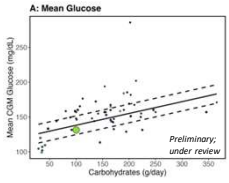
- Knot: 216g/day
- **↓25g/day carbohydrate intake associated with ↓0.35%HbA1c (p=0.0003)**

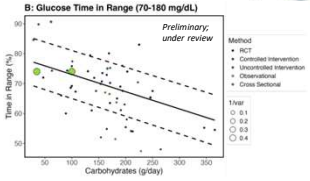
T1D Children:

- **↓25g/day carbohydrate intake associated with ↓0.19% HbA1c (p=0.015)**

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Results: Glycemic Control





CGM Mean Glucose

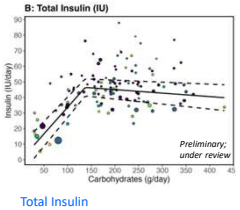
- **↓25g/day carbohydrate intake associated with ↓3.0mg/dL (p=0.002)**

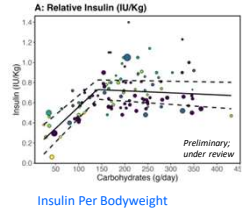
CGM TIR_{70-180}:

- **↓25g/day carbohydrate intake associated with ↑1.1% TIR (p=0.026)**

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Results: Insulin





Total Insulin

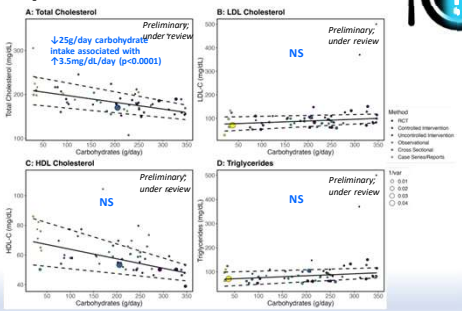
- **Knot: 137g/day**
- **↓25g/day carbohydrate intake associated with ↓7U/day (p<0.0001)**

Insulin Per Bodyweight

- **Knot: 140g/day**
- **↓25g/day carbohydrate intake associated with ↓0.1IU/kg (p<0.0001)**

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Results: Lipids



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2026 ADA/EASD Consensus



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Type 1 Diabetes: Very-Low Carb Diet

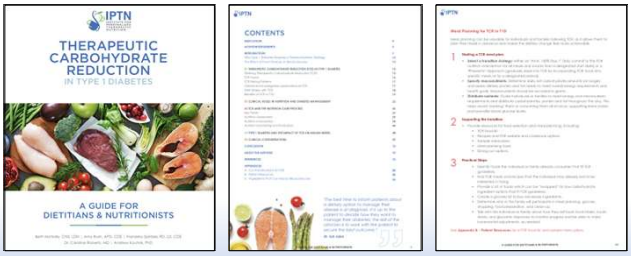
Risks:

- Frequent Hypoglycemia
  - No RCTs
  - Lower rates reported in VLCD observational analysis (n=314)
- Elevated LDL-C
  - No RCTs; Reported in non-T1D;
  - Meta-analysis doesn't show association.
- Euglycemic Ketoacidosis
  - No RCTs; Case report (caloric deficit).
- Restricts Pediatric Growth
  - No RCTs; Case report (caloric deficit)
  - Equivalent growth report in VLCD observational analysis (n=314)
- Disordered Eating Behavior
  - No RCTs; Case report (preexisting eating disorder); Reported with "restrictive eating"



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Type 1 Diabetes: International Healthcare Guidance



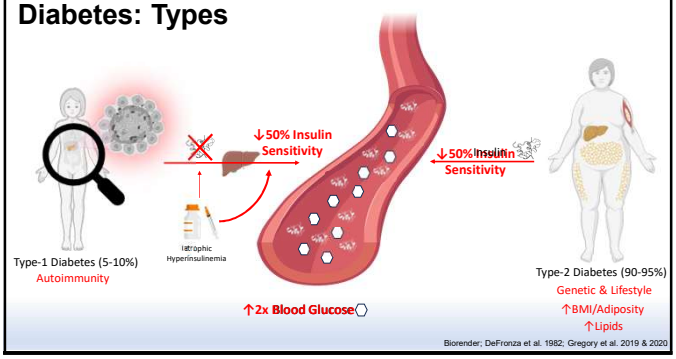
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Type 1 Diabetes: Very-Low Carb Diet

- Current therapeutic strategies do not reliably improve average HbA1c (~8%) more than 1%.
- Lower carbohydrate intake is associated with significant improvements in glycemic control and lower insulin load, without significant impact on LDL-C, HDL-C, or triglycerides.
- Administered under medical supervision. Monitor risks (nutrient deficient, hypoglycemia, euglycemia DKA, dyslipidemia).

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Diabetes: Types



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Type 2 Diabetes: Impact of Food



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Type 2 Diabetes: Impact of Food



CONTINUING EVOLUTION OF NUTRITIONAL THERAPY FOR DIABETES | APRIL 15 2019

Nutrition Therapy for Adults With Diabetes or Prediabetes: A Consensus Report FREE

In Special Collection: Continuing Evolution of Nutritional Therapy for Diabetes , ADA Medical Affairs Article Collection

Alison B. Evert; Michelle Dennison; Christopher D. Gardner; W. Timothy Garvey; Ka Hei Karen Lau; Janice MacLeod; Joanna Mitri; Raquel F. Pereira; Kelly Rawlings; Shamera Robinson; Laura Saslow; Sacha Uelmen; Patricia B. Urbanski; William S. Yancy, Jr.

Check for updates

Corresponding author: William S. Yancy Jr., will.yancy@duke.edu

Diabetes Care 2019;42(5):731–754

https://doi.org/10.2337/dci19-0014

PubMed 31000505

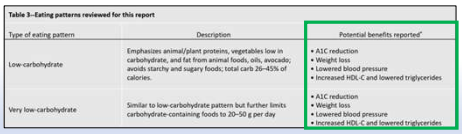
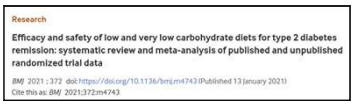


Table 3–Eating patterns reviewed for this report

Type of eating pattern	Description	Potential benefits reported*
Low-carbohydrate	Emphasizes animal/plant proteins, vegetables low in carbohydrate, and fat from animal foods, oils, avocado; avoids starchy and sugary foods; total carb 26–45% of calories.	• A1C reduction • Weight loss • Lowered blood pressure • Increased HDL-C and lowered triglycerides
Very low-carbohydrate	Similar to low-carbohydrate pattern but further limits carbohydrate-containing foods to 20–50 g per day	• A1C reduction • Weight loss • Lowered blood pressure • Increased HDL-C and lowered triglycerides

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Type 2 Diabetes: Remission

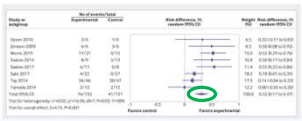


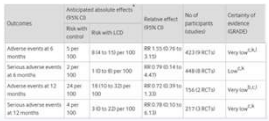
Research

Efficacy and safety of low and very low carbohydrate diets for type 2 diabetes remission: systematic review and meta-analysis of published and unpublished randomized trial data

BMJ 2021;372 doi: https://doi.org/10.1136/bmj.m4743 (Published 13 January 2021)

Cite this as: *BMJ* 2021;372:m4743





- Low-Carb: ↑32% Remission (<6.5% HbA1c) at 6 months
- Effect faded at 12 months (*limited data*)

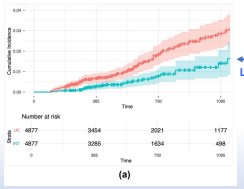
- Total adverse events: trivial & non-significant increase (risk difference 0.04)
- Serious adverse events: little or no effect

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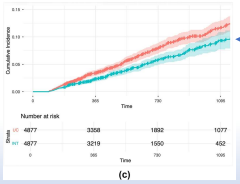
Type 2 Diabetes: Long-Term Endpoints (5-Year)



Cardiovascular Outcomes Among Adults with Type 2 Diabetes or Obesity Receiving Carbohydrate-Reduced Nutrition via Telemedicine: A Retrospective Claims-Based Cohort Study



LCD: ↓56% risk of new-onset CV events



LCD: ↓30% risk of new-onset ALL CVD

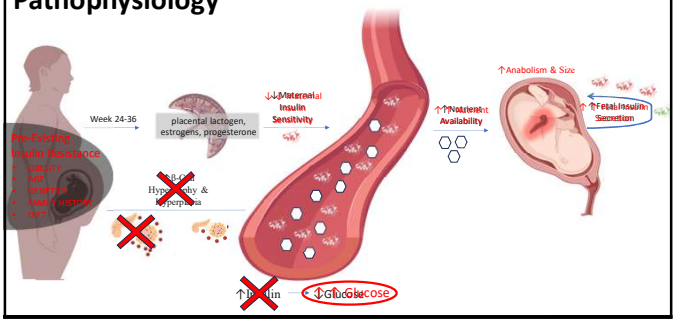
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Type 2 Diabetes: Low Carb Diet

- Low carbohydrate intake resulted in HbA1c, weight loss, blood pressure, HDL-C and Triglycerides
- Low carbohydrate intake increases the incidence of remission (HbA1c <6.5%), with minimal to no side effects.
- Low carbohydrate intake long-term (5-year) data suggest lower CV events compared to standard of care control.
- Risks include potential elevated LDL-C (mixed), medication-induced hypoglycemia, and transient adverse effects (dehydration, halitosis, hyperuricemia, and gastrointestinal symptoms) which typically resolve ≥4 weeks

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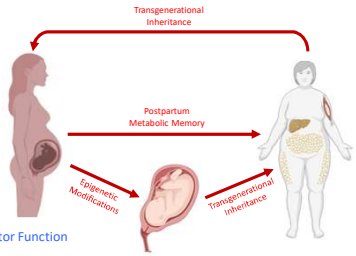
Gestational Diabetes: Pathophysiology



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Gestational Diabetes: Long-Term Clinical Implications

- Mother:
  - ↑6x – Obesity & Metabolic Syndrome
    - 50% don't lose 75% of their gestational weight
  - ↑7-10x – Type 2 Diabetes
    - 50-70% Women 5 years PP
  - ↑1.5-2.5x – MASLD
  - ↑2x – Depression
- Child:
  - ↑1.6-2.6x – Obesity & Metabolic Syndrome
  - ↑4.5x – Type 2 Diabetes
  - ↑2-8x – MASLD
  - ↑1.3x – Cardiovascular Risk
  - ↑1.4-1.7x – Impaired Cognitive & Psychomotor Function
  - ↑1.2x – Major Psychiatric Condition



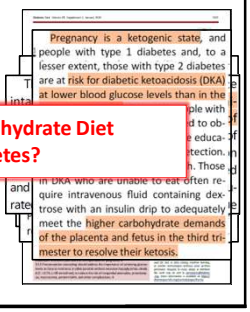
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Gestational Diabetes: Current Standard of Care

American Diabetes Association.

1. Recommends against a very-low-carbohydrate ketogenic diet.
2. Excess fat consumption is dang… overg…
3. Reco… 175g… "required" to fuel maternal brain and fetal brain development.
4. Minimize ketones due to concern for baby's neonatal health and development.

Evidence Against Low Carbohydrate Diet in Gestational Diabetes?


Pregnancy is a ketogenic state, and people with type 1 diabetes and, to a lesser extent, those with type 2 diabetes are at risk for diabetic ketoacidosis (DKA) at lower blood glucose levels than in the … in DKA who are unable to eat often require intravenous fluid containing dextrose with an insulin drip to adequately meet the higher carbohydrate demands of the placenta and fetus in the third trimester to resolve their ketosis.

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Gestational Diabetes: Impact of Food



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Gestational Diabetes: Low-Carb Clinical Evidence?



Study	Carb Intake	Evaluation	Outcome
Moreno-Castilla et al. 2013	Mod-Carb: 40% Control: 55%	RCT (n=152)	No Differences

1) ZERO trials evaluated the use of ketogenic diets in gestational diabetes.

2) Available evidence suggests carbohydrate reduction does not induce harm (and sometimes is helpful), with very limited evidence looking at "low-carb" intake.

↓Insulin
↓LGA
↓Cesarean

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Gestational Diabetes: 175grams of carbohydrates?



Dietary Reference Intakes: The Essential Guide to Nutrient Requirements (2006)

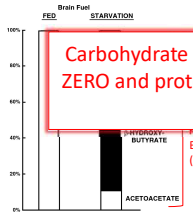
TABLE 1 Dietary Reference Intakes for Dietary Carbohydrates: Sugars and Starches by Life Stage Group

DRI for Pregnancy (made in 2006, and still adopted today) was **based on physiology of glucose metabolism in the brain…not trial evidence establishing diet requirements** for pregnancy or fetal brain energy metabolism. Let's look at the physiology…

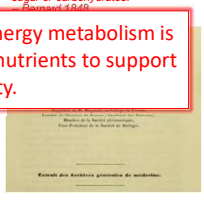
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Gestational Diabetes: 175grams of carbohydrates?

Carbohydrate requirements to meet brain energy metabolism: **0**
– Owen & Cahill 1969



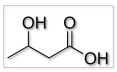
"Normally, there is always sugar in the blood of the heart and the liver. The sugar is formed by the liver; this is independent of the nutrition with sugar or carbohydrates."
– Pflüger 1948

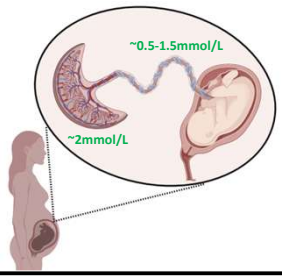


Carbohydrate required for brain energy metabolism is ZERO and protein can provide key nutrients to support glucose availability.

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Gestational Diabetes: Ketones & Neonatal Health/Development





For the FIRST TIME EVER…we now know that the fetus is in THERAPEUTIC KETOSIS (1.5-2mM) throughout pregnancy.

- **Ketones: 20–36% of fetal brain energy.**
- Ketones are not merely trace metabolites; they are **meaningful fetal brain substrates.**
- In utero ketosis now confirmed in 2 independent analyses (2023-Present).
- Given ketones' role in neurogenesis, brain health, and now fetal brain. metabolism…**it appears they are likely critical to fetal brain development in utero.**

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Summary

- People with T1D, T2D and Gestational Diabetes experience dysglycemia, insulin resistance, and/or elevated risk for comorbidities.
- Lower carbohydrate intake is associated
  - Type 1 Diabetes: significant improvements in glycemic control and lower insulin load, without significant impact on LDL-C, HDL-C, or triglycerides.
  - Type 2 Diabetes: significant improvement in glycemic control, weight, blood pressure, triglycerides, HDL-C, and remission. 5-Year data demonstrated lower cardiovascular disease risk.
  - Gestational Diabetes: evidence is limited evidence on low-carb and ZERO ketogenic diets trials.
- Low-carbohydrate diets are recommended under clinical supervision for type-1 and type-2 diabetes to mitigate potential diet-related risks. However, gestational diabetes guidelines recommend against their use.

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Science is a TEAM sport

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