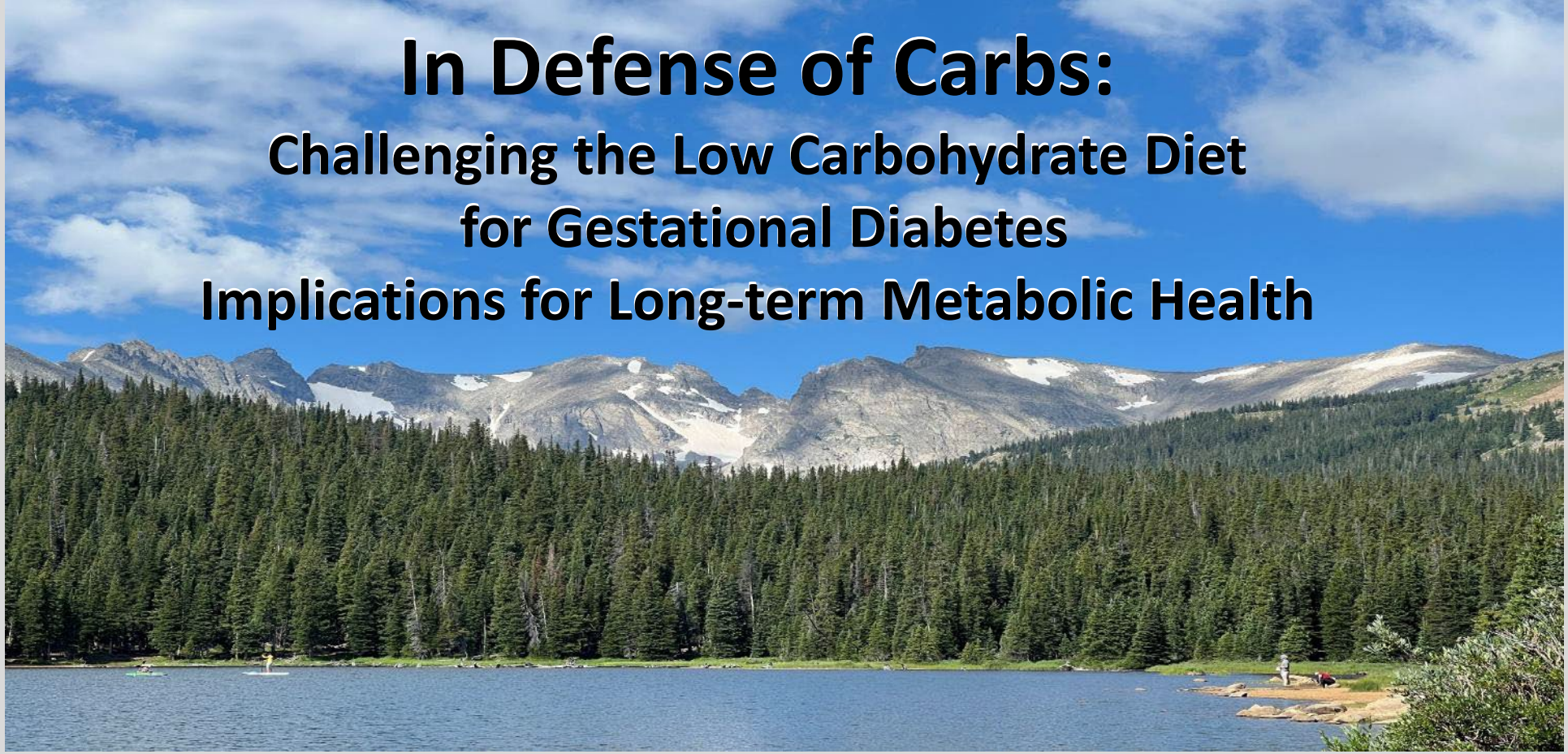


In Defense of Carbs:

Challenging the Low Carbohydrate Diet for Gestational Diabetes Implications for Long-term Metabolic Health

Teri L. Hernandez, PhD, RN, FAAN

Professor and Associate Dean for Research
University of Colorado Anschutz Medical Campus | College of Nursing

CU-CSU CCTSI Summit
August 13, 2025

uchealth

Children's Hospital Colorado

Infant GOLD

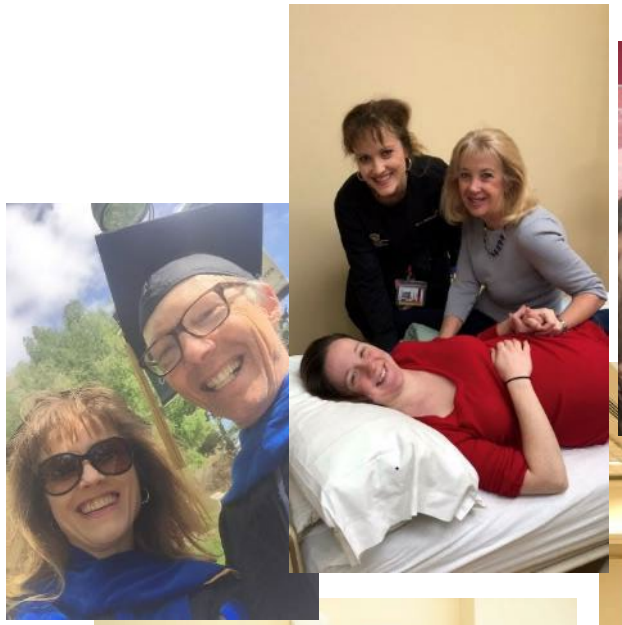
University of Colorado Anschutz Medical Campus
School of Medicine

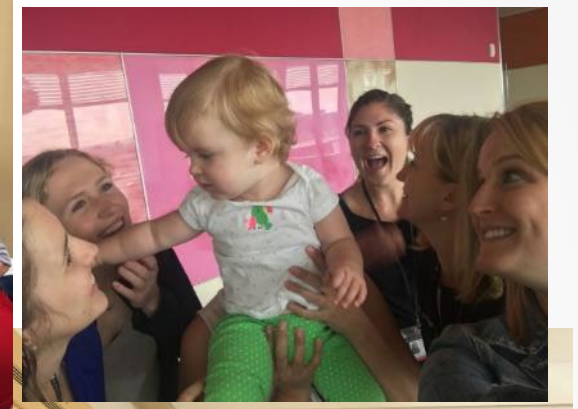
Colorado Clinical and Translational Sciences Institute (CCTSI)
UNIVERSITY OF COLORADO DENVER | ANSCHUTZ MEDICAL CAMPUS

CU NURSING 125 BOLDLY TRANSFORMING HEALTH TOGETHER

The Infant GOLD Team and Investigators

- Linda A. Barbour, MD, MSPH
- Jacob E. Friedman, PhD
- Sarah S. Farabi, PhD
- Bailey Fosdick, PhD
- Nicole Hirsch, MS
- Emily Dunn, RDN, CDE
- Kristy Rolloff, BA
- Jayne Martin-Carli, PhD
- Nancy F. Krebs, MD;
- Theresa L. Powell, PhD
- Regina Reynolds, MD
- Rachael E. VanPelt, PhD
- Laurie Moss, MS





Teri.Hernandez@CUAnschutz.edu

Nursing

Infant GOLD

Disclosure: Teri L. Hernandez

- Funded by NIH, NICHD: R01 HD102726
- Harold Hamm Diabetes Center, University of Oklahoma Health Sciences Center
- NIH/NCATS Colorado CTSA UL1 TR002534
- NIH, NIDDK: R01 DK101659
- Janssen Research and Development
- No Conflicts of Interest

Infant GOLD

Investigations in the **G**estational **O**rigins of **L**ifelong **D**evelopment

www.infantgoldresearch.org

Objectives

1. Make the case for flexibility in dietary carbohydrate content for Gestational Diabetes (GDM)
2. Present highlights of clinical trial results from the CHOICE diet parallel randomized controlled trial
   - *A Colorado approach to prevention*
3. Discuss implications for long-term metabolic health

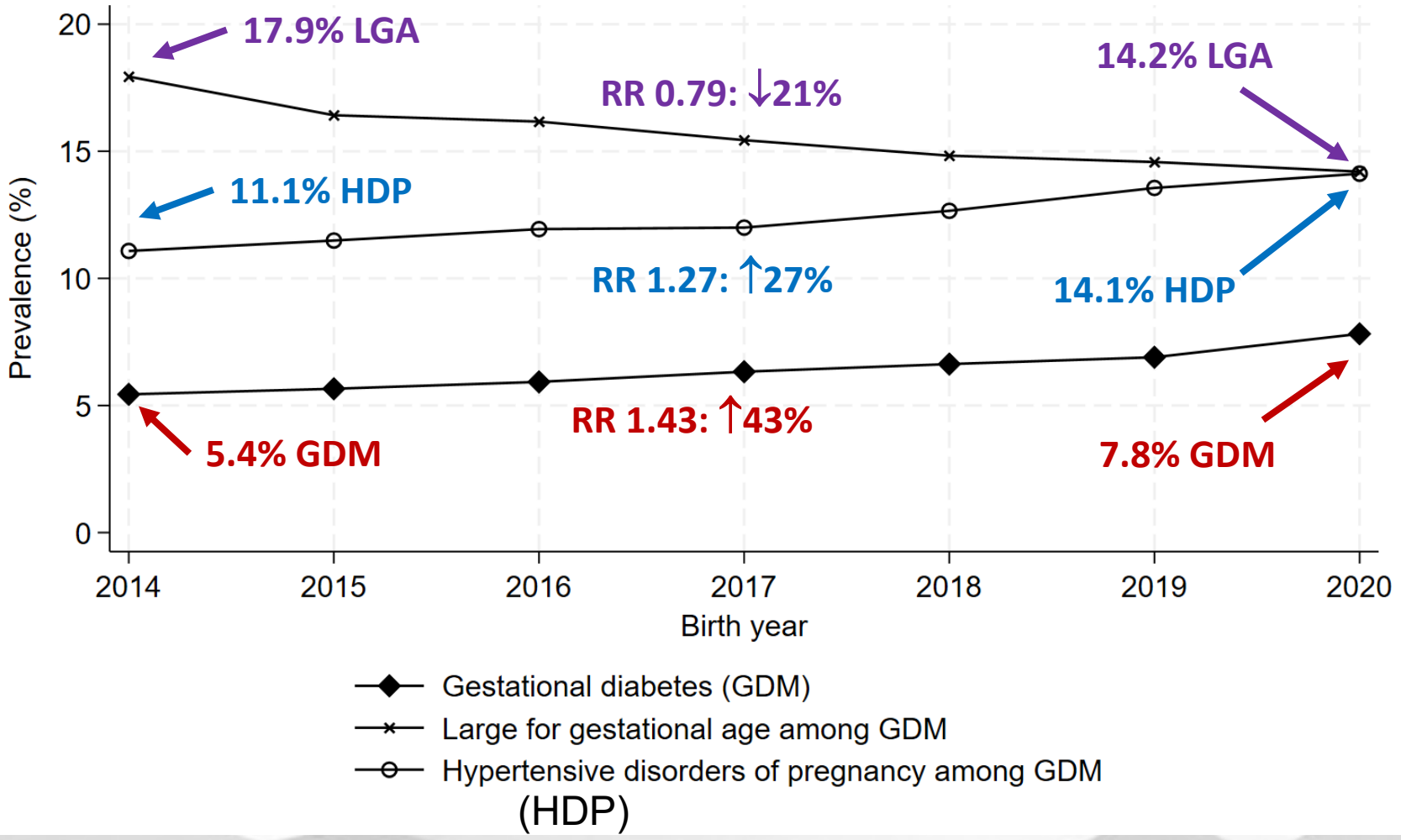
Lake Isabelle
North of Boulder, Colorado
August 2023

The Case for Flexibility in Dietary Carbohydrate Content

...

for Gestational Diabetes

Increasing Prevalence of GDM 2014-2020 with Decreased Large-for-Gestational Age



N= 25,437,281 total births

-National Center for Health Statistics, birth certificates
-n=1,620,820 (6%) with GDM

-Despite lower LGA over time, LGA prevalence was 15.5% in GDM vs. 9.4% in controls

RR = risk ratio

Valent, A; Garg, B; and Hernandez TL, 2024, in preparation

Nutrition Therapy in GDM: Doomed from the Start? Anxiety, Rigid Adherence, and Unintended Consequences

Until GDM diagnosis, pregnancy was "normal"…

- Suddenly: High risk pregnancy label, "diet", ↑rigid control of glucose, ↑surveillance, medications
- Anxiety, fear, depression

Psychology related to nutrition therapy in GDM[1-5]

- Focus: rigid restriction of carbohydrate
- Rapid adaptation in late pregnancy is challenging; food selection is mentally taxing
- Infringement on cultural/social beliefs
- Feel confined by the diet
  - Narrow range of "acceptable foods," limited food choices
- Rigid diet control: the most difficult component to treatment
  - **Unintended consequences: ↑↑fat intake**
- **Medicalization of eating**
  - "It feels like medically promoted disordered eating"

University of Colorado Hospital, circa 2002

1. Lawson EJ, 1994, Social Health Illn, 16(4):536
2. Hui AL, 2014, Diabetes Educ, 40(5); 668
3. Teixeira PJ, 2015, BMC Med, 13:84
4. Martis, R. 2018, BMC Preg Childbirth, 18:91
5. Benton M, 2023, PLOS One, 18(7):e0288395

A Low-Carbohydrate Diet in GDM is Conventional Therapy

- **Nutrition therapy is first line treatment for GDM across diagnostic criteria**
- Historically, diet designed to blunt post-prandial glycemia[1]
  - To prevent fetal overgrowth and large-for-gestational age (LGA)—as birthweight, or excess adiposity
  - 1990: 40% CHO; 45% fat; 15% protein
  - Pre-insulin era: Joslin diet was 2% carbohydrate, 70-80% fat
- The current evidence does not support one type of diet prescription for primary treatment of GDM and the quality of evidence is low[2]
- Evidence supports: ANY diet modification that *improves nutritional pattern once the diagnosis is made* reduces maternal glucose and birth weight (BW)[3,4]
  - Meta-analysis of 18 RCTs (n=1151 women). Fasting glucose ↓4mg/dL, postprandial glucose ↓8 mg/dL. Lower need for adjunctive medication (35%), birth weight ↓ 171g
- Infants born LGA or with ↑adiposity have higher risk for childhood overweight, insulin resistance, hypertension, some leukemias, and later diabetes and cardiovascular disease[5]

1. 1990, J Am Coll Nutr, 9(4): 320;1991, Diabetes, 40(Suppl 2), 172
2. Han, S, Cochrane Database Systematic Reviews, 2017, 2:CD009275
3. Yamamoto JM, 2018, Diabetes Care, 41:1346
4. Hernandez TL & Barbour LA, 2018 Diab Res Clin Pract, April 03
5. Scifres, CM, 2021, Obstet Gynecol Clin N Am, 48:325

Developmental Origins of Health and Disease: A "Thrifty" Phenotype

Fetal Under-nutrition

Changes in Gene Expression/ Organ Development

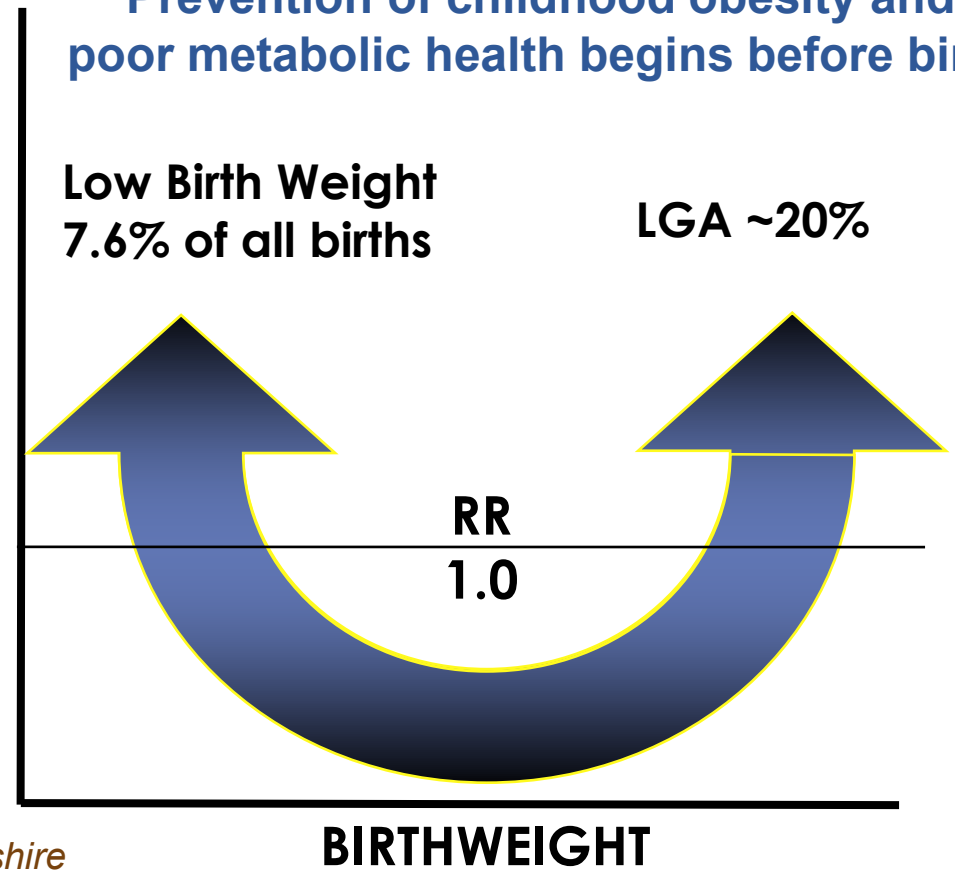
Rapid Catch-up Growth

Glucose-Conserving bias in metabolism?

Diabetes Metabolic Disease CVD

Hertfordshire
Helsinki
Dutch Famine

Prevention of childhood obesity and poor metabolic health begins before birth



Fetal Over-nutrition

Epigenetic changes in Gene Expression/ Organ Development

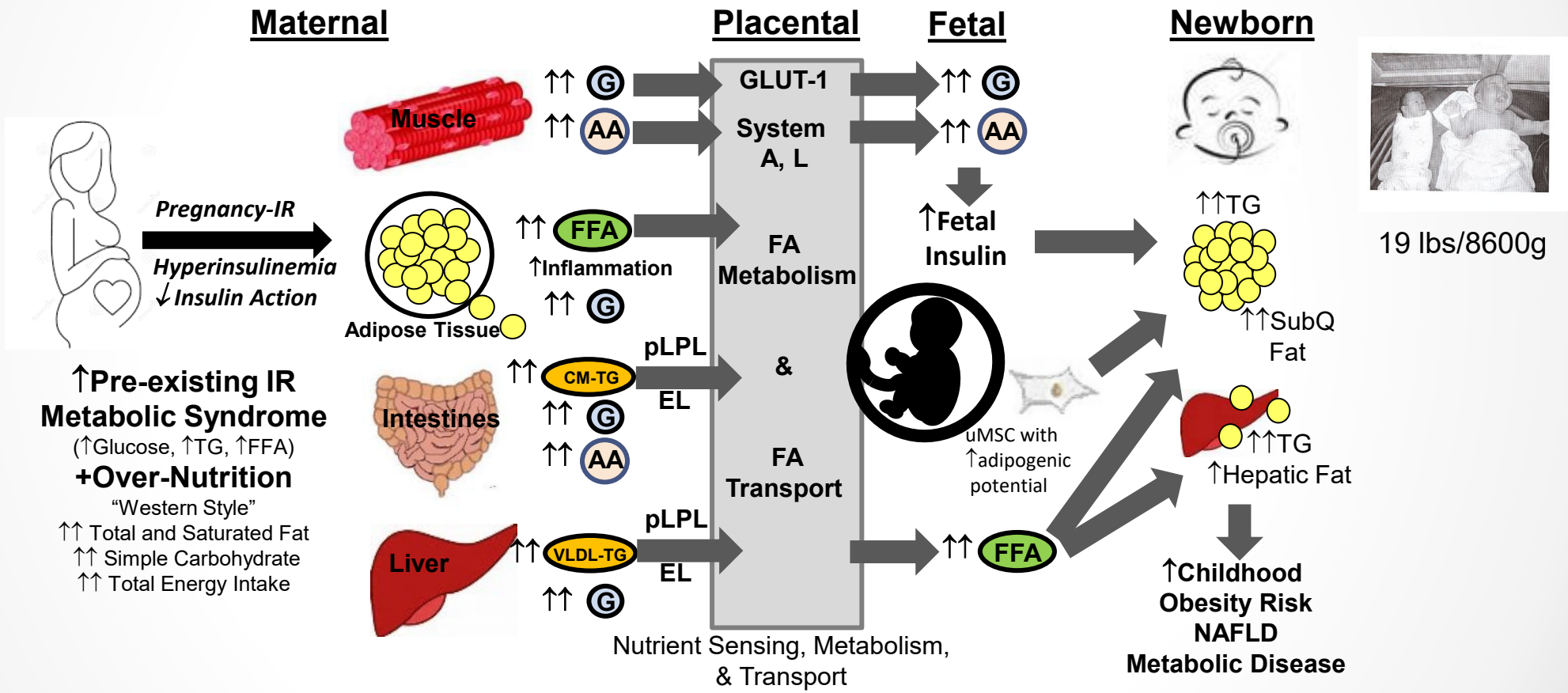
Environmental Stimuli Rapid Catch-up Growth

Diabetes Metabolic Disease CVD

Pima Indians
NW University

Hales & Barker, 1992, Diabetologia; 35:595
Barker, DJP, 2005, Horm Res; 64(suppl 3); 2-7
Vaag, AA, 2012, Diabetologia; 55:2085

Maternal Nutrition: Primary Intervention for Manipulation of Gestational Metabolism



19 lbs/8600g

Pedersen, 1952
Freinkel, 1980, Diabetes, 29(12):1023
Barbour LA & Hernandez TL, 2018, Clin Ther, Sept 17

Mom's garden
Hoffman Estates, Illinois
June 2024

The CHOICE Diet Randomized Trial

Highlights of Clinical Trial Results

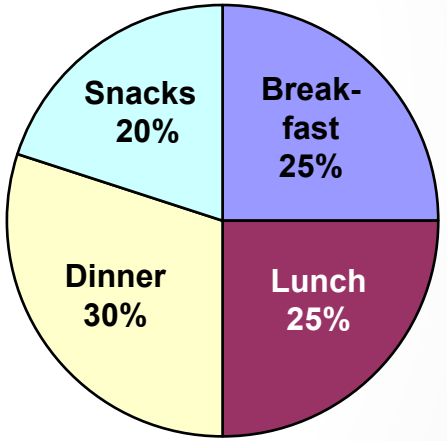
• • •

"…the placenta and the fetus develop in an incubation medium that is wholly derived from maternal fuels."
-Norbert Freinkel
1980 Banting Lecture

Nutrition Arms:
All Meals were Provided through CCTSI Bionutrition Core

- **CHOICE™ = Choosing Healthy Options In Carbohydrate Energy**
  - 60% carb, mostly complex
  - 25% fat
  - 15% protein
- **LC/CONV = Conventional Low Carbohydrate**
  - 40% carb
  - 45% fat
  - 15% protein
- Both diets
  - Eucaloric
  - SFA- 35-45%; MUFA- 35-45%; PUFA- 15-20%
  - **Simple Sugars: fixed at 70±5g in both diets**
  - Carbs are 'complex:' low-moderate glycemic index
  - Fiber is similar (~24g/day in LC, ~29g/day in CHOICE)

Caloric Distribution



Infant GOLD

Hernandez, TL, 2014, Diabetes Care, 37(5):1254.
R01 DK101659

Hypothesis

7-8 weeks of CHOICE (60% carbohydrate, mostly complex) vs. a Conventional low carbohydrate diet (40%) would improve glycemia, insulin resistance, reduce free fatty acids (FFA), and reduce newborn adiposity

Diabetes Care
American Diabetes Association

Randomization to a Provided Higher-Complex-Carbohydrate Versus Conventional Diet in Gestational Diabetes Results in Similar Maternal 24-Hour Glycemia and Newborn Adiposity

Teri L. Hernandez, Sarah S. Farabi, Bailey K. Fosdick, Nicole Hirsch, Emily Z. Dunn, Kristy Rolloff, John P. Corbett, Elizabeth Haugen, Tyson Marden, Janine Higgins, Jacob E. Friedman, and Linda A. Barbour

Diabetes Care 2023;46(11):1–10 | https://doi.org/10.2337/dc23-0617

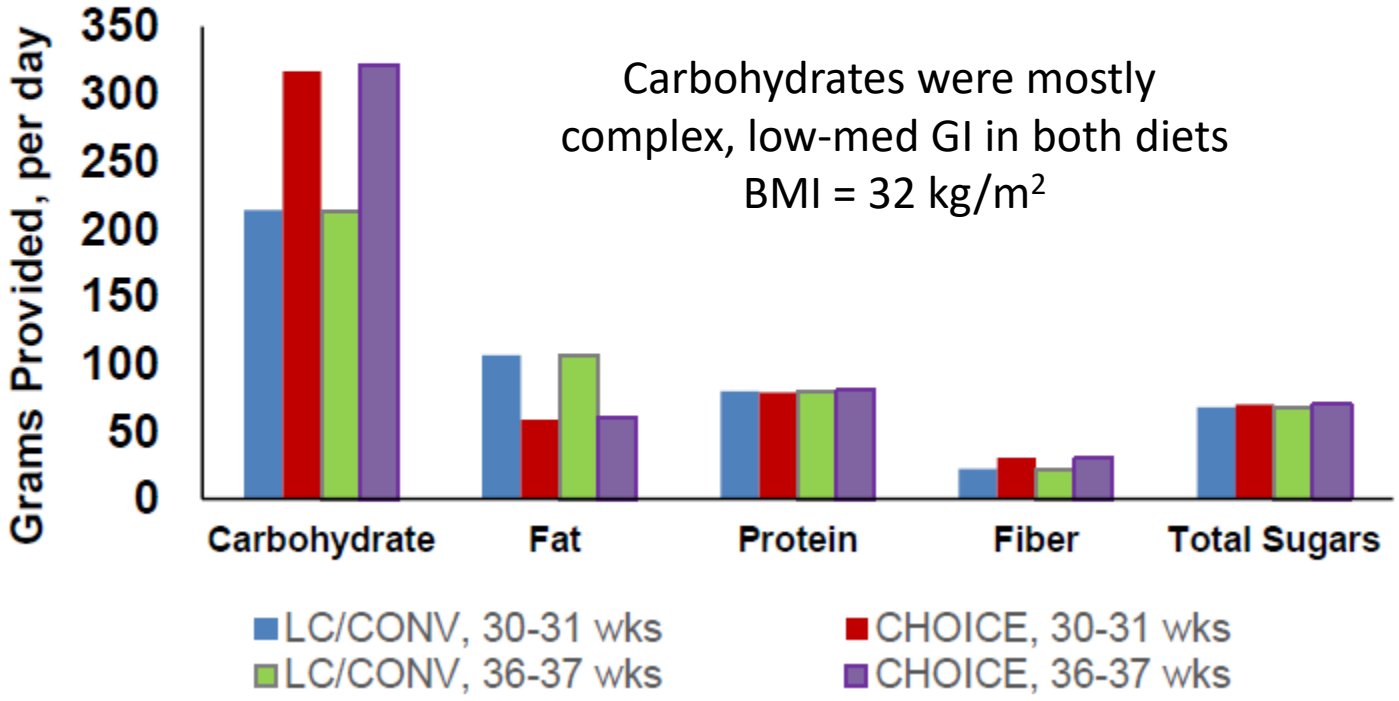
Newborn body Composition by PEAPOD

Infant GOLD

Hernandez TL, R01 DK101659

RCT: 7-8 wks, All Meals Provided
Lower Carbohydrate vs. Higher Carbohydrate

Conventional: 40% CHO, 45% Fat, 15% Pro
CHOICE: 60% CHO, 25% Fat, 15% Pro



Carbohydrates were mostly complex, low-med GI in both diets
BMI = 32 kg/m^2

CHO = Carbohydrate

	40% CHO	60% CHO
Carbohydrate, g/d	214	316
Fat, g/d	106	59
Protein, g/d	80	79
Calories, kcal/d	2101	2098
Saturated Fat, g/d	34	18
Sugars, g/d	68	70

At Randomization, ~31 wks
Eucaloric Diets
Adherence >90%, both groups

Hernandez, TL, Diabetes Care, 2023, 46:11 1-10

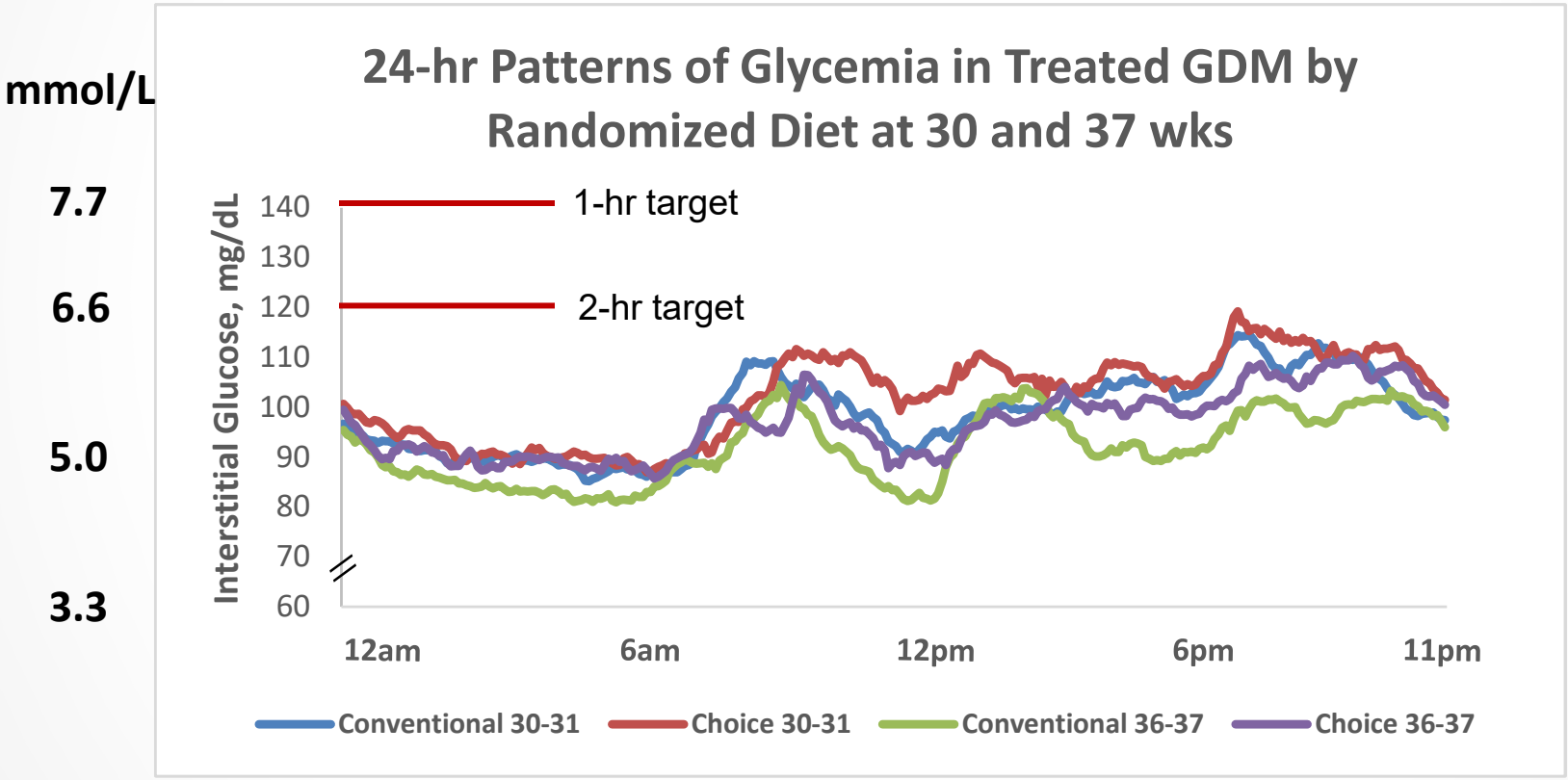
Infant GOLD

Participant Characteristics

Women with A1 GDM, Baseline		Mean±SEM
	CONVENTIONAL	**CHOICE**
N=59 randomized	28	31
Required Medication/Pregnancy Complication Exclusion	2/3	1/6
Completed the study	23	23
Caucasian/Hispanic/Asian/Black, %	78/17/13/9	74/17/17/0
Weeks gestation, study baseline	31±0.1	32±0.1*
Age, yrs	32±1	33±1
BMI, pre-pregnancy, kg/m^2	28±1	30±1
BMI, kg/m^2, study baseline	32±1	32±1
Gravida/Para	2/1	2/1
Characteristics at Delivery		
Gestational Age, delivery, wks	39±0.2	39±0.3
Vaginal/C-Section delivery, %	78/4	61/17
BMI at delivery	32±1	34±1
Delta weight (delivery-study baseline), kg	1.8±0.3	2.0±0.4
Total Gestational Weight Gain, kg	11±1.2	10±0.9
Days on Diet	54±2	48±2

Infant GOLD

No Between-Group Differences in 24-hour Glycemia



40% CHO diet: (214g/day)

60% CHO diet: (316g/day)

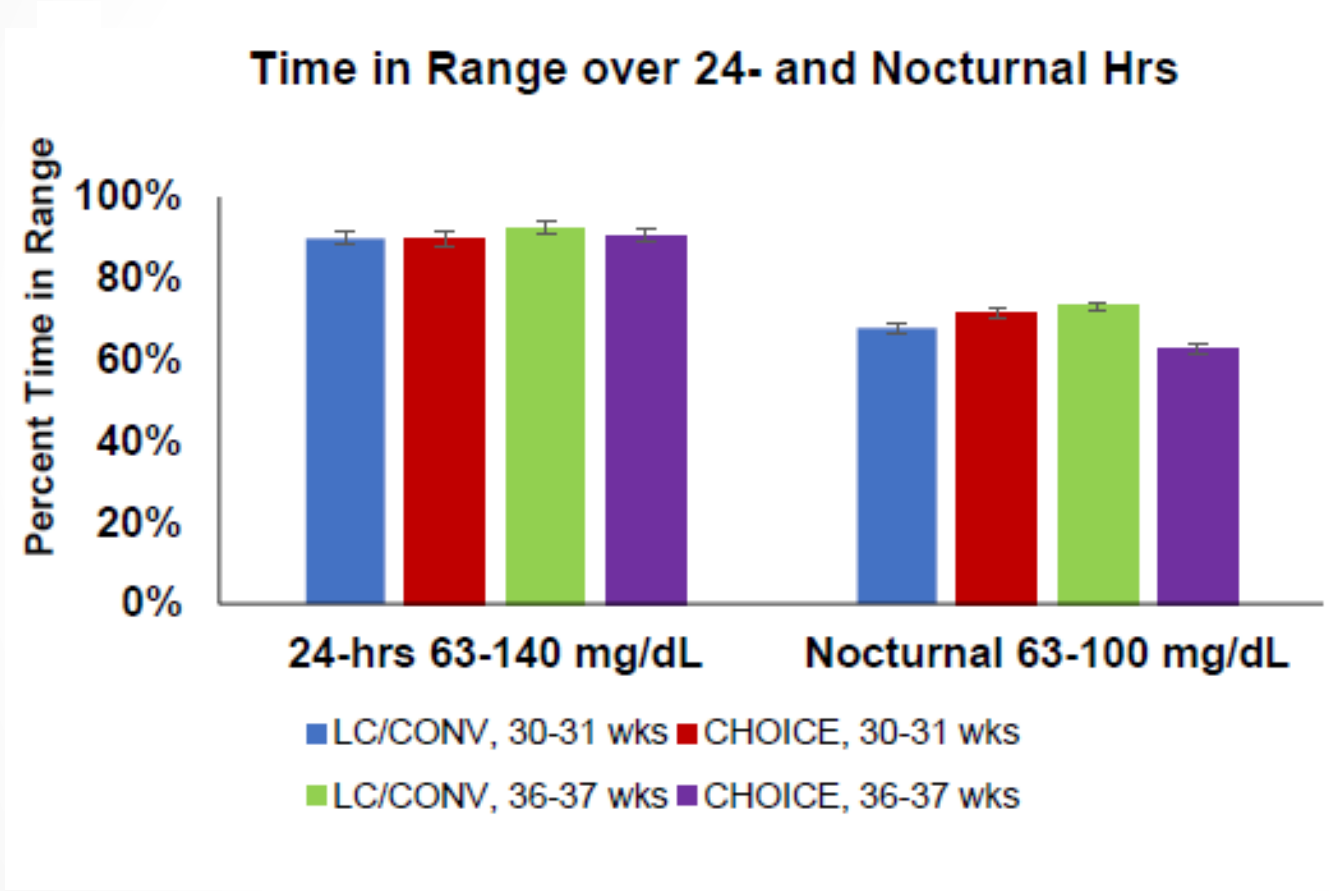
Mean ± SEM
All between-group Comparisons, >0.05

No increases in glycemic measures over time with ↑insulin resistance

Hernandez, TL, Diabetes Care, 2023, 46:11 1-10

Infant GOLD

No Between-Group Differences: %Time in Range



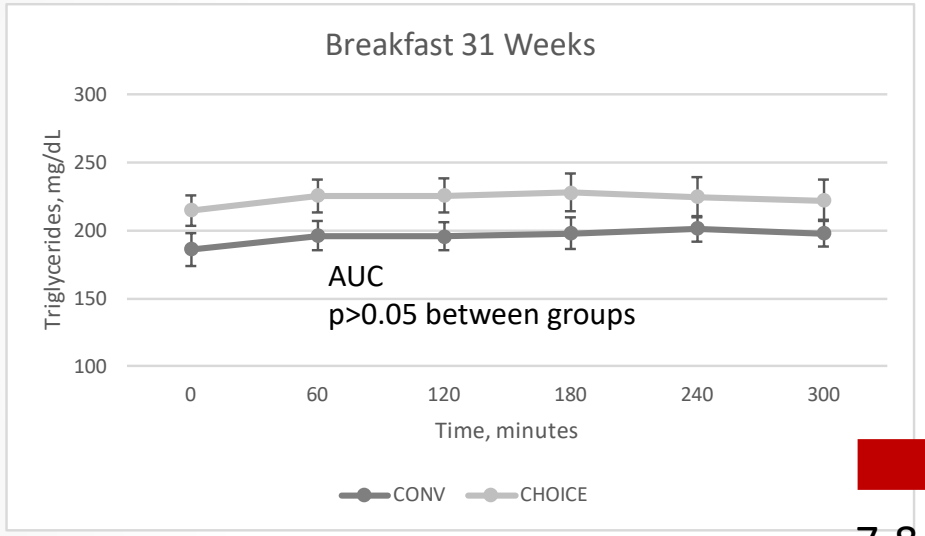
40% CHO-45% Fat (214g/d) vs. 60% CHO-25% fat (316g/d)

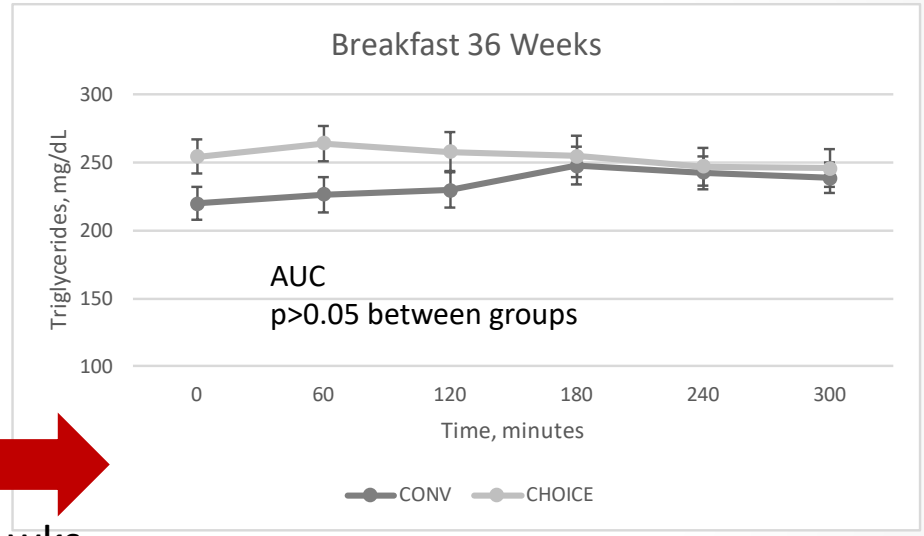
R01 DK101659

Hernandez, TL, Diabetes Care, 2023, 46:11 1-10

Similar Increase in Triglycerides on both Diets

40% CHO-45% Fat vs. 60% CHO-25% fat





7-8 wks

Fasting TG:
CONV: 186
CHOICE: 217

Women on CHOICE
at higher TG at study baseline

Fasting TG:
CONV: 219
CHOICE: 257

Women on CONV had 5% higher Increase in TG over time (p>0.05)
—clinically significant?

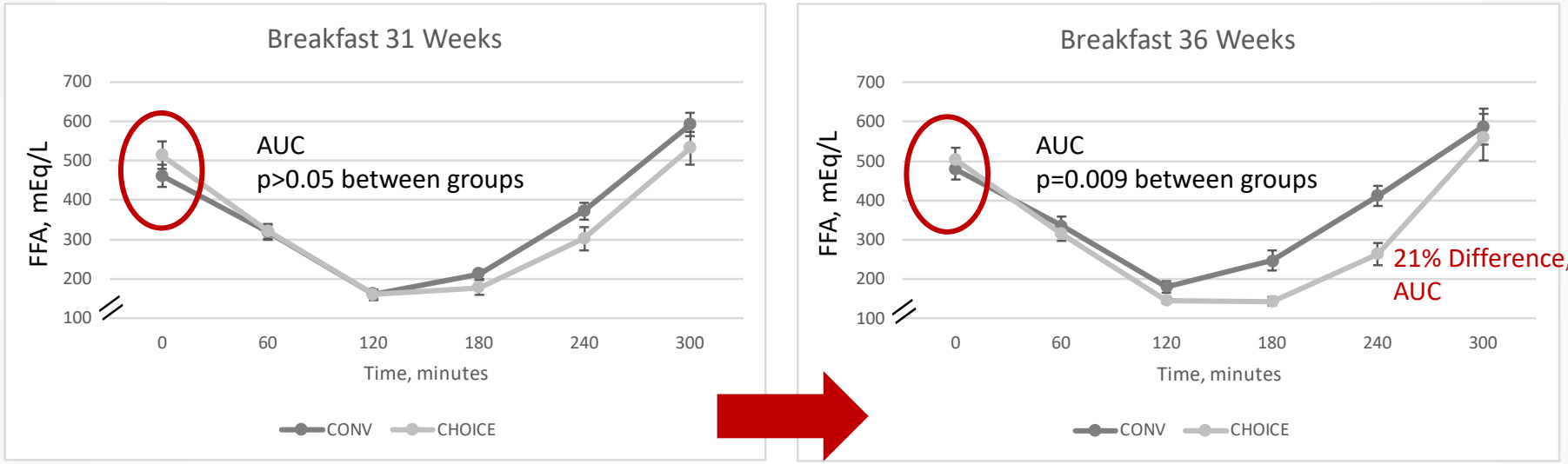
Breakfast test meals
30% of total energy intake
Mean±SEM

Fasting TG increased by ~33-40 mg/dL
in both groups (p<0.001 for both, within group change)

Infant GOLD

Hernandez, TL, Diabetes Care, 2023, 46:11 1-10

Lower Postprandial FFA
Higher Complex Carbohydrate Diet after 7-8 wks



7-8 wks

Breakfast test meals
30% of total energy intake
Mean±SEM

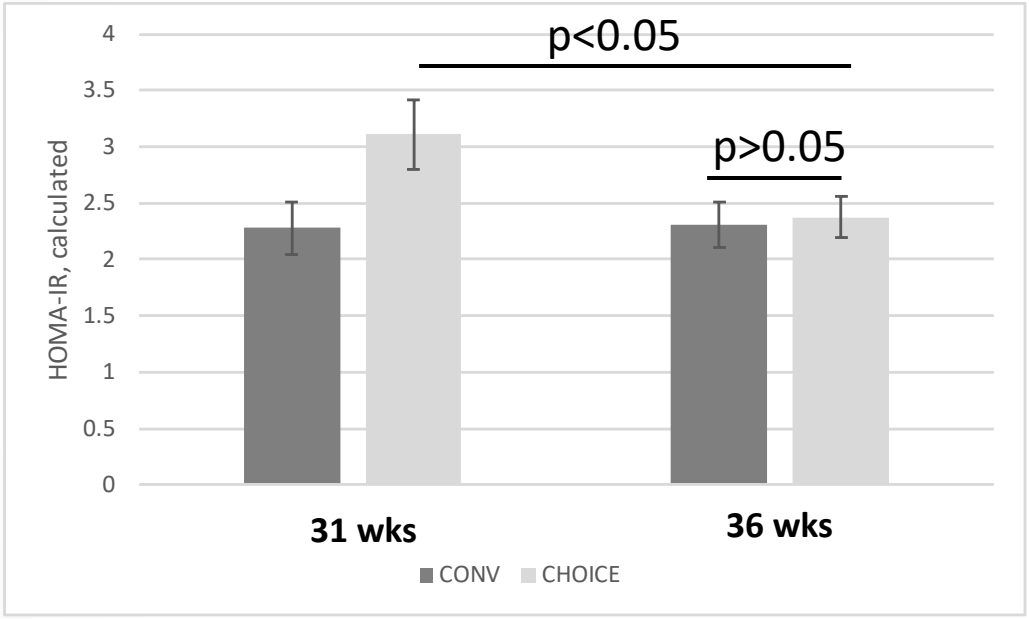
FFA AUC <u>increased</u> on the Conventional diet and <u>decreased</u> on CHOICE, resulting in 21% decreased FFA exposure on Choice compared to CONV

40% CHO-45% Fat (214g/d) vs. 60% CHO-25% fat (316g/d)

R01 DK101659

Hernandez, TL, Diabetes Care, 2023, 46:11 1-10

Improved Insulin Resistance by HOMA-IR on Choice by 36-37 wks Weeks



Fasting plasma glucose/insulin, OGTT day

Insulin Resistance by Matsuda Index

	31 Wks	36 Wks
CONV	3.1±0.2	3.1±0.3
CHOICE	2.5±0.2	2.8±0.2

Higher HOMA-IR indicates ↑ insulin resistance
Higher Matsuda Index indicates ↑insulin sensitivity

Infant GOLD

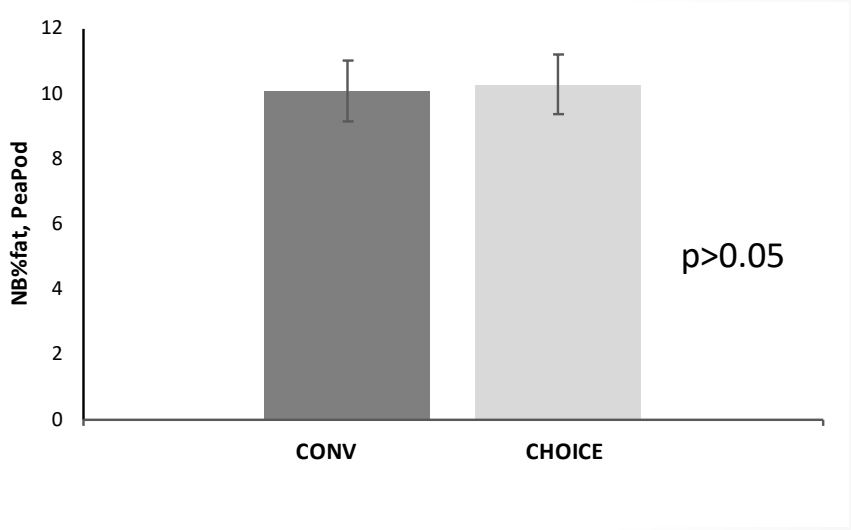
Hernandez, TL, Diabetes Care, 2023, 46:11 1-10

Primary Outcome: Similar Neonatal Adiposity and Cord Blood Insulin between Diets

	Conventional	CHOICE
Birth weight, g	3303±470	3293±389
Body fat, %	10.25±4.5	10.8±4.3
LGA, %	17	13
SGA, %	4	0
Gender (M/F)	11/12	11/12
TG, mg/dL, cord	48±24	43±12
Glucose, mg/dL, cord	77±21	83±28
Insulin, uIU/L, cord	6.6±5	7.2±3
C-peptide, ng/mL, cord	0.69±0.27	0.83±0.35

Mean±SD

LGA=large-for-gestational age; SGA=small-for-gestational age



Primary Outcome

These data reveal implications for eucaloric conditions

Infant GOLD

Hernandez, TL, Diabetes Care, 2023, 46:11 1-10

Implications

...

for Long-Term

Metabolic Health

"Top of the World"
Pike's Peak: 14,115 feet
Colorado Springs, Colorado
August 2023

Infant GOLD

Choices for Women can support a *Food as Medicine* Approach

TABLE 2
Recommended reproductive diet patterns

Name	Includes	Excludes	Benefits	Risks
Optimal diets				
Mediterranean diet	Plant-based foods—vegetables, fruits, whole grains, legumes, nuts, herbs, spices, olive oil, fish, poultry, and red wine Up to 40% calories from fat	Limits red meat a few times per month	Reduces the risk of CVD, mortality, cancers, and cognitive diseases	
Dietary approaches to stop hypertension	Balanced complex carbohydrates (58%), lower fat (28%), and moderate protein (18%) High in fiber, calcium, phosphorus, magnesium, and potassium	Low in cholesterol, fat, and sodium	Reduces weight, lowers BP and cholesterol, and reduces the risk of CVD and bone loss	Needs vitamin D supplementation
Flexitarian diet	Vegetarian most of the time, more vegetables, whole grains, plant-based or nonmeat proteins ("new meat"), dairy, and "sugar and spice" Focus on home prepared food with <5 ingredients	Meat and dairy in moderation if at all	Lowers BP and cholesterol, reduces weight, and reduces the risk of heart disease, stroke, and diabetes mellitus	May need calcium, vitamin B12, and iron supplementation
Nordic diet	Fruits, vegetables, legumes, potatoes, whole grains, nuts, seeds, rye bread, fish, seafood, low-fat dairy, herbs, spices, and canola oil	Rare red meat and animal fats No sugar-sweetened beverages, added sugars, processed meats, and refined fast foods	Reduces weight and lowers BP and inflammatory markers	
Diets to avoid during pregnancy				
Atkins diet 20-40-100	Low carbohydrate (20 g), high fat, beef, pork, poultry, fish, eggs, cheese, and sources of fat	Limit starchy vegetables, grains, legumes, simple sugars, and milk		Needs vitamin C, B vitamins, folate, calcium, and magnesium
Paleo diet	Lean meats, fish, eggs, nuts, seeds, fruits, vegetables, and oils	Processed foods, wheat, other grains, legumes, dairy, potatoes, refined sugar, salt, and refined oils	Reduces weight and lowers the risk of diabetes mellitus, heart disease, and cancer	Needs calcium, B vitamins, andwhole grain nutrients
Ketogenic diet	Extreme carbohydrate restriction ketosis, skin-on poultry, fattier beef, pork, fish, green leafy vegetables, oils, and solid fats	Avoid starchy root vegetables, bread, pasta, other grains, and fruit	Reduces weight	Not recommended in pregnancy because of altered neonatal brain development Needs vitamin C, B vitamins, folic acid, calcium, and fiber

BP, blood pressure; CVD, cardiovascular disease.

Marshall. Nutrition in pregnancy: lifelong consequences. Am J Obstet Gynecol 2021.

TABLE 3
Common ground for healthy dietary patterns

- Whole, unprocessed foods and beverages
- Rich in fruits and vegetables
- Whole grains and complex carbohydrates, including ancient grains
- Healthy fats (monounsaturated and polyunsaturated), including nuts and seeds
- Healthy fish
- Plant-based protein
- Drink more water
- Lean meats and dairy products

Marshall. Nutrition in pregnancy: lifelong consequences. Am J Obstet Gynecol 2021.

[1] Marshall, N (2022) Am J ObGyn, May;226(5):607-632

A Less Restrictive Carbohydrate Approach is Culturally Adaptive

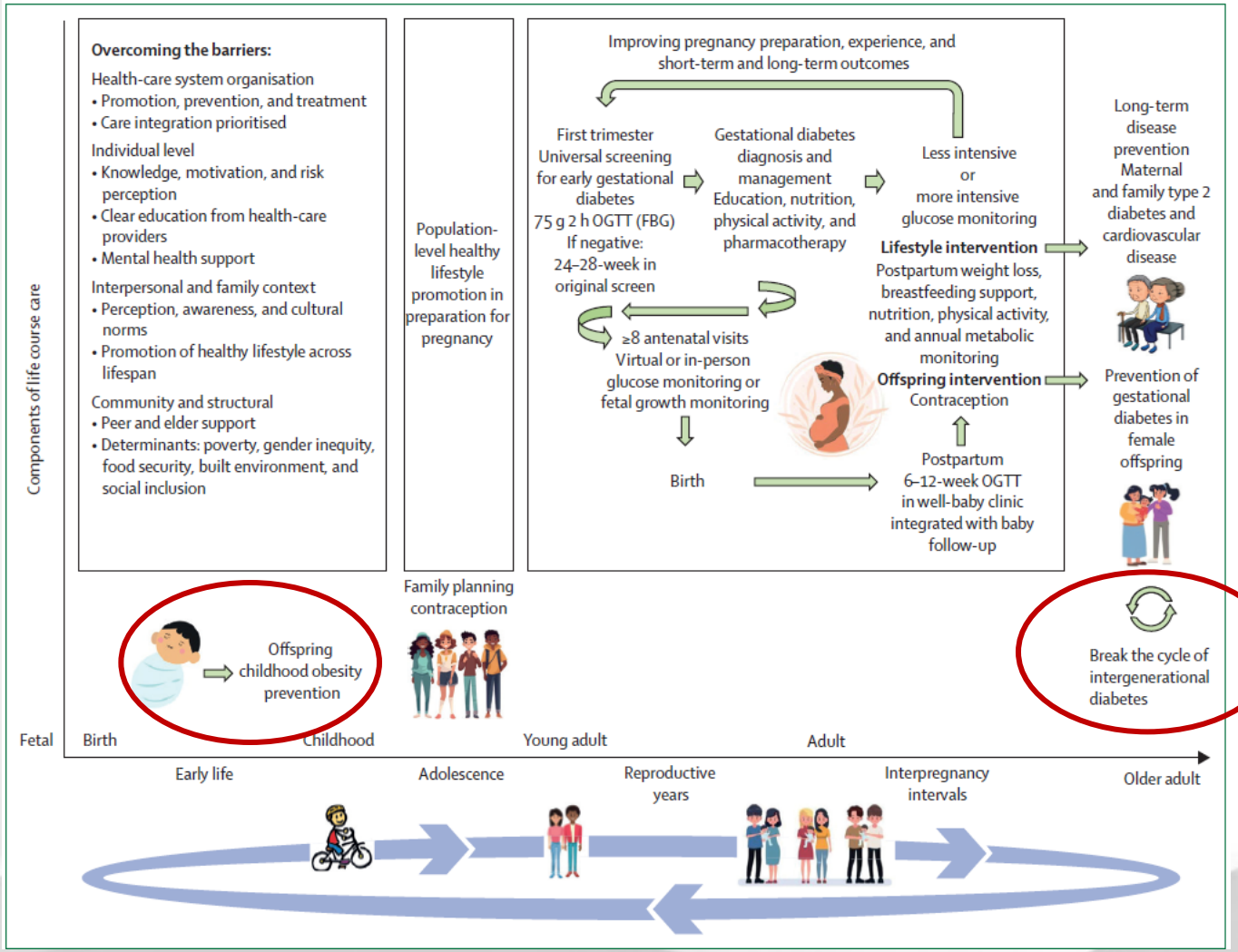
Table 1 – Local/traditional foods from varied geographical regions that qualify for a less carbohydrate-restricted dietary approach in GDM.

Geographical region	Examples of traditional foods that qualify for less restricted GDM Nutrition therapy approach
North America	– Whole grain breads, pasta, brown or parboiled rice, oats – Vegetables, fruits, beans, lentils – Low-fat dairy, lean poultry and fish – Occasional meats, cheese and nuts
Latin America	– Whole grains like amaranth, maize, quinoa, brown rice – Vegetables, fruits, beans – Lean poultry, fish, low-fat dairy – Occasional meats, nuts and cheese
Mediterranean Region	– Whole grain bread/pasta, brown rice, couscous – Vegetables, fruits, beans, lentils – White fish, lean poultry, low-fat dairy – Occasional nuts, cheese, meats and shellfish
Africa	– Whole grains like millets, sorghum, teff, parboiled rice – Vegetables, fruits, roots, tubers, beans – Fish, eggs, poultry – Occasional meats and dairy
South Asia	– Whole wheat, millets, barley, rye, buckwheat, parboiled rice, wheat rotis – Vegetables, roots, tubers, fruits – Beans, lentils, dals, low-fat dairy, lean poultry, fish – Occasional meats, nuts and cottage cheese (paneer)
East Asia	– Noodles and brown rice – Soybeans, fish, seafood, vegetables, wild plants, seaweed, mushrooms – Occasional lean meats, shellfish, dairy

Infant GOLD

Hernandez TL & Barbour LA, 2018, Diabetes Res Clin Pract,Apr 19

A Lifecourse Approach to Prevention of Diabetes and Cardiovascular Disease is Urgently needed



Consistent Risk Factors for childhood overweight/ Obesity can be addressed through nutrition in pregnancy[1]

- ↑pre-pregnancy BMI
- Prenatal tobacco exposure
- Excess GWG
- Higher neonatal birth weight
- Higher neonatal adiposity
- Accelerated infant weight gain

Healthy nutrition is a key component to lifecourse prevention of diabetes in mother, offspring and families

Remember the U-shaped curve

1. Baidal JAW, 2016, Am J Prev Med; 50(6): 761-779 2. Simmons D, 2024, Lancet; 404(10448):193

In Defense of Carbs: Implications Moving Forward

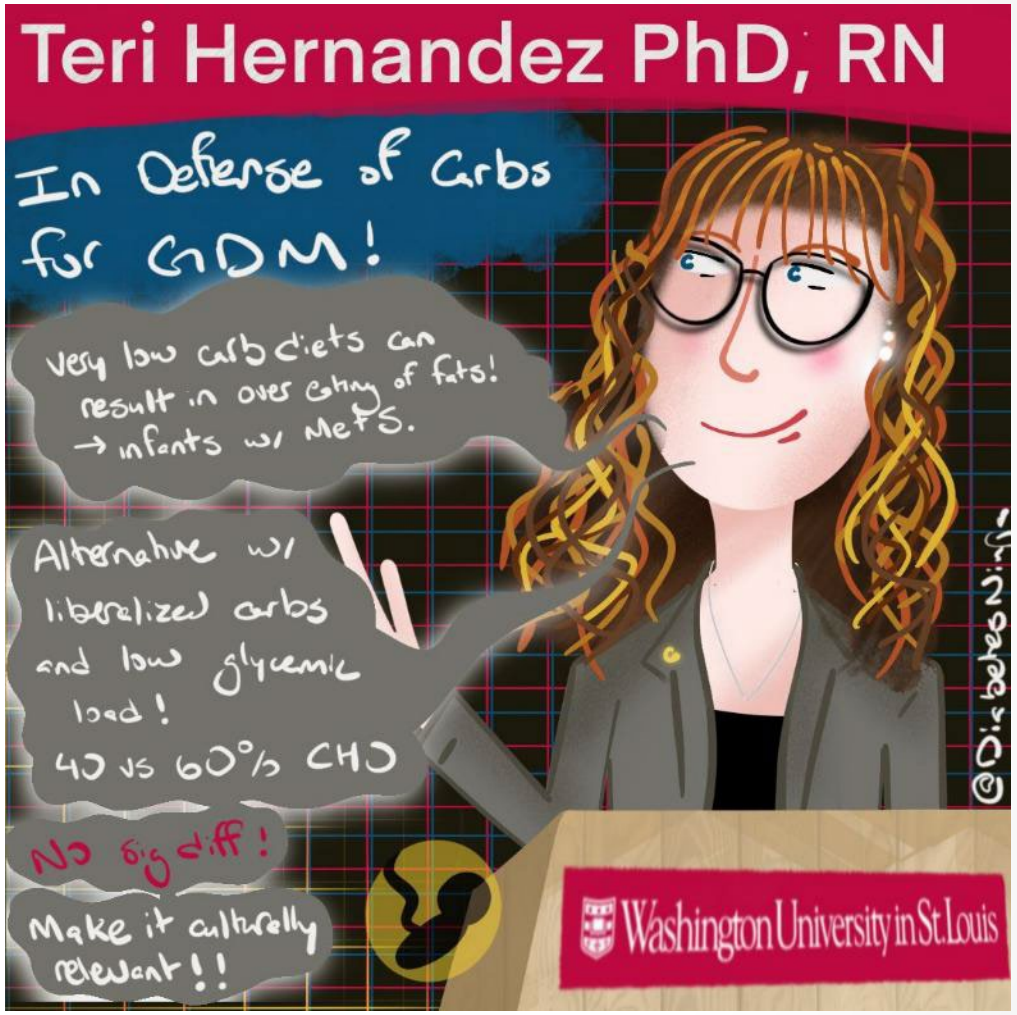
In our Colorado approach to prevention of fetal overgrowth:

- **First controlled data in humans to support that liberalization of higher complex carbohydrate results in:**
  - Glucose that meets treatment targets
  - Lower FFA
  - No difference in neonatal %fat or cord insulin levels
    - ***Expanding nutrition options in GDM***
- **Liberalization of high-quality carbohydrates in GDM supports long-term healthy lifecourse development trajectories**
  - For women, children, and families

Infant GOLD

- Linda A. Barbour, MD, MSPH
- Jacob E. Friedman, PhD
- Rachael E. Van Pelt, PhD
- Nicole Hirsch, MS, CLC
- Sarah Farabi, PhD, RN
- Emily Dunn, MS, RDN, CDE
- Kristy Rolloff, BS
- Elizabeth Phillips, BA
- Laurie Moss, MS
- Nancy Krebs, MD
- Claire Ingram, PA
- Joe Hinojosa, MS
- Evangelique Lopez, BA
- Janine Higgins, PhD
- Tyson Marden, MS
- Synneva Hagen-Lillevik, PhD, RD
- Eli Provencio-Vasquez, PhD, RN
- Paul J. Rozance, MD

Thank you!



Center for Nursing Inquiry
COLLEGE OF NURSING
UNIVERSITY OF COLORADO ANSCHUTZ MEDICAL CAMPUS

Teri.Hernandez@CUAnschutz.edu

Infant GOLD