



**Pennington Biomedical  
Research Center**  
Louisiana State University



# **Be the Reason Kids Greaux Healthy**

## **Annual Childhood Obesity Conference**

# **Preventing Childhood Obesity Before It Begins**

**The Critical Role of Maternal Health, Early Feeding Environments, and Family Influences**

Presented by Emily Flanagan, PhD and Jennifer Savage Williams, PhD

# **Breaking the Cycle:** ***Pregnancy, Infant Feeding, and the Intergenerational Transmission of Obesity***

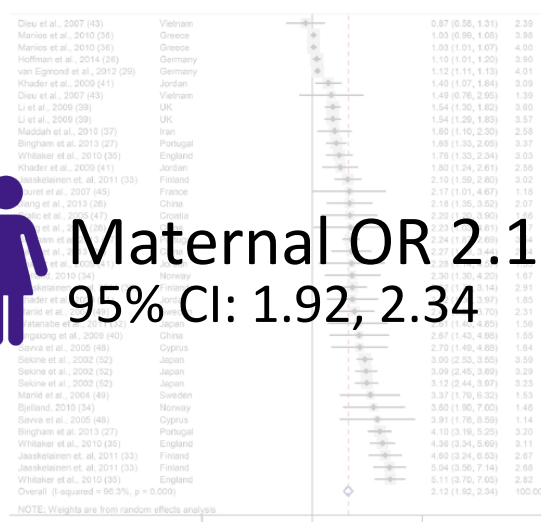
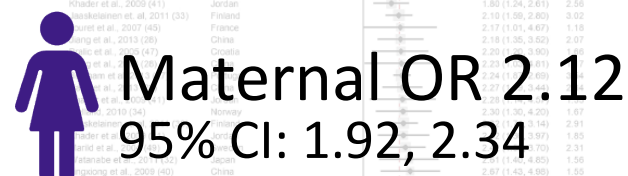
**Emily W. Flanagan, MS, PhD**  
Developmental Physiology Laboratory  
**Pennington Biomedical Research Center**  
Baton Rouge, LA





Paternal OR 1.92  
95% C: 1.74, 2.12

| Author et al. (Year)           | Country   | OR (95% CI)       |
|--------------------------------|-----------|-------------------|
| Vihakurja et al., 2010         | England   | 1.45 (1.08, 1.95) |
| Li et al., 2006 (38)           | China     | 1.48 (1.22, 1.80) |
| Crisu et al., 2007 (43)        | Venezuela | 1.49 (0.82, 2.33) |
| Jaskasselaan et al., 2011 (33) | Finland   | 1.89 (1.23, 2.91) |
| Wahlsten et al., 2006 (39)     | USA       | 2.08 (1.45, 2.96) |
| Li et al., 2003 (25)           | China     | 2.10 (1.63, 2.70) |
| Li et al., 2007 (26)           | China     | 2.10 (1.63, 2.70) |
| Jaskasselaan et al., 2011 (33) | Finland   | 2.10 (1.63, 2.70) |
| Li et al., 2007 (26)           | China     | 2.10 (1.63, 2.70) |
| Li et al., 2013 (28)           | China     | 2.50 (1.44, 2.70) |
| Wahlsten et al., 2006 (39)     | USA       | 2.50 (1.44, 2.70) |
| Sejvar et al., 2007 (36)       | USA       | 2.55 (1.68, 2.90) |
| Wahlsten et al., 2006 (39)     | USA       | 2.55 (1.68, 2.90) |
| Hatcher et al., 2013 (27)      | England   | 2.55 (1.68, 2.90) |



Adv Nutr 2017;8:436-48

# Elevated Adiposity is Present at Birth

N= 826 mother-infant dyads

Infant adiposity ( $\leq 72\text{h}$ ) – air displacement plethysmography



## Prepregnancy BMI

|                        | Unadjusted increase per<br>1 kg/m <sup>2</sup> (95% CI) | Adjusted increase per<br>1 kg/m <sup>2</sup> (95% CI) |
|------------------------|---------------------------------------------------------|-------------------------------------------------------|
| Fat mass, g            | 4.12 (2.53, 5.72)                                       | 5.21 (3.54, 6.89)                                     |
| Fat-free mas, g        | 4.48 (0.99, 7.97)                                       | 7.71 (4.50, 10.91)                                    |
| Percentage of body fat | 0.10 (0.06, 0.14)                                       | 0.12 (0.08, 0.16)                                     |

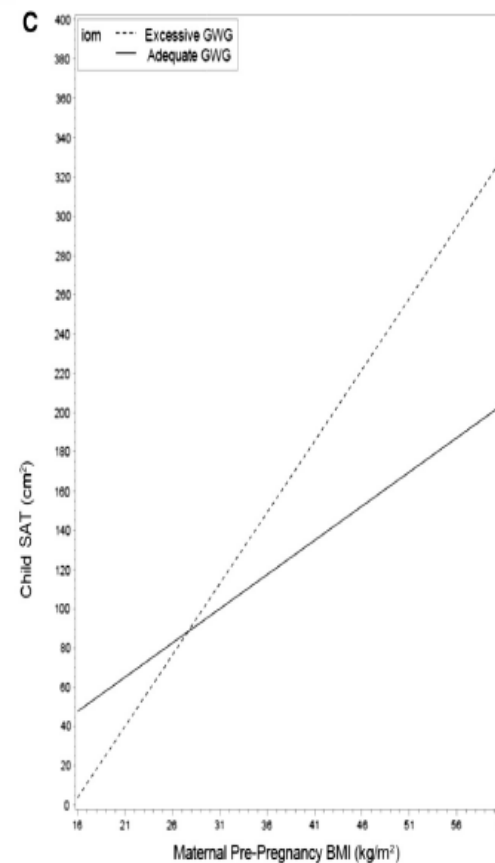
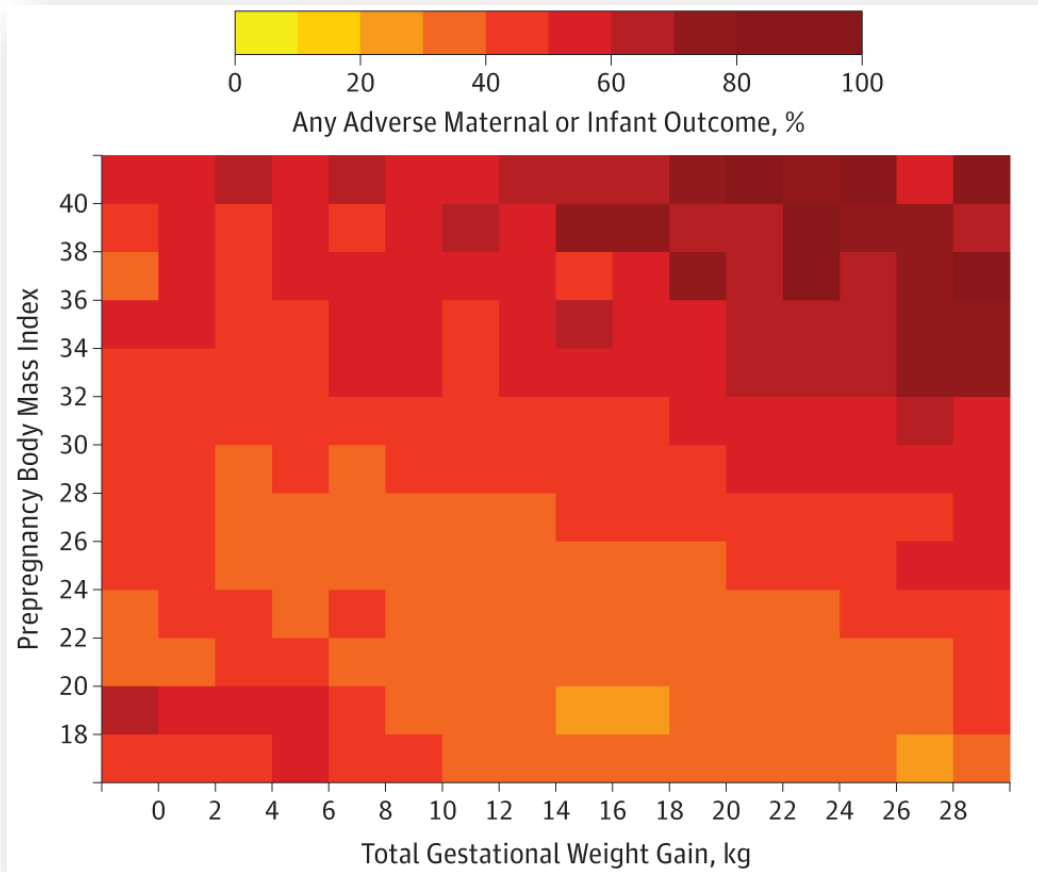
Mom: 24 kg/m2  
Baby: 10% fat



Mom: 40 kg/m2  
Baby: ^ 2%?

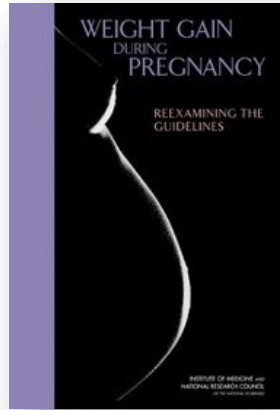


# Maternal size + Gestational weight gain = Double Insult

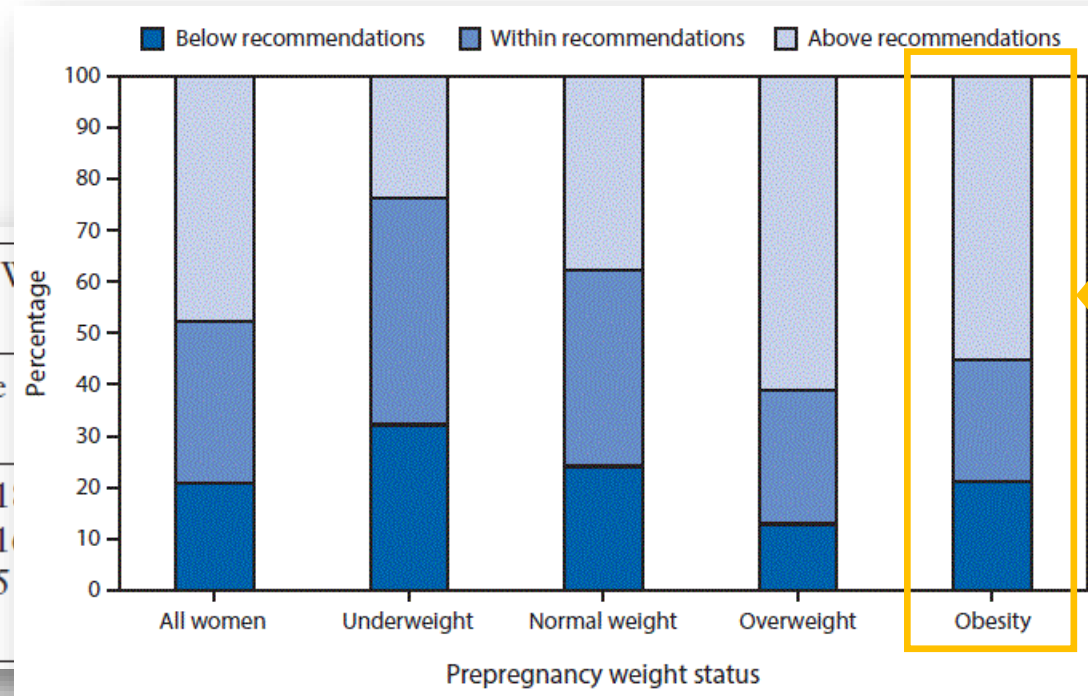


**Macrosomia:** absolute birth weight >4,000 g (~8.75 lbs)  
**Large for gestational age (LGA):** birth weight >90<sup>th</sup> %ile for gestational age

# Recommendations for Weight Gain in Pregnancy



| Prepregnancy BMI                             | Total Weight Gain<br>Range in kg |
|----------------------------------------------|----------------------------------|
| Underweight (< 18.5 kg/m <sup>2</sup> )      | 12.5-18                          |
| Normal weight (18.5-24.9 kg/m <sup>2</sup> ) | 11.5-16                          |
| Overweight (25.0-29.9 kg/m <sup>2</sup> )    | 7-11.5                           |
| Obese (≥ 30.0 kg/m <sup>2</sup> )            | 5-9                              |

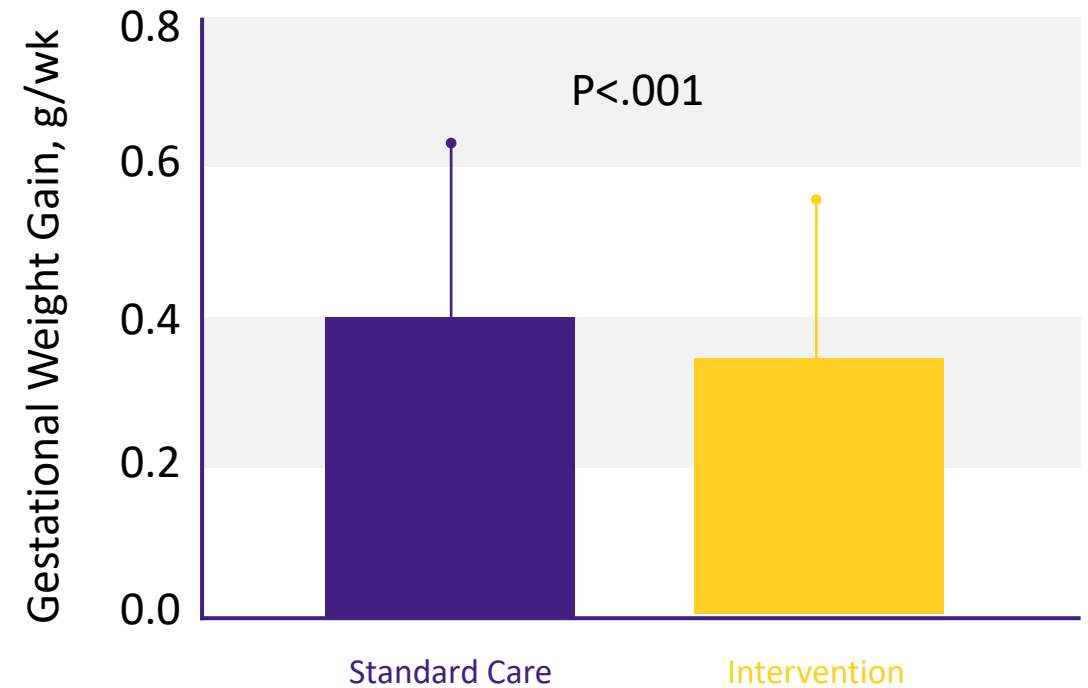
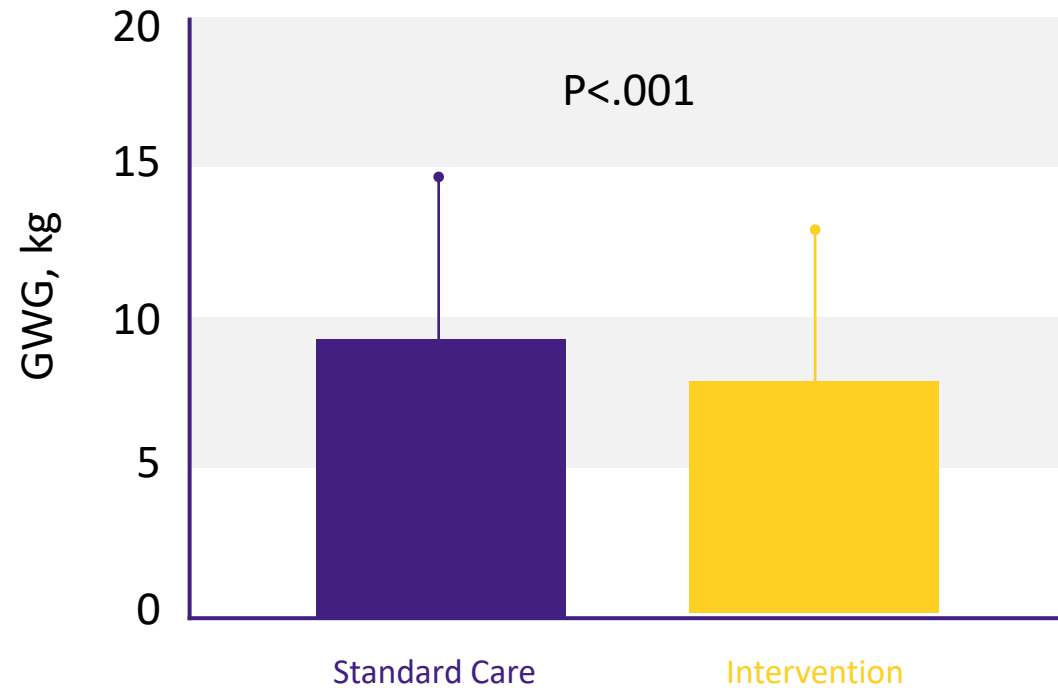


Two out of every three pregnant individuals with obesity gain excess weight in pregnancy

# Lifestyle Interventions in Reduce GWG

8

\*\*Adjusted for baseline BMI category (overweight, obese)



# No effect on size at birth!

9

|                                      | Intervention<br>(N=574) | Standard of care<br>(N=565) | Intervention Effect<br>Odds Ratio (95% CI) | P-value |
|--------------------------------------|-------------------------|-----------------------------|--------------------------------------------|---------|
| Fetal/neonatal death                 | 13/574 (2.3%)           | 22/565 (3.9%)               | 0.57 [0.28, 1.15]                          | 0.11    |
| Fetal death < 24 weeks               | 8/574 (1.4%)            | 18/565 (3.2%)               |                                            |         |
| Fetal death ≥ 24 weeks               | 2/574 (0.3%)            | 4/565 (0.7%)                |                                            |         |
| Neonatal death                       | 3/573 (0.5%)            | 0/565 (0.0%)                |                                            |         |
| Birth weight (g) **, #               | 3306 ± 588              | 3268 ± 571                  |                                            | 0.15    |
| SGA < 10 <sup>th</sup> percentile #  | 40/563 (7.1%)           | 51/543 (9.4%)               | 0.74 [0.48, 1.13]                          | 0.16    |
| LGA ≥ 90 <sup>th</sup> percentile    | 60/563 (10.7%)          | 48/543 (8.8%)               | 1.23 [0.83, 1.84]                          | 0.31    |
| Macrosomia (birth wt ≥ 4000 g)       | 48/563 (8.5%)           | 43/543 (7.9%)               | 1.15 [0.75, 1.79]                          | 0.52    |
| Birth weight for length z-score #,†  | -0.18 ± 1.29            | -0.27 ± 1.29                |                                            | 0.24    |
| NICU/intermediate nursery stay **, # | 71/564 (12.6%)          | 68/543 (12.5%)              | 1.05 [0.73, 1.51]                          | 0.80    |

# Hypothesized reasons why interventions (to date) generally have been unsuccessful

1 Interventions have little specificity  
The diet (calorie) goals for pregnant women are not well-defined

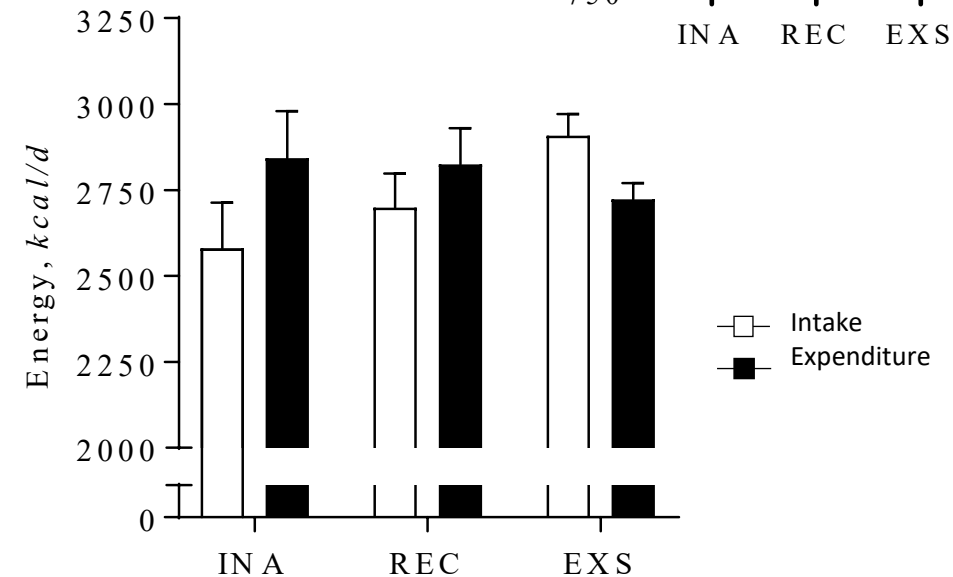
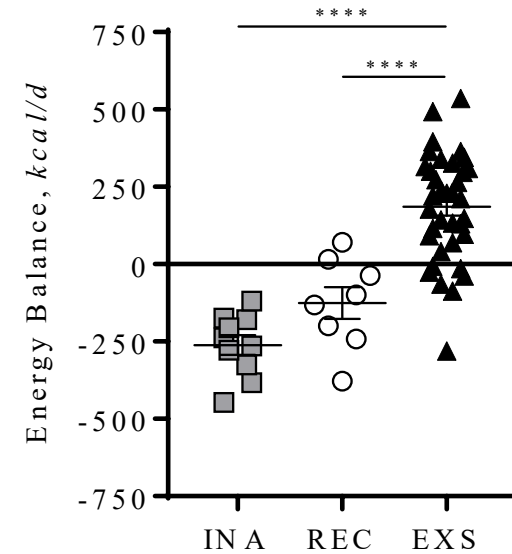
- IOM: +340 to +450 calories per day in the 2<sup>nd</sup> and 3<sup>rd</sup> trimester
- ACOG: endorsement, and 'women with obesity may need fewer calories

Energy Balance

INA:  $-262 \pm 32$  kcal/d

REC:  $-125 \pm 52$  kcal/d

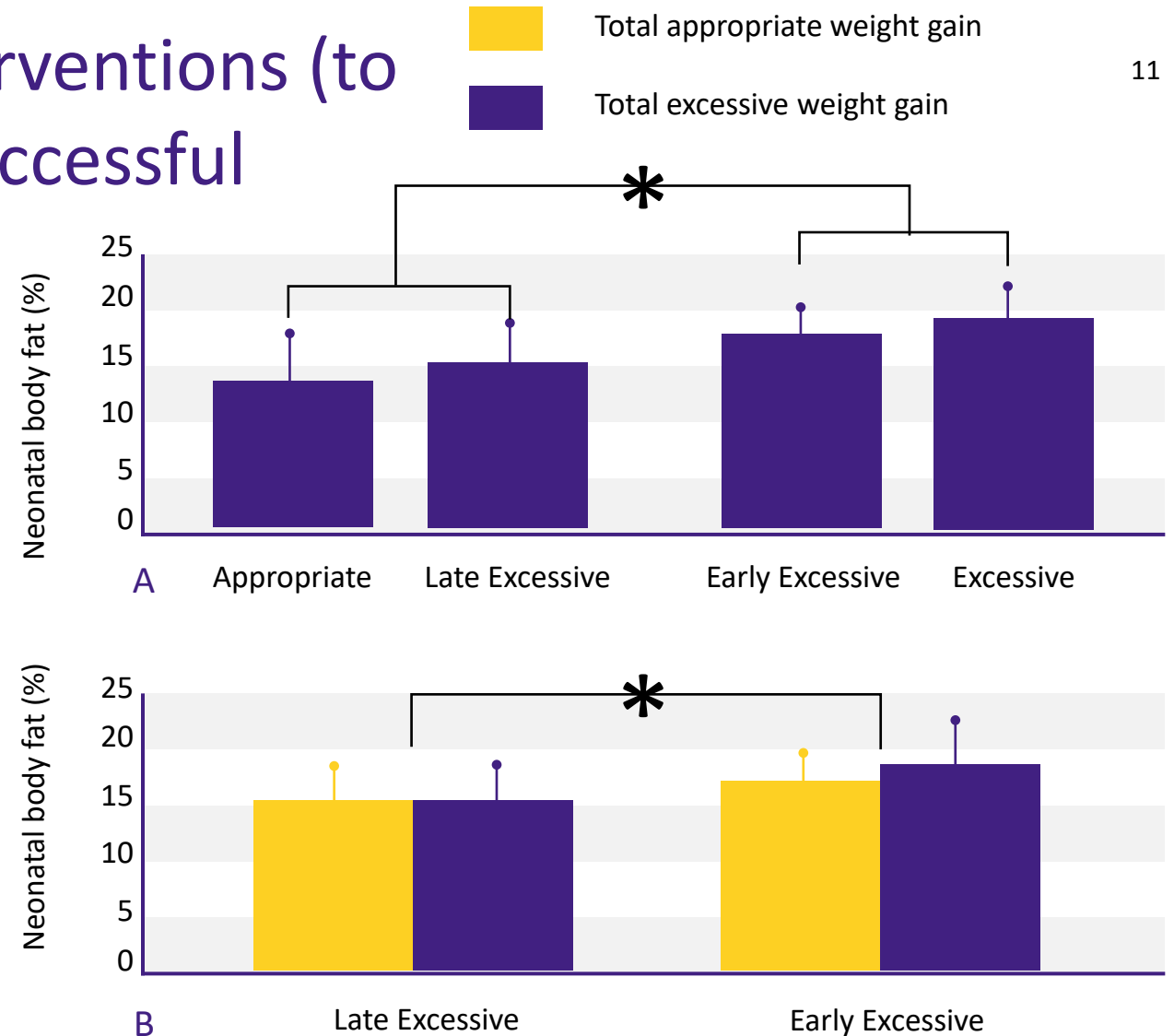
EXC:  $+186 \pm 29$  kcal/d



# Hypothesized reasons why interventions (to date) generally have been unsuccessful

## 2 Timing Matters! Most interventions are too short (they begin at 16-20 weeks)

- N= 172 singleton gestation
- Early GWG = pregravid to 16-20 GA
- Late GWG = 16-20 to delivery



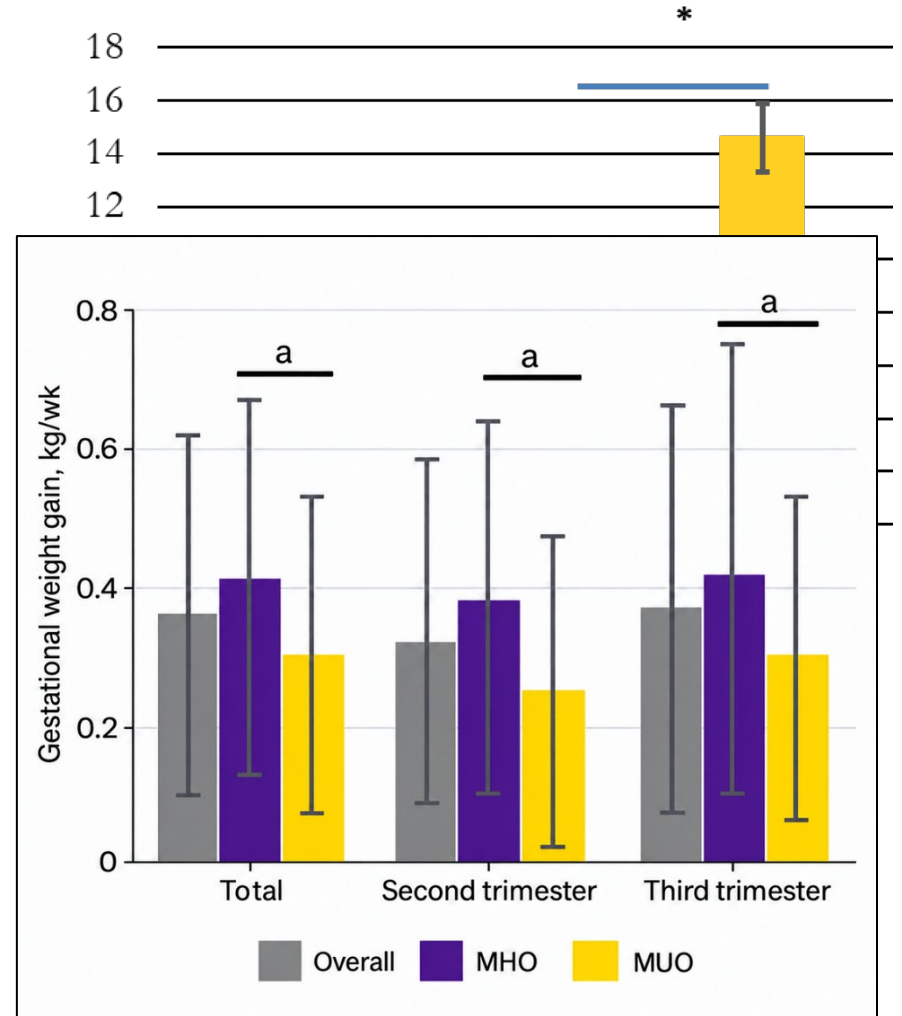
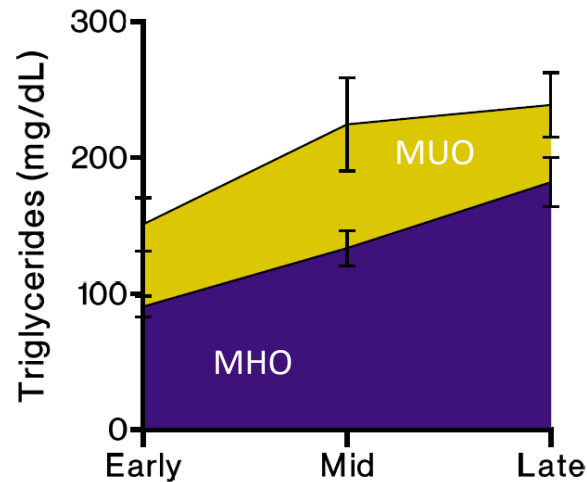
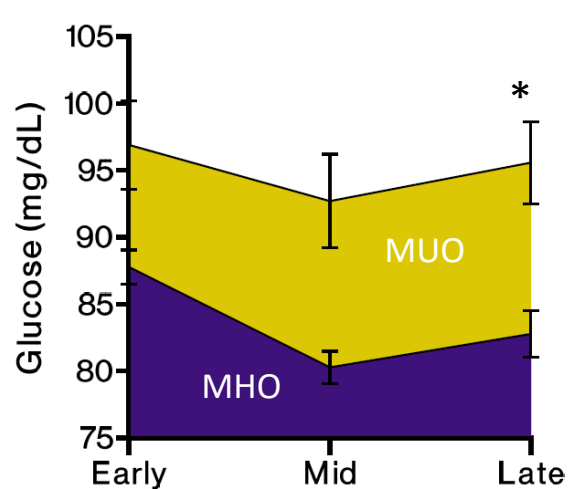
# 3 Or maybe it has nothing to do with maternal weight or weight gain?

Metabolically healthy obesity  
“MHO”

Obesity with no  
other risk factors  
for metabolic  
syndrome

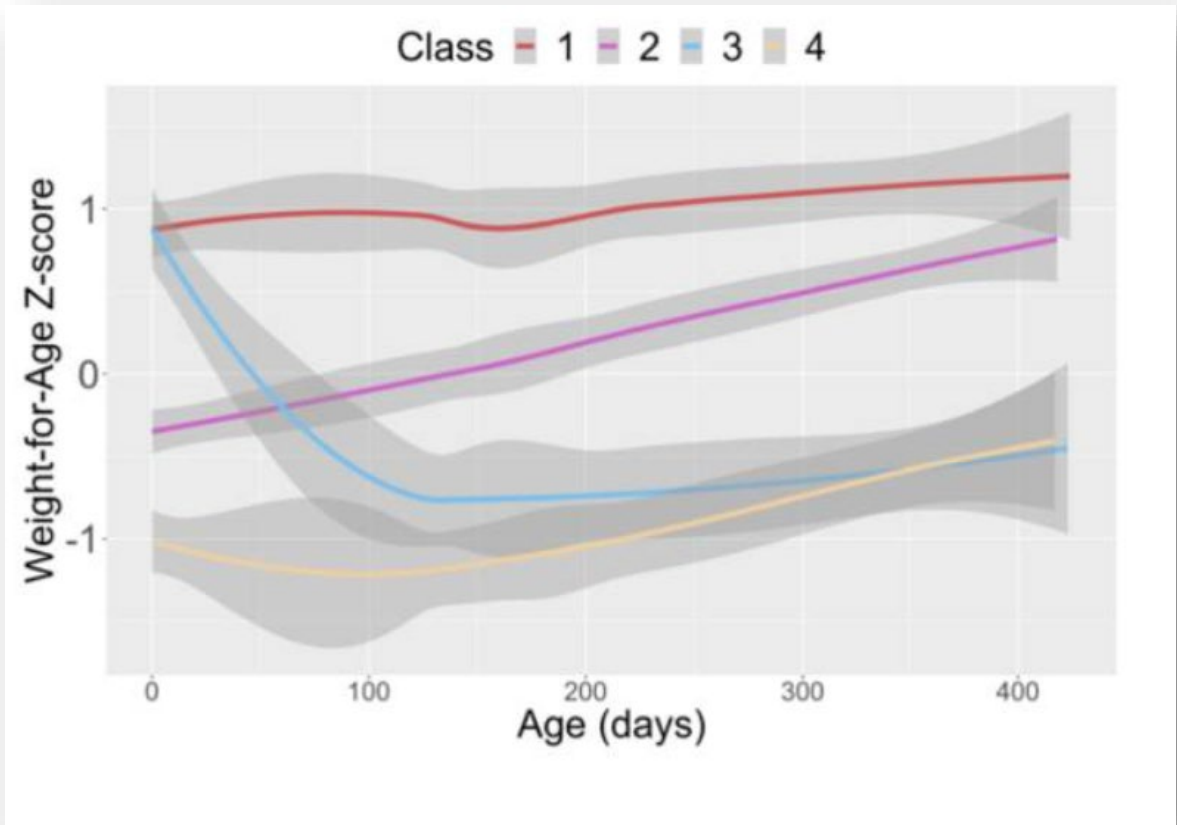
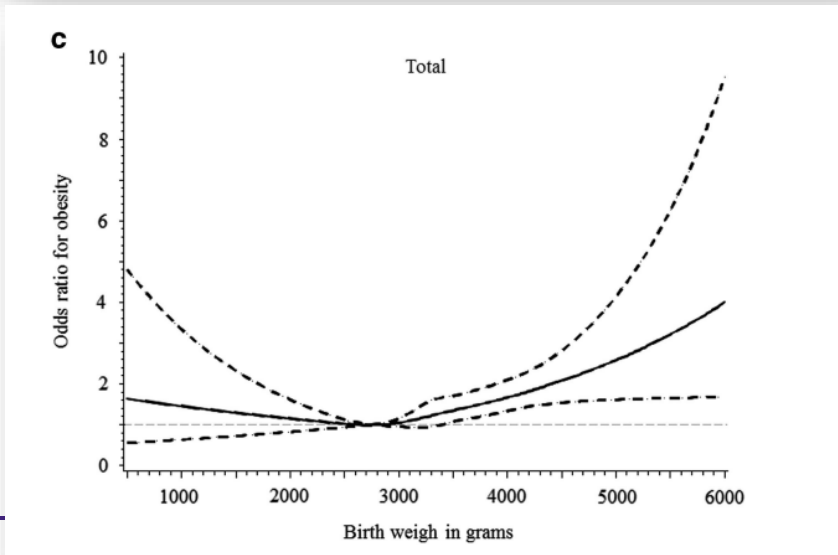
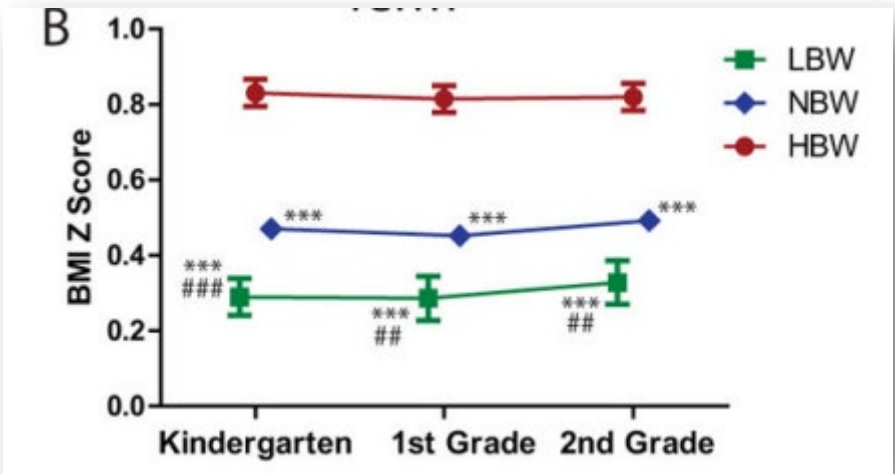
Metabolically unhealthy obesity  
“MUO”

Obesity ≥2  
risk factors



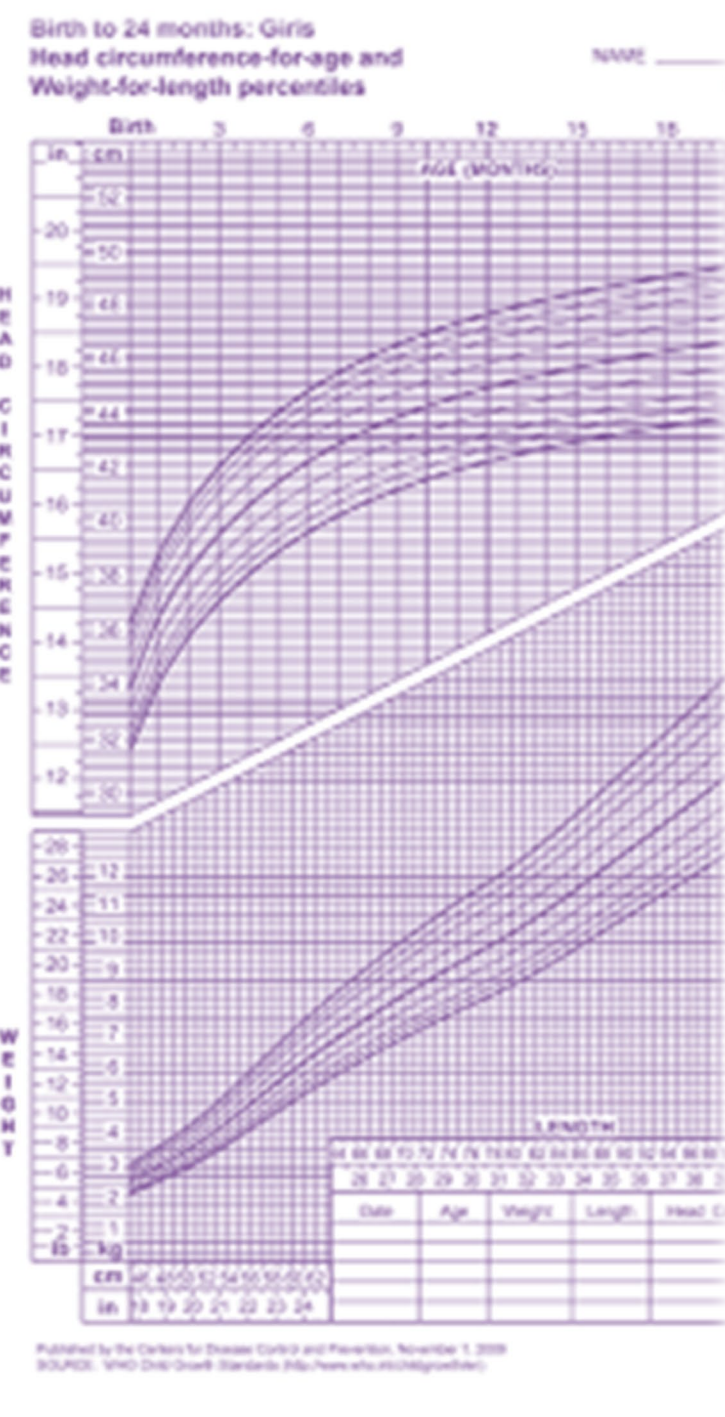
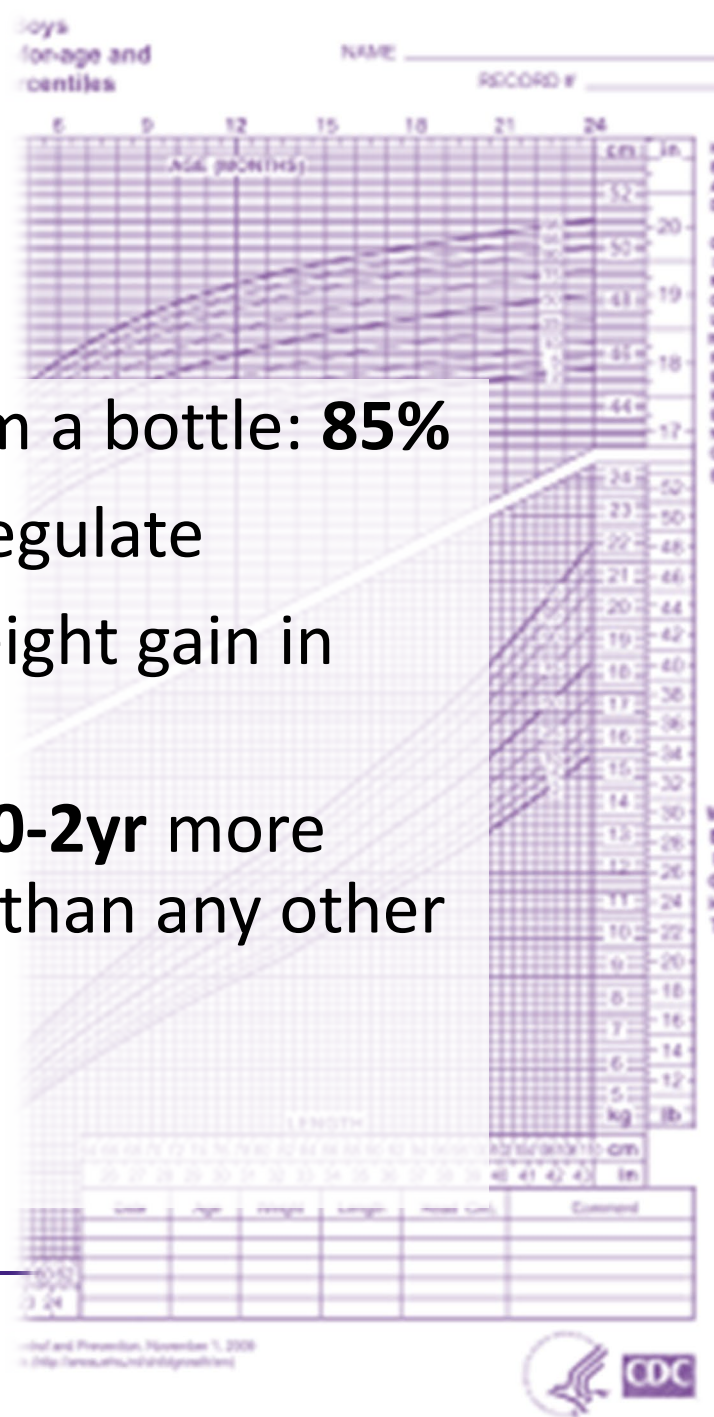
Gestational weight gain is therefore important, but an imperfect proxy for the biological environment experienced by the fetus.

Size at birth is one component. Postnatal growth trajectories matter, too.



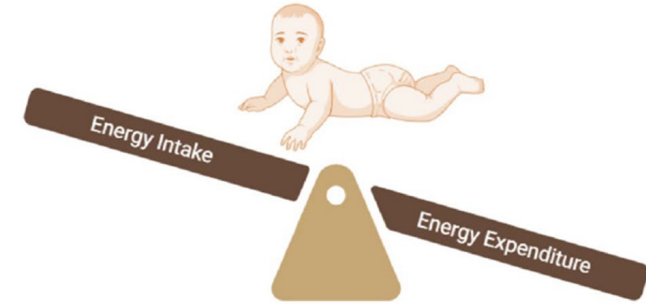
# Why early nutrition matters

- Infants consuming milk from a bottle: **85%**
- Infants **lack ability** to self-regulate
- Infants with accelerated weight gain in first year: **39%**
- Accelerated weight gain at **0-2yr** more predictive of youth obesity than any other time



# Growth is Governed by Energy Balance

- Energy intake is primary driver of growth
- **Low energy requirements** mean infants can easily be overfed



### 3 Unique States of Energy Imbalance in Infants

Energy Intake = Energy Expenditure + Cost of Growth = Appropriate Growth  
Energy Intake > Energy Expenditure + Cost of Growth = Overnutrition  
Energy Intake < Energy Expenditure + Cost of Growth = Undernutrition

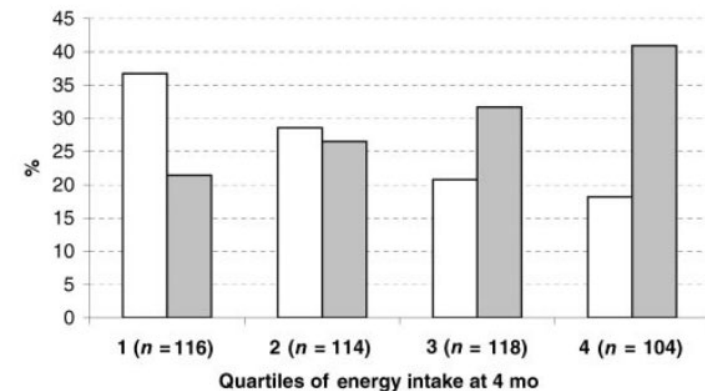


FIGURE 2

Percentages of infants who showed rapid (■) or slower (□) weight gain between 0 and 2 years, by quartiles of dietary energy intake at age 4 months, in formula- or mixed-fed infants ( $P < .0001$  for trend).

# How much should babies eat



...

**How to know if you are overfeeding your formula fed baby?**

This is our schedule  
6 am 5.5 oz  
8:30 am 4.5 oz  
11:30 am 4.5 oz  
2:30 pm 4.5 oz  
5 pm 4.5 oz  
6 pm 4.5 oz  
7:30 pm 5 oz

▼

## Age-specific feeding recommendations

...

**How many ounces is your baby drinking**

My almost 3 month old is a little thin. The Ped isn't worried but of course I am.

He takes 2 to 3 sometimes 4 ounces every 2 to 3 hrs  
During the day  
And 2to 3 ounces  
Every 4 hrs at night

Thanks 🙏

...

My boy will be 2 months tomorrow and he just started taking 6 oz at each feed about every 3-4 hours. I'm not sure if that's too much though but he has his check up tomorrow so I will be asking his pediatrician.

|                |               |
|----------------|---------------|
| 2 months       | 4 to 5 ounces |
| 4 months       | 4 to 6 ounces |
| 6 to 12 months | 7 to 8 ounces |

|                  |           |
|------------------|-----------|
| to 36 ounces     | 320 - 720 |
| to 40 ounces     | 480 - 800 |
| to 40 ounces     | 480 - 800 |
| ounces 48 ounces | 480 - 960 |
| to 48 ounces     | 560 - 960 |

\*Estimated using 20 kcal/ounce

# The Pediatric Clinician's Opportunity ... And Challenge

## AAP Periodicity Schedule

| Infancy   |
|-----------|
| 3-5 Days  |
| 1 Month   |
| 2 Months  |
| 4 Months  |
| 6 Months  |
| 9 Months  |
| 12 Months |

Opportunity for growth  
monitoring / nutrition  
tailoring

- Clinicians report discomfort managing overfeeding and rapid weight gain
- More comfortable with management of inadequate (9% of infants)
- Only **62.5%** perceive primary cause of rapid weight gain to be overfeeding

*“Typically, I do not get concerned. I think if I saw an infant crossing [growth] curves rapidly, I would step back and think about some syndromes. It would be rare for me to really be concerned about just a baby growing rapidly.”*

*“Usually, I monitor infants gaining too much weight much less than I do babies who are gaining too little weight.”*

# The Pediatric Clinician's Opportunity ... And Challenge

**Doctor said my baby is  
overweight?? Haha**

*My baby got her 4 months shots  
today.*

*He started off [the visit] by saying  
my baby is being over fed???*

**Response:**

*That doc sounds very judgmental*

**Original Poster:**

*I didn't like how he approached it.  
I'm definitely switching doctors.*

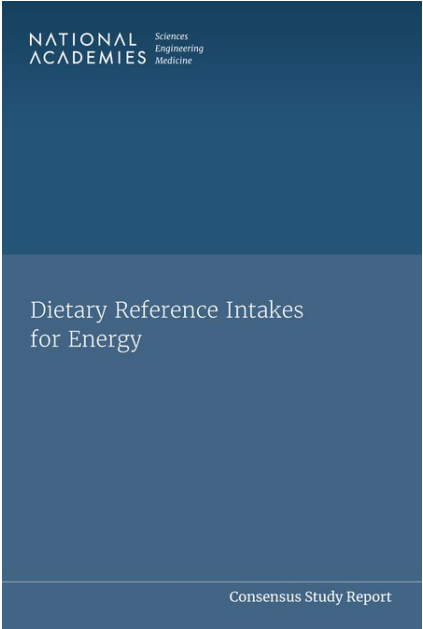
# Toward Precision Nutrition:

## *Dietary Reference Intakes for Energy*

DRI for energy is used to provide guidance for maintaining energy (im)balance in individuals of a defined age, sex, and weight

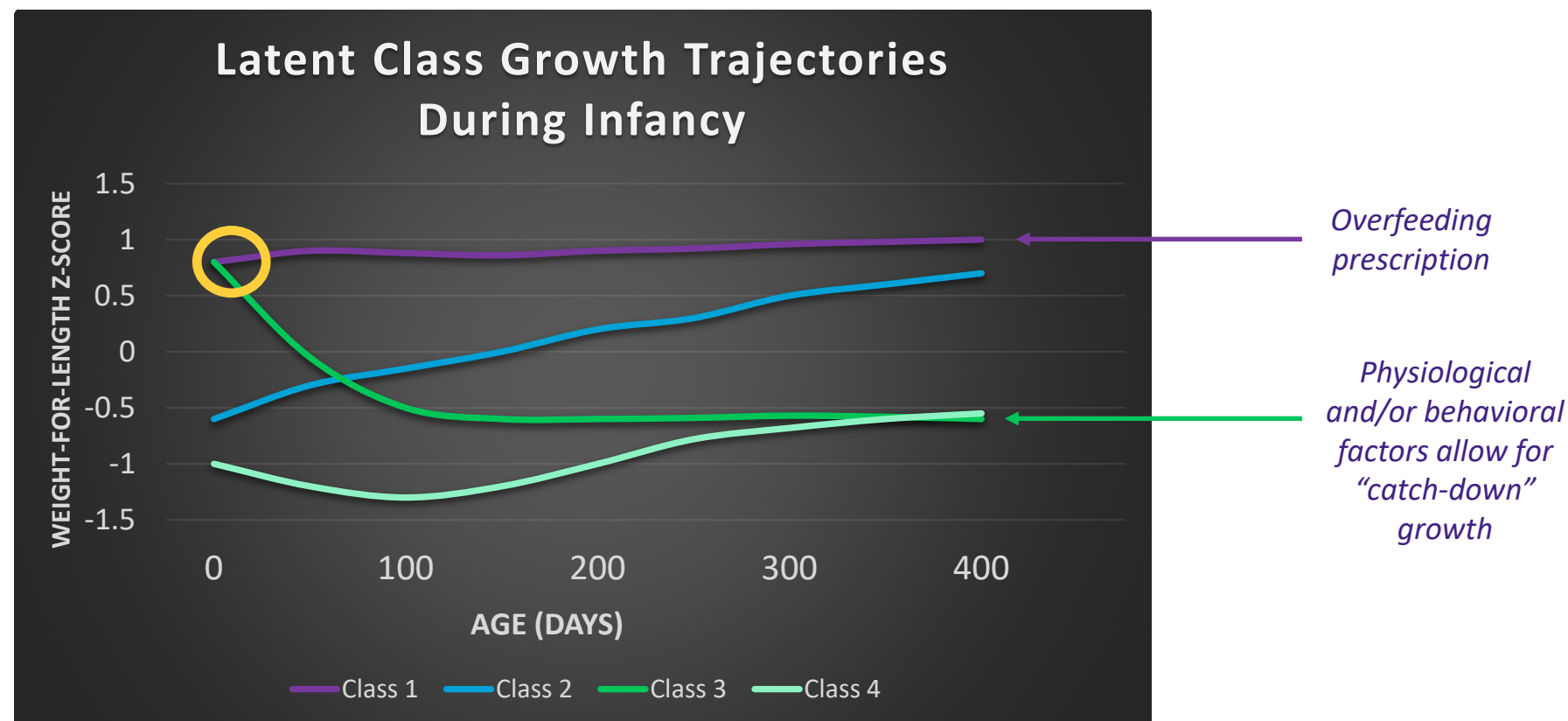
Published in [2005](#); Updated in [2023](#)

Clinical reference standards adopted by the AAP



| Table. Energy Requirement Equations for Children 0-3 yrs |     |                                                                                |                       |     |                       |
|----------------------------------------------------------|-----|--------------------------------------------------------------------------------|-----------------------|-----|-----------------------|
| Energy Expenditure                                       |     |                                                                                | Energy Cost of Growth |     |                       |
| Child Age                                                | Sex | Energy Expenditure Estimate                                                    | Child Age             | Sex | Energy Cost of Growth |
| 0 Months - 2.99 Years                                    | M   | $-716.45 - (1.00 * \text{age}) + 17.82 * \text{height}) + (15.06 * \text{wt})$ | 0-2.99 months         | M   | +200                  |
|                                                          | F   | $-69.15 + (80.0 * \text{age}) + (2.65 * \text{height}) + (54.15 * \text{wt})$  |                       | F   | +180                  |
|                                                          |     |                                                                                | 3-5.99 months         | M   | +50                   |
|                                                          |     |                                                                                |                       | F   | +60                   |
|                                                          |     |                                                                                | 6 – 12 months         | M   | +20                   |
|                                                          |     |                                                                                |                       | F   | +20                   |

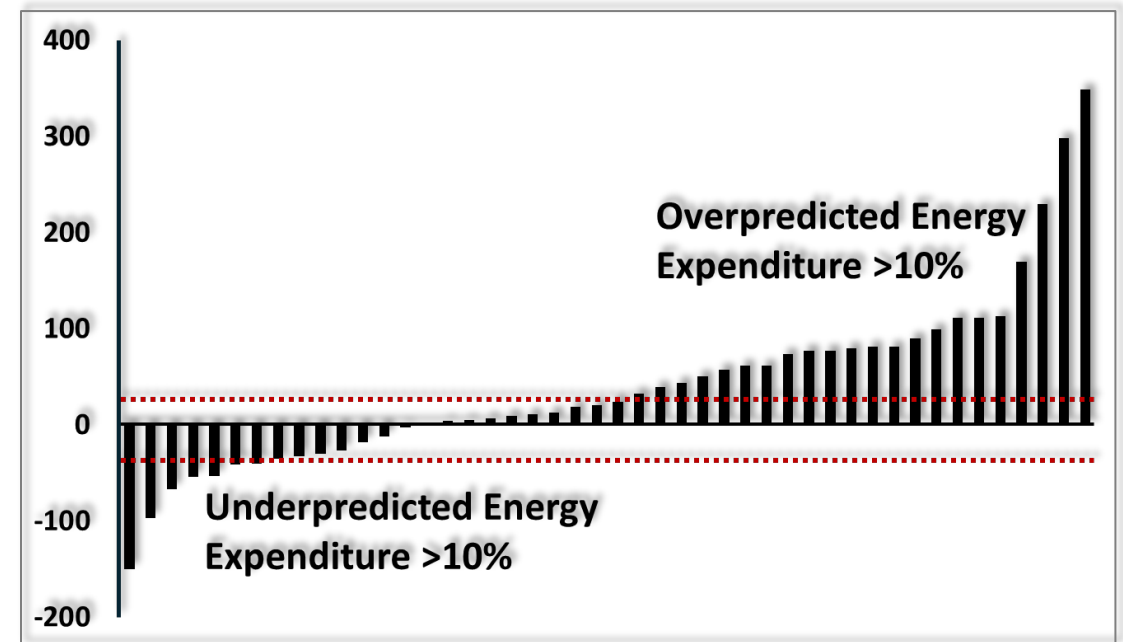
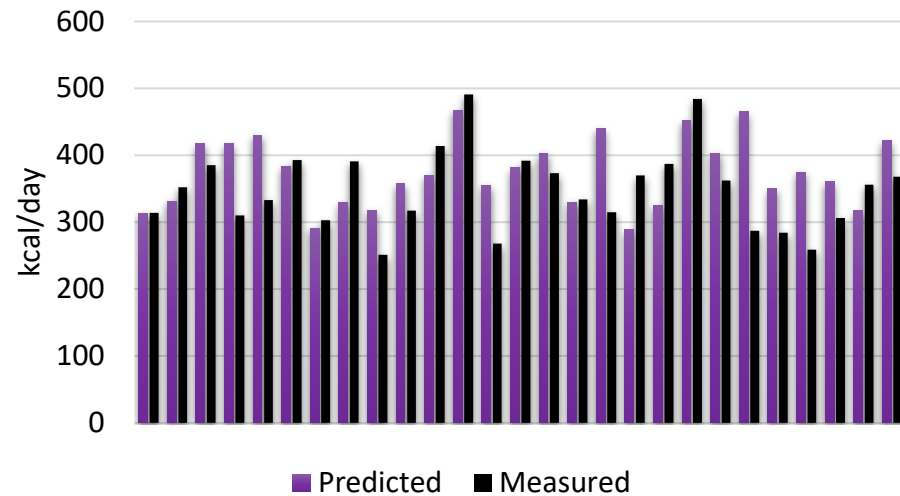
# The Challenge with the DRI



# DRI Estimates versus measured energy requirements

Age: 4-12 Weeks  
7day DLW study

Measured TDEE:  $354 \pm 47$   
Predicted TDEE:  $395 \pm 90$   
Prediction Error: 16%

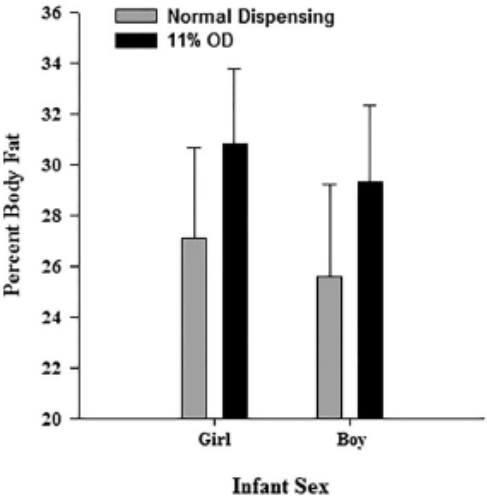
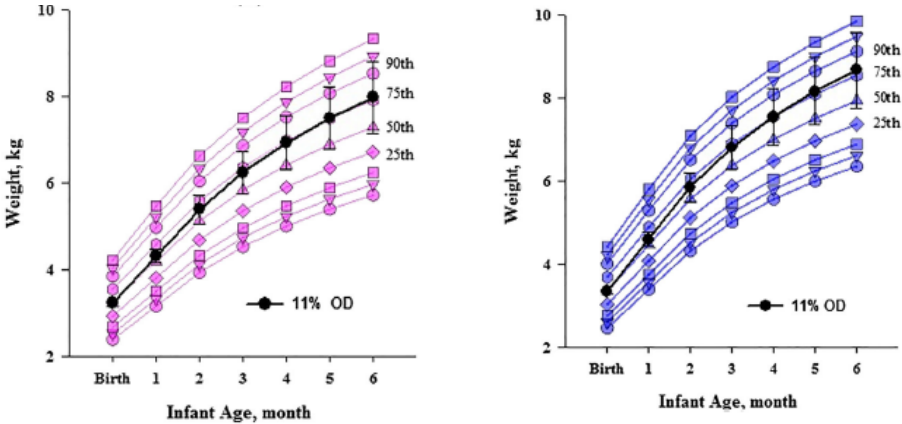


# Clinical Implications of “Modest” Overfeeding

ORIGINAL RESEARCH

WILEY **pediatricobesity**

Unintentional error in formula preparation and its simulated impact on infant weight and adiposity



## Mathematical Model of Human Growth and Energy Expenditure Dynamics from Birth Through Adulthood

Energy Intake = Energy Expenditure (DLW) + Δ Energy Stores (Fat/Fat-Free Mass)

Dynamics of childhood growth and obesity: development and validation of a quantitative mathematical model

Kevin D Hall, Nancy F Butte, Boyd A Swinburn, Carson C Chow

$$\frac{d(\rho_{FFM}FFM)}{dt} = p(I - E) + g(t)$$

$$\rho_{FFM} \frac{dFM}{dt} = (1 - p)(I - E) - g(t)$$

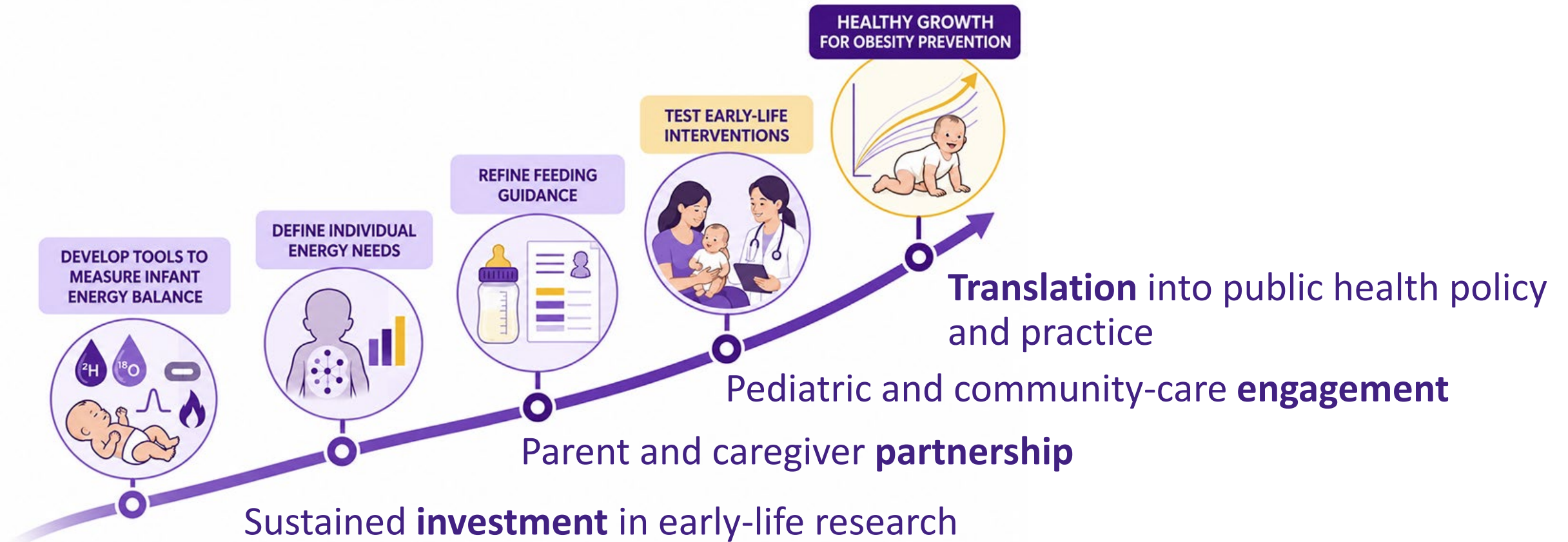
| Model Parameter            | Description                          | Value for Males                                                       | Value for Females |
|----------------------------|--------------------------------------|-----------------------------------------------------------------------|-------------------|
| $\beta_{FFM}$              | Effective energy density             | $87.3 \frac{kcal}{kg^2} \times \log[FFM(kg)] + 698.2 \frac{kcal}{kg}$ |                   |
| $\frac{dM_{heart}}{dt}$    | Heart mass growth rate               | 0.0055                                                                | 0.0060            |
| $\frac{dM_{kidney}}{dt}$   | Kidney mass growth rate              | 0.0043                                                                | 0.0055            |
| $\frac{dM_{liver}}{dt}$    | Liver mass growth rate               | 0.0245                                                                | 0.0309            |
| $\frac{dM_{residual}}{dt}$ | Residual tissue growth rate          | 0.9552                                                                | 0.9448            |
| $Y_{heart}$                | Heart metabolic rate                 | 440 kcal/kg/day                                                       | 440 kcal/kg/day   |
| $Y_{kidney}$               | Kidney metabolic rate                | 440 kcal/kg/day                                                       | 440 kcal/kg/day   |
| $Y_{liver}$                | Liver metabolic rate                 | 200 kcal/kg/day                                                       | 200 kcal/kg/day   |
| $Y_{muscle}$               | Muscle metabolic rate                | 13 kcal/kg/day                                                        | 13 kcal/kg/day    |
| $a_b$                      | Parameter for brain mass             | 1.42                                                                  | 1.31              |
| $b_b$                      | Parameter for brain mass             | 1.96                                                                  | 1.94              |
| $c_b$                      | Parameter for brain mass             | 5.30                                                                  | 5.01              |
| $n_b$                      | Parameter for cellularity            | 2.56                                                                  | 2.39              |
| $b_c$                      | Parameter for cellularity            | 211.64                                                                | 53.47             |
| $k_c$                      | Parameter for cellularity            | 300.02                                                                | 73.59             |
| $b_m$                      | Parameter for brain metabolism       | 3313                                                                  | 3313              |
| $c_m$                      | Parameter for brain metabolism       | 1.71                                                                  | 1.71              |
| $d_m$                      | Parameter for brain metabolism       | 3.92                                                                  | 3.92              |
| $e_m$                      | Parameter for brain metabolism       | 2112                                                                  | 2112              |
| $f_m$                      | Parameter for brain metabolism       | 12.86                                                                 | 12.86             |
| $g_m$                      | Parameter for brain metabolism       | 1.66                                                                  | 1.66              |
| $a_p$                      | Parameter for p-ratio                | 20.43                                                                 | 20.43             |
| $b_p$                      | Parameter for p-ratio                | 10.99                                                                 | 10.99             |
| $c_p$                      | Parameter for p-ratio                | 3                                                                     | 3                 |
| $A$                        | Parameter for growth function        | 10.74                                                                 | 7.92              |
| $B$                        | Parameter for growth function        | 1.47                                                                  | 2.34              |
| $n$                        | Parameter for growth function        | 0.89                                                                  | 1.35              |
| $D$                        | Parameter for growth function        | 12.19                                                                 | 7.74              |
| $t_0$                      | Parameter for growth function        | 14.35                                                                 | 12.19             |
| $\tau_0$                   | Parameter for growth function        | 1.88                                                                  | 0.87              |
| $K$                        | Constant in energy expenditure model | 138.03 kcal/day                                                       | 138.63 kcal/day   |
| $\delta_0$                 | Constant in physical activity model  | 11.06 kcal/kg/day                                                     | 7.65 kcal/kg/day  |
| $\delta_1$                 | Constant in physical activity model  | -1.06 kcal/kg/day                                                     | 2.35 kcal/kg/day  |
| $\delta_2$                 | Constant in physical activity model  | 18.06                                                                 | 14.21             |

Pediatric Growth Model  
Hall et. al, 2013



# Early Obesity Prevention

## What will it take to get there?



# Thank you!

Leanne Redman, PhD  
Eric Ravussin, PhD  
Stephanie Waldrop, MD  
Stewart Gordon, MD  
Jennifer Rood, PhD

## **Developmental Physiology Laboratory**

Abby Altazan  
Ariel Barlow  
Madison Dickey  
Taylor Dejean  
Kimberly Billiot  
Em Simeon  
Caitlin Hebert

## **Bioimaging Core**

Heaver Peavy  
Julia StAmant  
Kori Murray  
Blanca Desharnais  
Kevin McKlveen

## **Biostatistics**

Kimberly Drews, PhD  
Shangping Yang, PhD  
Robbie Beyl, PhD

**Clinical Chemistry Core**  
**Mass Spectrometry Core**  
**Clinical Core**  
**Inpatient Core**

## **Baylor University**

William Wong, PhD

## **K12 Mentors**

Kristen Boyle, PhD  
**CU Anschutz**

Namalavan Ambalavayn, MD  
**UAB Medical Center**

Ellen Demerath, PhD

**U. Minn School of Public Health**

## **F32 Mentors/Collaborators**

**University of Sherbrooke**  
Denis Blondin, PhD  
**Mayo Clinic**  
Harry Hu, PhD

F32HD108022  
K12TR004769  
P30DK072476

# Tiny humans helping with big discoveries

---

## **Developmental Physiology Laboratory**





# Preventing Childhood Obesity Before It Begins

*The Critical Role of Maternal Health, Early Feeding Environments, and Family Influences*

Jennifer Savage  
September 24, 2026



Scan to connect on LinkedIn



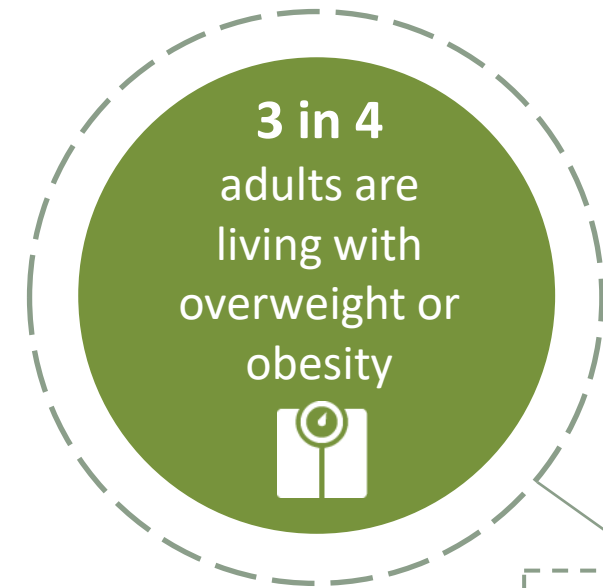
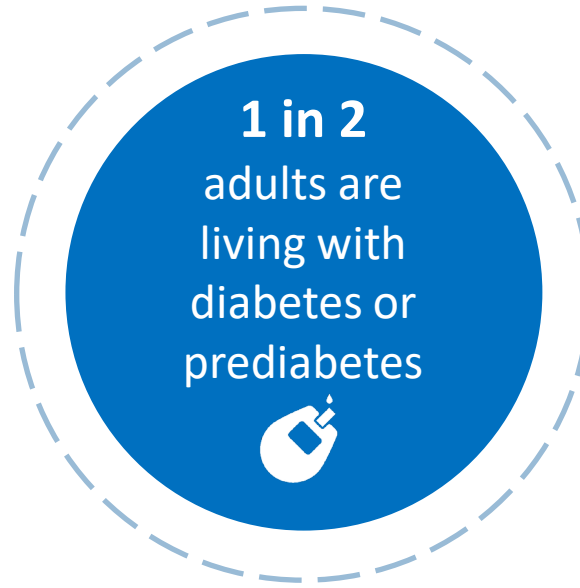
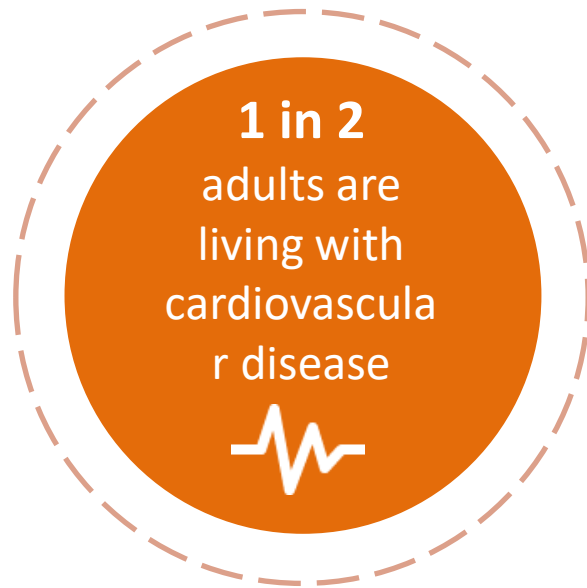
PennState



**Child Health  
Research Center**

*Transforming discoveries into  
lifelong wellbeing for children  
and communities.*

# Public Health Challenges & Advancing Health Equity

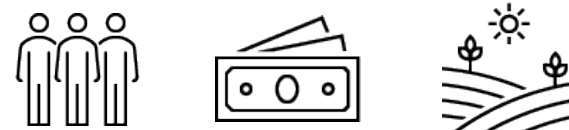


**1 in 3**  
children

## Behavioral Factors



## Sociopolitical Factors



# Recommendations for Supporting Growth from the Start

1

## **Connecting Caregivers & Integrating High-Quality Care**

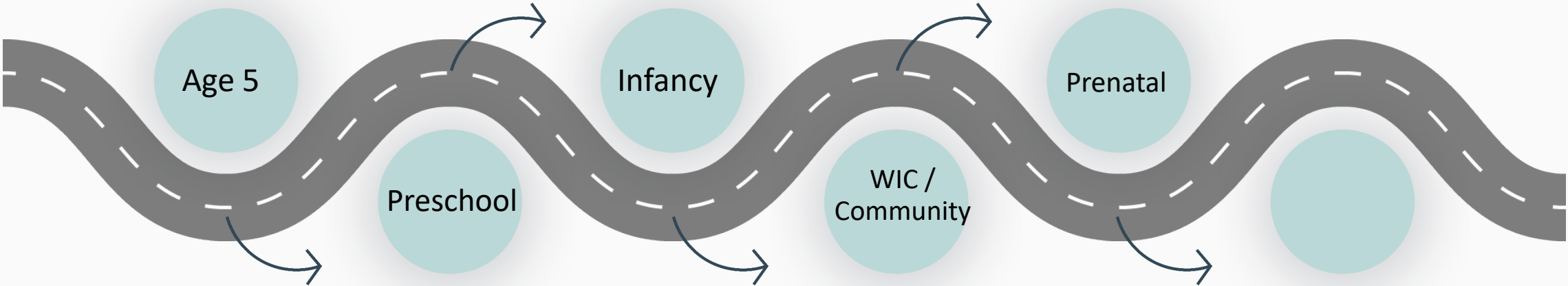
- Supplemental Nutrition Program for Women, Infants, and Children (WIC)
- Regular pediatric well-child visits

2

## **Responsive Caregiving**

- Helps children learn how to self-regulate and support healthy growth and development
- Supports healthy feeding, eating habits and sleep routines

# SCIENTIFIC JOURNEY



# Dr. Leann L. Birch

*Pioneer of Developmental Science in Children's Eating Behavior*



**70+**

Graduate students &  
postdocs mentored

**260+**

Peer-reviewed  
publications

**80,000+**

Citations of  
her research

**\$30M+**

Federal research  
funding secured

## The Field She Help Build: Leann's Birch's Legacy in Child Nutrition and Eating Behavior



Susan  
Johnson



Jennifer  
Fisher



Kirsten  
Davison



Lori  
Francis



Alison  
Ventura



Stephanie  
Anzman-Frasca



Brandi  
Rollins



Katherine  
Balantekin



Paige  
Berger

# Girls NEEDS: Where I started

- 10-yr NIH longitudinal study



# The legacy of Girls' NEEDS project

**The behaviors we observed at age 5 had antecedents much earlier.**

- Individual differences in food responsiveness, picky eating, and overeating cues (Abramovitz & Birch, 2000; Fisher et al., 2002; Francis & Birch, 2005)
- 34–65% of girls reported concepts of dieting and weight loss (Abramovitz & Birch, 2002)
- Weight trajectories were already diverging. Girls with two overweight parents at age 5 (Francis et al., 2006)
  - Steeper BMI increases
  - 8.1× more likely to be overweight by age 13
- Parent feeding practices were associated with child eating behavior (Birch et al., 2001)

**The realization: “We are too late?”**

## Moving the starting line backward



**What if prevention begins before obesity is visible?**

# Before weight, there is behavior

- Appetite
- Satiety responsiveness
- Food responsiveness
- Eating in the absence of hunger
- Emotional regulation
- Executive function and self-regulation



# Experimental approaches to probing eating regulation

- Portion size
- Energy density
- Eating in the absence of hunger (EAH)
- Restriction / food exposure

# What did experiments teach us?

## **Larger portions → more intake**

By ages 4–5, children ate more when served larger portions (Savage, 2012).

## **Energy density → changes intake**

Children eat more when served higher energy-dense foods (Leahy, 2008, Fisher, 2007)

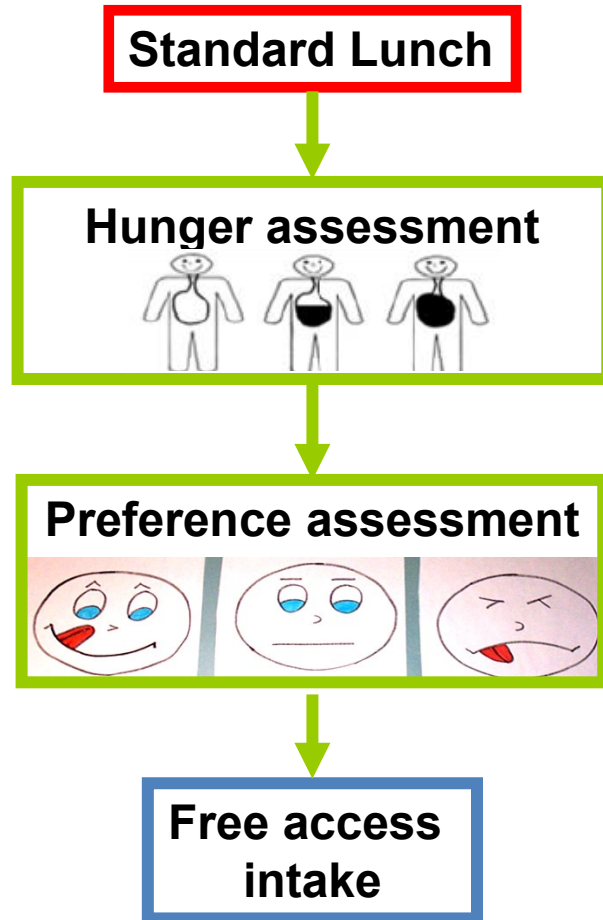
## **Restriction → changes response to food**

Maternal restriction at age 5 predicted greater eating in the absence of hunger later in childhood (Birch et al., 2003; Fisher & Birch, 2002).

)

# Eating in the absence of hunger

The propensity to eat in response to the presence of highly palatable foods despite satiety



# Eating in the absence of hunger

From laboratory to classroom to the natural home food environment



|                                                                        |                                                                        |                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                             |
|------------------------------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Right before you started eating, how <b>hungry</b> did you feel?       | Right before you started eating, how <b>tired</b> did you feel?        | What are you eating or drinking? (Check all that apply)                                                                                                                                                                                                                                 | Where are you eating?                                                                                                                                                                                                                                       |
| <input type="checkbox"/> Not at all <input type="checkbox"/> Extremely | <input type="checkbox"/> Not at all <input type="checkbox"/> Extremely | <input type="checkbox"/> Fruit or veggies<br><input type="checkbox"/> Dairy<br><input type="checkbox"/> Salty snacks<br><input type="checkbox"/> Sweet foods<br><input type="checkbox"/> Fried foods<br><input type="checkbox"/> Sweet drink<br><input type="checkbox"/> Something else | <input type="checkbox"/> At home, in the kitchen or dining room<br><input type="checkbox"/> At home, in another room<br><input type="checkbox"/> At a friend's house<br><input type="checkbox"/> At a restaurant<br><input type="checkbox"/> Somewhere else |



# What did experiments teach us?

## **Larger portions → more intake**

By ages 4–5, children ate more when served larger portions (Savage, 2012).

## **Energy density → changes intake**

Children eat more when served higher energy-dense foods (Leahy, 2008, Fisher, 2007)

## **Restriction → changes response to food**

Maternal restriction at age 5 predicted greater eating in the absence of hunger later in childhood (Birch et al., 2003; Fisher & Birch, 2002).

**Girls who eat in the absence of hunger → 4.6 X more likely to be overweight (Fisher, 2002)**

**How much of eating behavior is learned?**

# The parent enters the picture

**What parents do around food matters:**

Restriction

Pressure

Structure

Food as reward

Food to soothe

Feeding in response to distress

Parenting may shape how children learn to regulate eating.

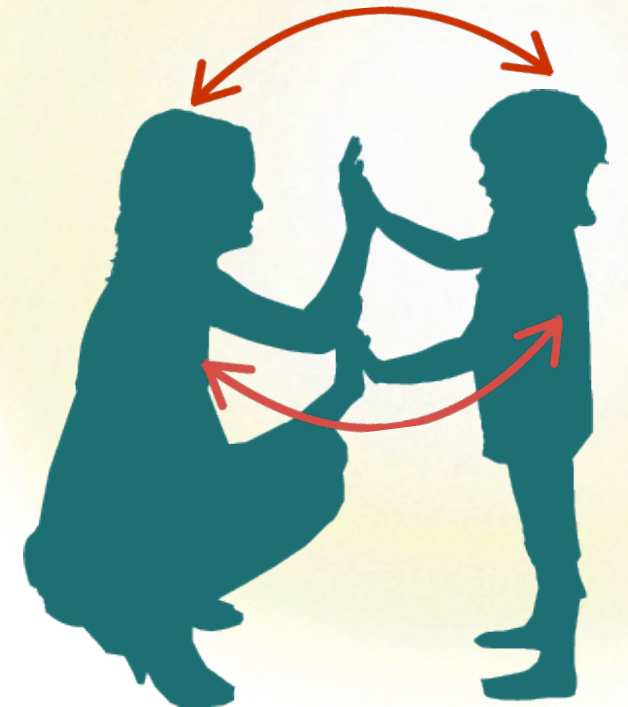


# Responsive Parenting

Defined as a mother's/caregiver's prompt, contingent, & developmentally-appropriate interaction with child

## Why target responsive parenting?

- Language development
- Attachment
- Emotional growth
- Social competence
- School readiness
- Self regulation
- Weight status?



# The conceptual shift

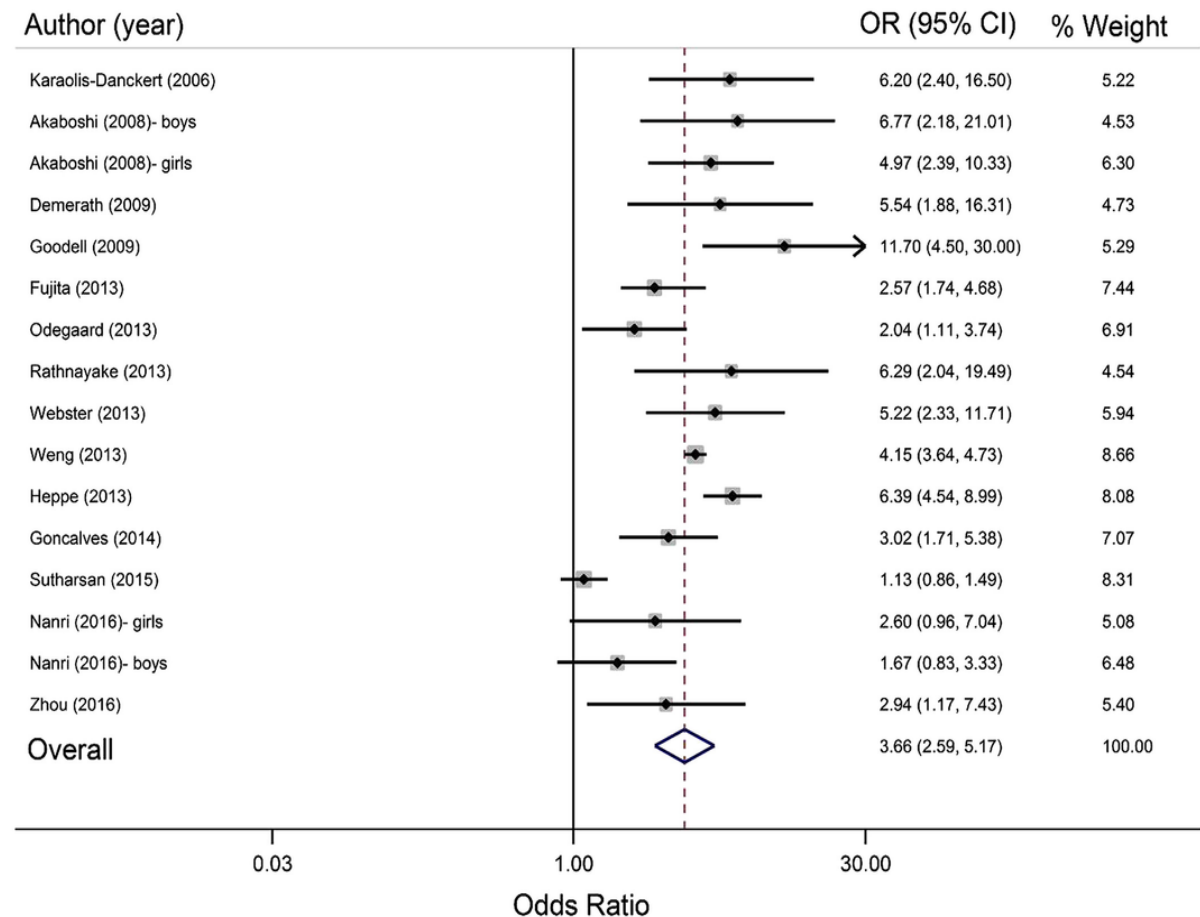
How do we get children to eat healthier?

How do we help children develop healthy self-regulation?



# Early growth predicts later risk

- Rapid weight gain and catch-up growth in infancy → greater later adiposity.
- The association supported across longitudinal cohorts



# Can we change the trajectory?

What if we intervene before the trajectory becomes established?



# The Intervention Nurses Start Infants Growing on Healthy Trajectories (INSIGHT)

Primary Aim: To evaluate a responsive parenting (RP) intervention that is designed to prevent rapid infant weight gain and childhood obesity at age 3 years among first-born infants.

Tell parents **WHAT** to feed.



Teach parents **HOW** to respond.

**Responsive parenting:**

- feeding
- soothing
- sleep
- routines
- active play
- emotional regulation

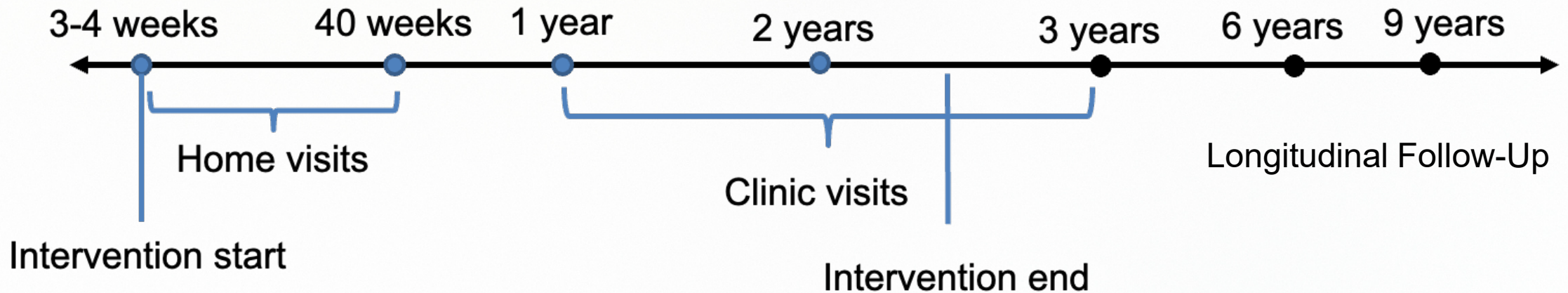


# INSIGHT design

Mother-infant dyads (n=279) were randomized to either:

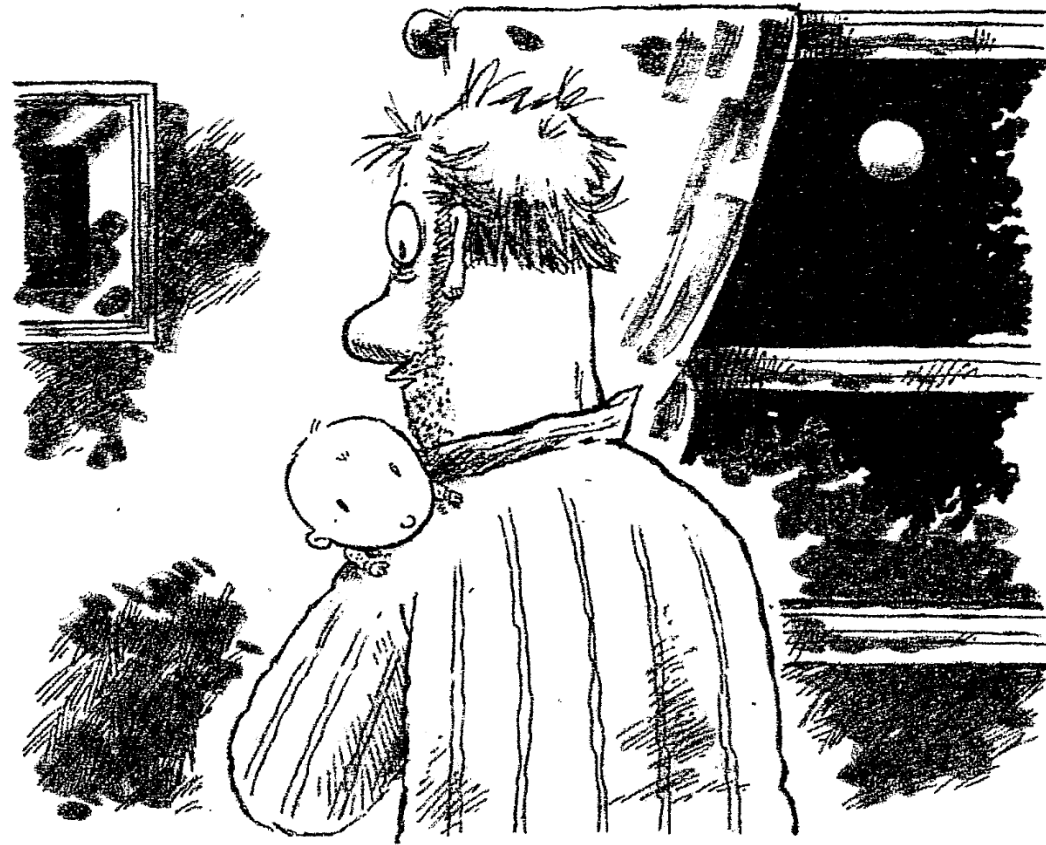
Responsive parenting intervention

Safety control group



Most parents want their child to...

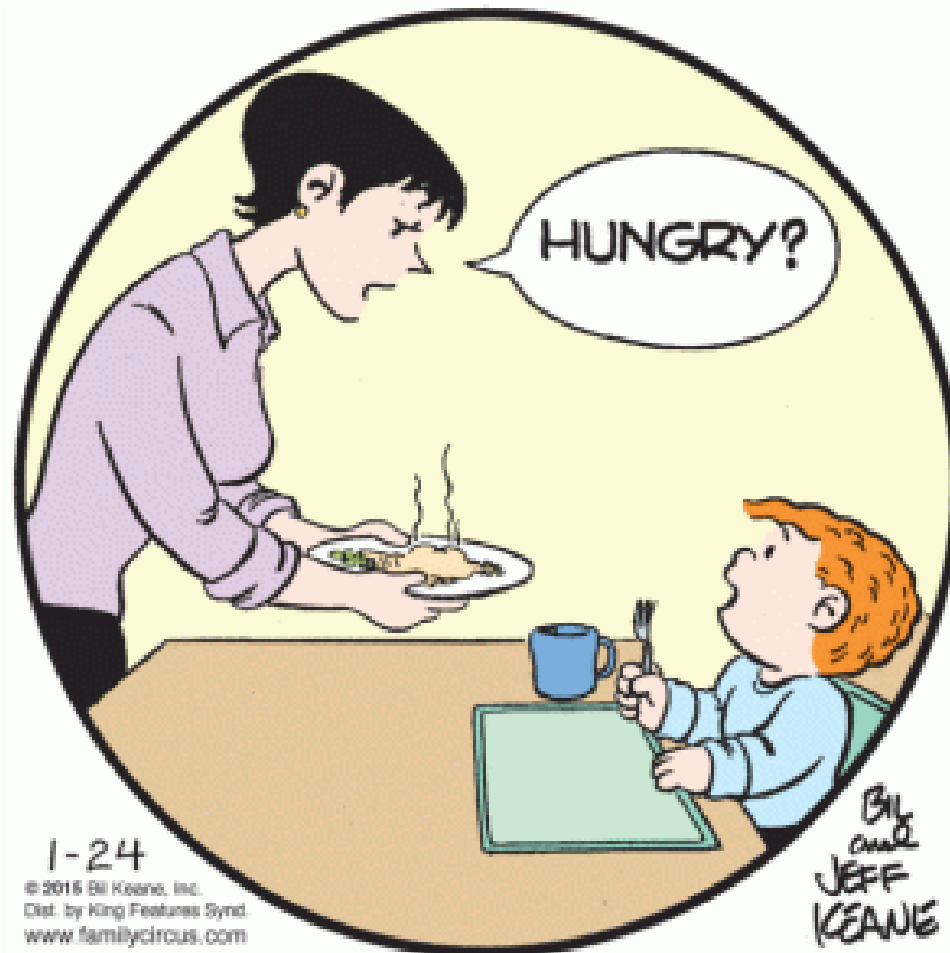
- Sleep through the night



"Someday you'll be a teenager, and you'll want to sleep all the time...and then I'll have my revenge."

Most parents want their child to...

- Sleep through the night
- Be a “good eater”



“That depends on what it is.”

Most parents want their child to...

- Sleep through the night
- Be a “good eater”
- Happy, not fussy



"Of course I know what he wants when he cries. He wants you."

# INSIGHT: Responsive Parenting Initiatives for Reducing Obesity during Childhood



- Who: Predominantly white, mother-infant dyads
- When: Birth to 30 months (9 contacts)
- What: Responsive parenting versus safety control group
- Delivered by: Home visiting nurses in the home

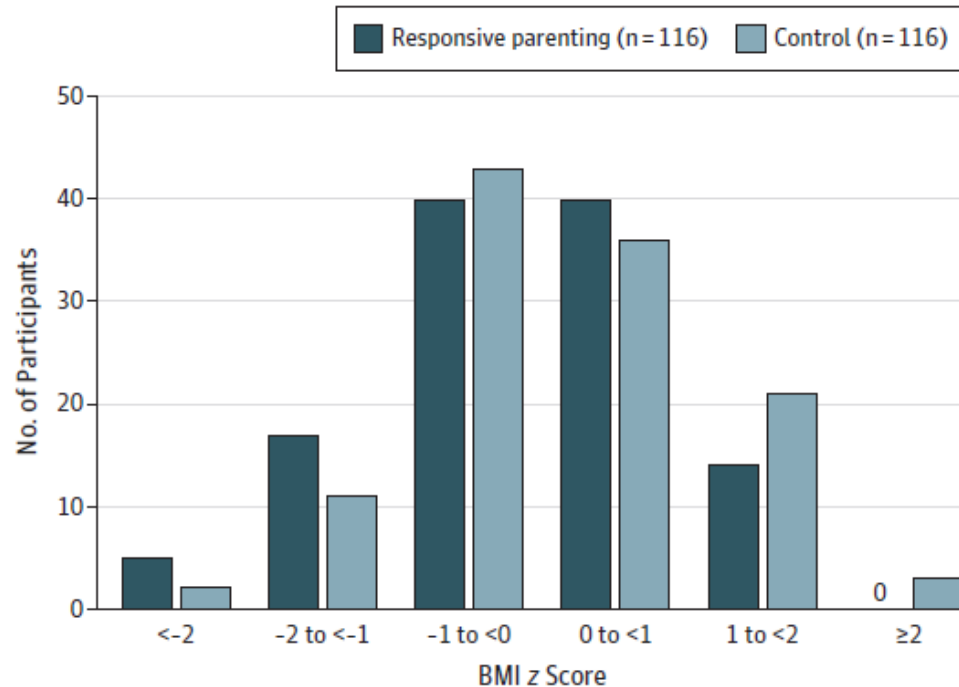


## Key Findings for the Responsive Parenting Group:

- Less rapid weight gain
- Lower BMI in early childhood
- Less use of food to soothe
- Less daily screen time

# 3 Year Primary Outcome: BMI z-score

Figure 2. Distribution of BMI z Score at Age 3 Years Among Children Receiving Responsive Parenting vs Home Safety (Control) Interventions<sup>a</sup>



BMI indicates body mass index (calculated as weight in kilograms divided by height in meters squared).

<sup>a</sup> Mean BMI z scores: -0.13 for responsive parenting vs 0.15 for control; absolute difference, -0.28 (95% CI, -0.53 to -0.01); analysis of variance  $P = .04$ .

Responsive Parenting BMI z-score -0.13  
Control BMI z-score +0.15;

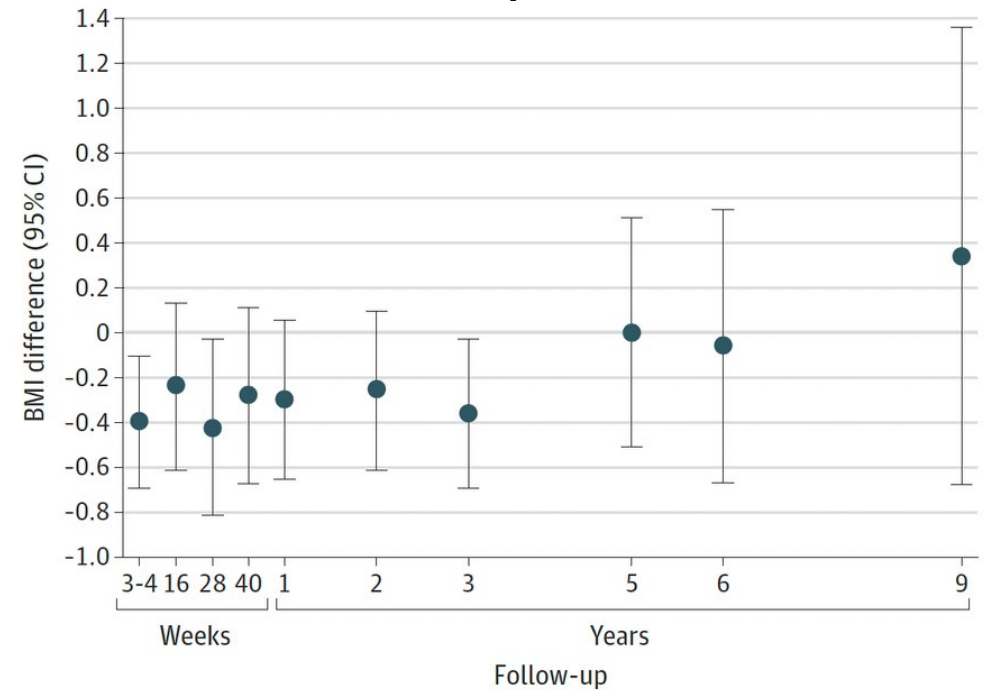
Absolute difference -0.28 (95% CI -0.01 to -0.53);  $P=.04$

Z-score difference exceed the 0.20-0.25 difference suggested by the United States Preventive Services Task Force as clinically meaningful

# Did the effects last?

- An early-life responsive parenting intervention → lower BMI from age 3 to 9 years compared with a control intervention.
- In cross sectional comparison, there were no study group differences in weight-related outcomes at ages 5, 6, and 9 years

**Mean Difference in BMI Between Children Who Received Responsive Parenting vs Home Safety (Control) Interventions at Each Study Time Point**



# What actually changed?

**Not simply WHAT infants ate**

**But HOW parents responded**



Structure • Feeding responsibility • Soothing • Routines • Sleep

# Spillover effect of INSIGHT on secondborn sibling

2018 Census– 79% of all children under 18 have at least one sibling

- Lower BMIz at 1 year
- Sleep longer, better sleep behaviors thru 1 year
- More vegetables eaten, greater variety at 1 year
- Mothers use less pressure, more consistent meal routines, less food to soothe



## Next step: translation to broader population

- Large trials like INSIGHT demonstrate program efficacy, but....
  - Expensive, not feasible on large scale
  - Homogenous population – highly educated, high income, low depression
  - May not translate well to other populations
- How do we translate to broader populations?

# Rapid weight gain during infancy may be a key risk factor underlying these disparities



Rapid weight gain (RWG) is one of the most consistent factors associated with later overweight and obesity



RWG is twice as common among Black infants as it is among White infants



Differences in RWG account for > 70% of difference between White and Black children's BMI z scores in early childhood

# Sleep SAAF: Responsive Parenting Initiatives for Reducing Obesity during Childhood



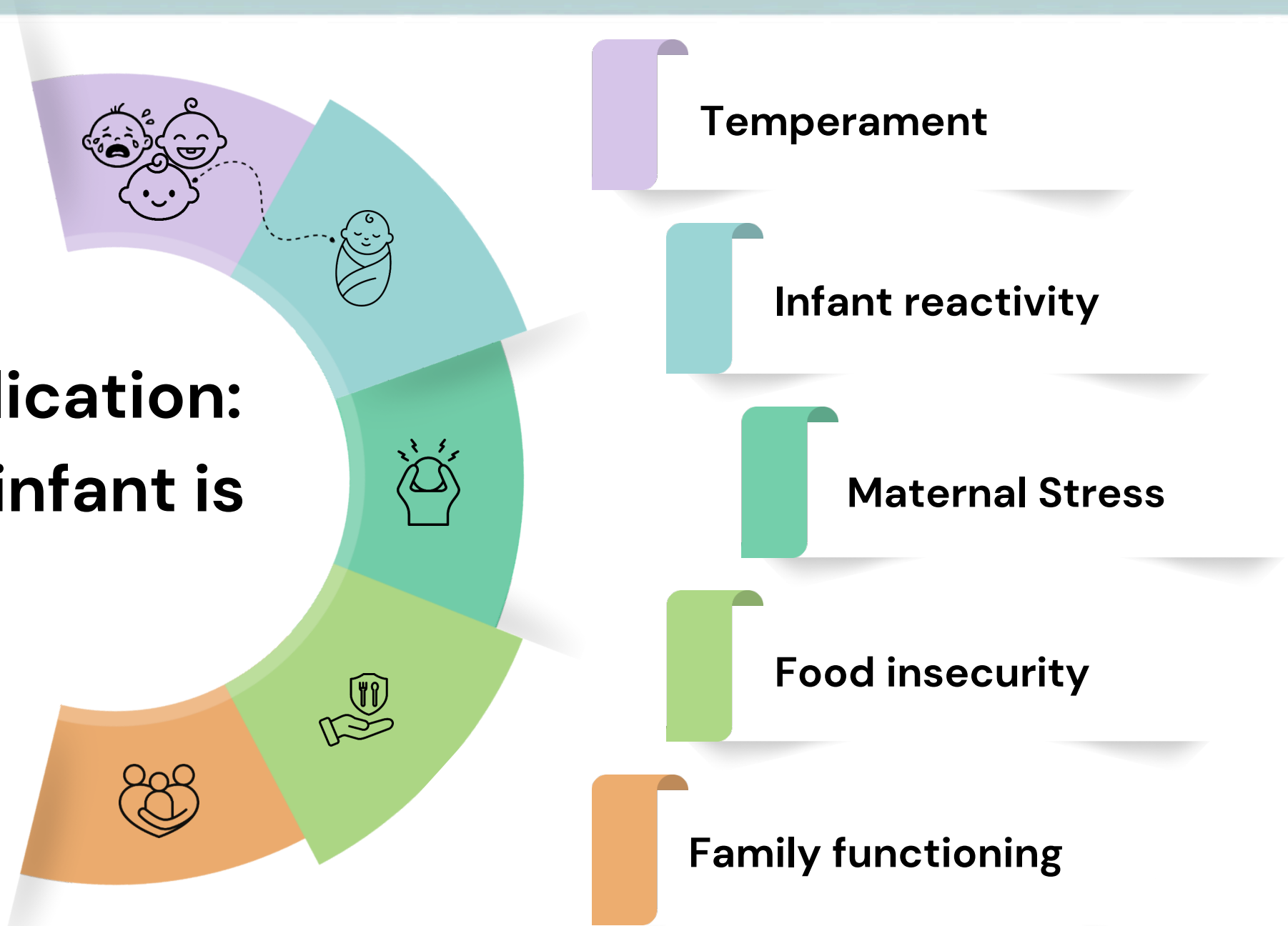
- Who: Black/African American, mother-infant dyads
- Where: Home visits
- When: 3 weeks (~ 2 hour) and 16 weeks (~ 1 hour)
- What: Responsive parenting versus safety control group
- Delivered by: Community Health Workers in the home



## Key Findings for Responsive Parenting Group:

- Positive effects on sleep (night wakings and total sleep)
- Positive effects on responsive feeding
- Less pressure to finish the bottle
- Less rapid infant weight gain (effect size  $d = 0.24$ ,  $p = 0.15$ )

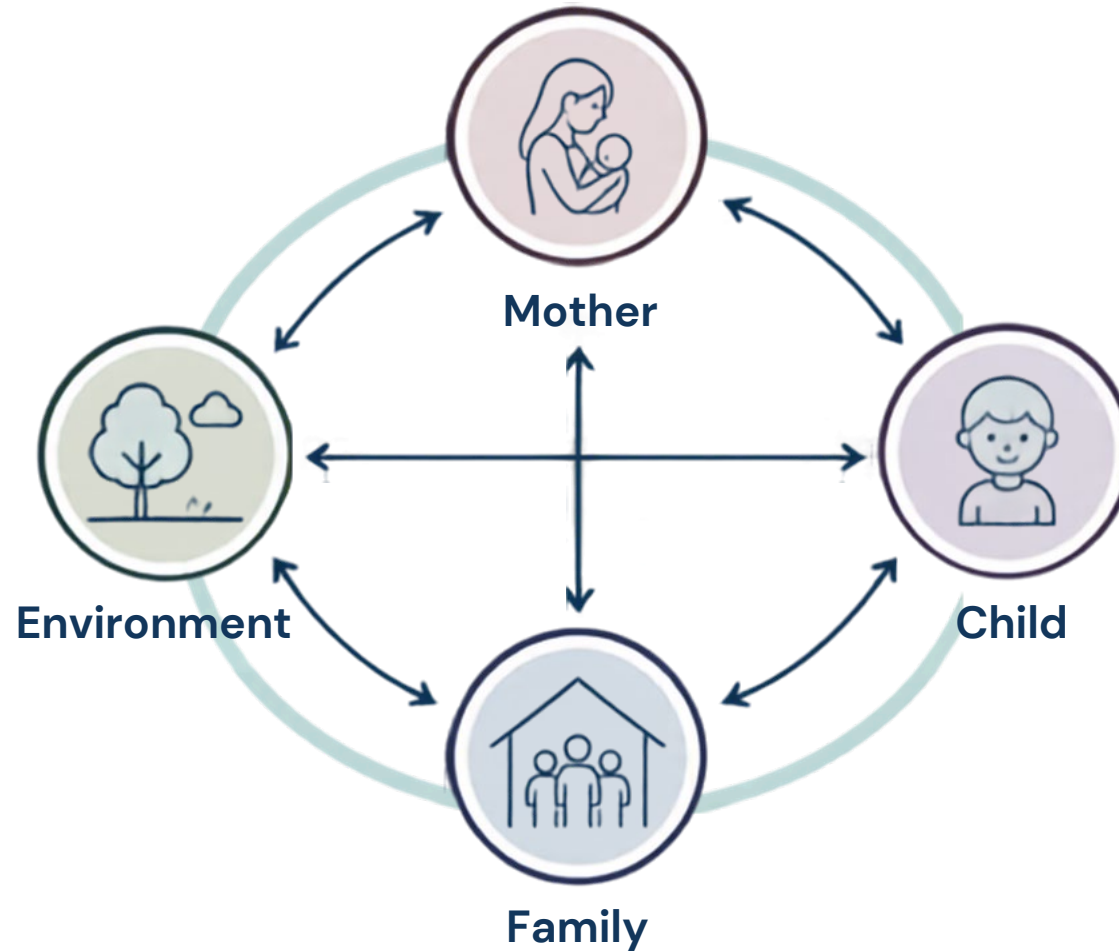
**The complication:  
not every infant is  
the same**



**The same parenting behavior may not operate identically across families.**

# The intervention was never really about the infant.

## We intervened on the parent-child system.



# Context changes the equation

- Food insecurity
- Stress
- Family functioning
- Return to work
- Siblings
- Rurality
- Access to resources



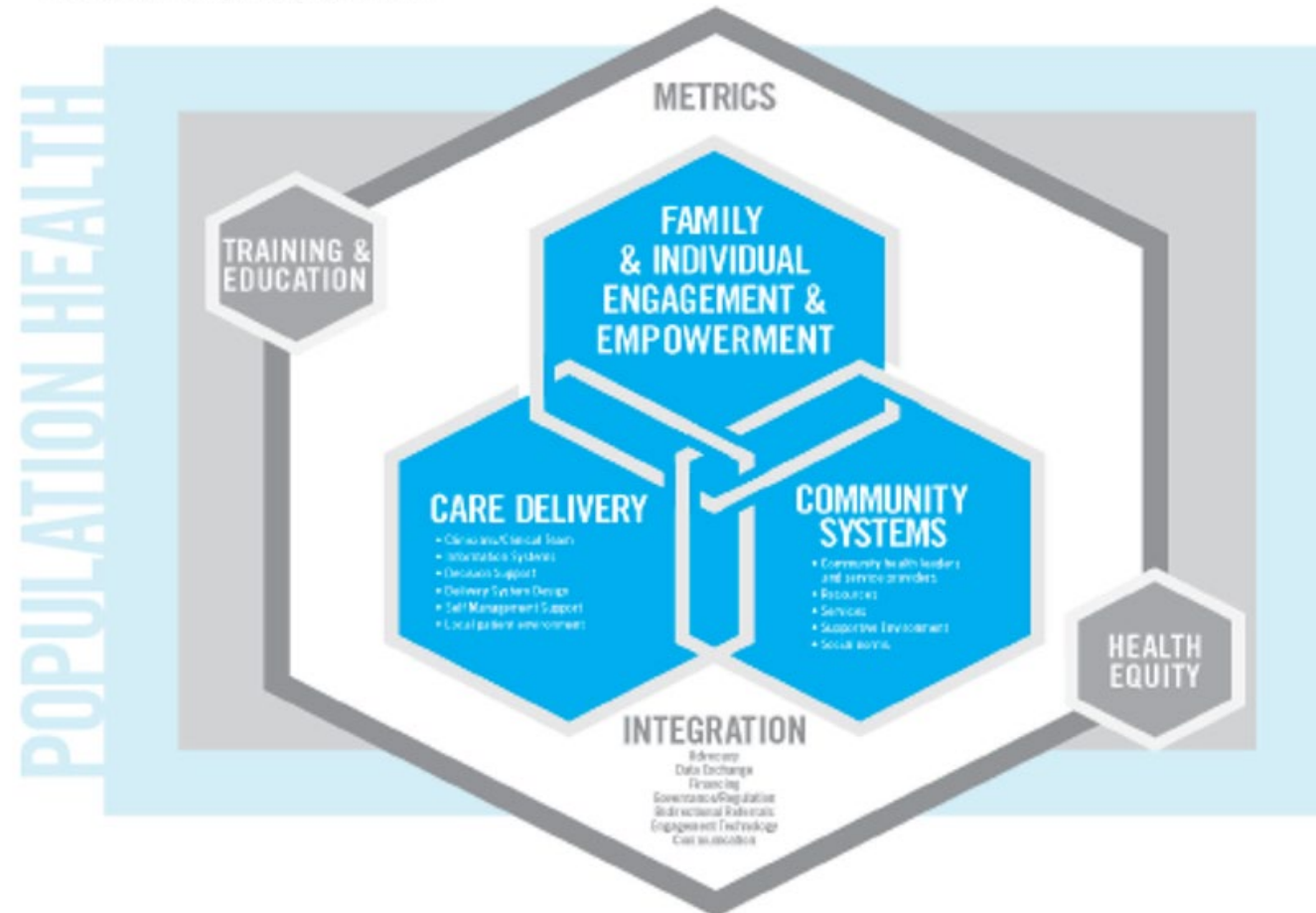
# **Can prevention live where families already are?**

What happens if we move the intervention into systems families already use?

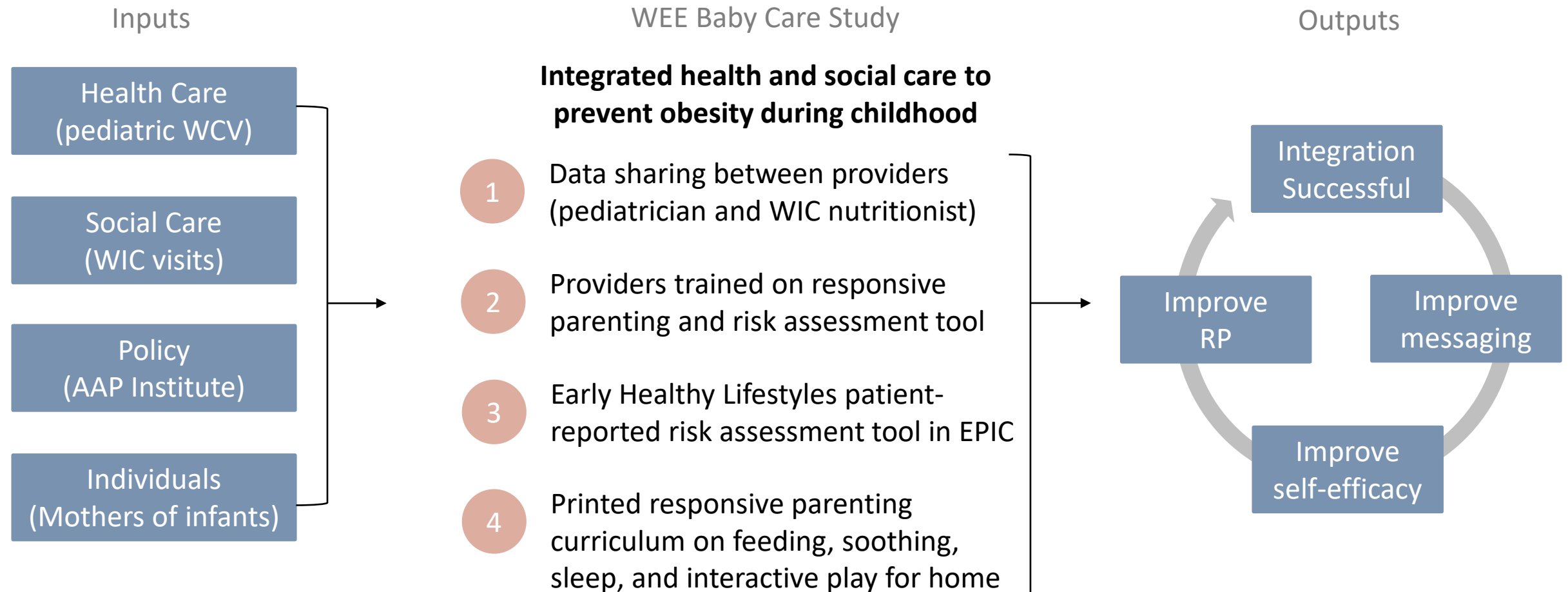
# WEE Baby Care Integrated Health Care and Social Care on Responsive Parenting to Support Families

## A FRAMEWORK TO OPTIMIZE THE PREVENTION AND TREATMENT OF OBESITY AND IMPROVE POPULATION HEALTH

People are more likely to engage in a healthcare system integrated within their community, where settings and resources reinforce healthy behaviors, provide person-centered care, and undergo continuous evaluation and improvement. Stakeholders recognize their interdependency and act in a coordinated and collaborative fashion to improve health and achieve health equity. This drives behavior change and ultimately helps to prevent and treat obesity and improve population health.



# WEE Baby Care – Responsive Parenting Enhancements



# Key WEE Baby Care Findings



CHILDHOOD OBESITY  
December 2023 | Volume 19, Number 8  
© Mary Ann Liebert, Inc.  
DOI: 10.1089/chi.2022.0137

Open camera or QR reader and  
scan code to access this article  
and other resources online.



## Coordination Between Primary Care and Women, Infants, and Children to Prevent Obesity for Infants from Low-Income Families: A Pragmatic Randomized Clinical Trial

Jennifer S. Savage, PhD,<sup>1</sup> Amy M. Moore, PhD, RD,<sup>1</sup> Samantha M.R. Kling, PhD, RD,<sup>2</sup>  
Michele Marini, MS,<sup>1</sup> Erika Hernandez, PhD,<sup>1</sup> Jennifer Franceschelli Hosterman, DO,<sup>3</sup>  
Sandra Hassink, MD,<sup>4</sup> Ian M. Paul, MD, MSc,<sup>5</sup> and Lisa Bailey-Davis, DEd, RD<sup>6</sup>

### Abstract

**Background:** Rapid weight gain during infancy is associated with risk for later obesity, yet little research to date has examined the effect of a responsive parenting (RP) intervention with care coordination between pediatric primary care providers and Women, Infants, and Children nutritionists on infant weight.

**Methods:** The Women, Infants, and Children Enhancements to Early Healthy Lifestyles for Baby (WEE Baby) Care study is a pragmatic, randomized clinical trial for mothers and infants ( $n=288$ ) designed to examine the effect of a patient-centered RP intervention that used advanced health information technology strategies to coordinate care to reduce rapid infant weight gain compared with standard care. General linear models examined intervention effects on infant conditional weight gain scores, weight-for-age  $z$  scores, BMI, and overweight status (BMI-for-age  $\geq 85$ th percentile) from birth to age 6 months, and mothers' use of food to soothe from age 2 to 6 months.

**Results:** There were no intervention effects on infant conditional weight gain scores or overweight status at 6 months. Infants in the RP intervention had lower mean weight-for-age  $z$  scores [ $M=-0.04$ , standard error (SE)=0.04 vs.  $M=0.05$ , SE=0.04;  $p=0.008$ ] and lower mean BMI ( $M=16.05$ , SE=0.09 vs.  $M=16.24$ , SE=0.09;  $p=0.03$ ) compared with standard care. Mothers' use of emotion-based food to soothe was lower in the RP intervention compared with standard care from age 2 to 6 months [ $M$  difference=-0.32, standard deviation (SD)=0.81 vs. 0.00, SD=0.90;  $p=0.01$ ].

**Conclusions:** This pragmatic, patient-centered RP intervention did not reduce rapid infant weight gain or overweight but was associated with modestly lower infant BMI and reduced mothers' use of emotion-based food to soothe.

**Trial Registration:** clinicaltrials.gov identifier: NCT03482908

- Infants in responsive parenting intervention had:
  - lower BMI at 6 months
  - less food to soothe non-hunger distress
- Most common education codes documented by WIC nutritionists: hunger and fullness, food to soothe, and self-soothe to sleep

# Key WEE Baby Care Findings



JMIR PEDIATRICS AND PARENTING

Kling et al

## Original Paper

Advanced Health Information Technologies to Engage Parents, Clinicians, and Community Nutritionists in Coordinating Responsive Parenting Care: Descriptive Case Series of the Women, Infants, and Children Enhancements to Early Healthy Lifestyles for Baby (WEE Baby) Care Randomized Controlled Trial

Samantha MR Kling<sup>1,2,3,4</sup>, PhD, RD; Holly A Harris<sup>1,5</sup>, PhD; Michele Marini<sup>1</sup>, MS; Adam Cook<sup>4</sup>, BA; Lindsey B Hess<sup>1</sup>, MPH; Shawnee Lutzer<sup>4</sup>, BS; Jacob Mowery<sup>4</sup>, BA; Scott Bell<sup>6</sup>, BS; Sandra Hassink<sup>7</sup>, MD, MS, FAAP; Shannon B Hayward<sup>8</sup>, MS; Greg Johnson<sup>6</sup>, BS; Jennifer Franceschelli Hosterman<sup>4</sup>, DO; Ian M Paul<sup>9,10</sup>, MD; Christopher Seiler<sup>4</sup>, MBA; Shirley Sword<sup>4</sup>, MS, RD; Jennifer S Savage<sup>1,3</sup>, PhD; Lisa Bailey-Davis<sup>4,11</sup>, DEd, RD

<sup>1</sup>Center for Childhood Obesity Research, The Pennsylvania State University, University Park, PA, United States

<sup>2</sup>Evaluation Sciences Unit, Division of Primary Care and Population Health, Department of Medicine, Stanford University, Stanford, CA, United States

<sup>3</sup>Department of Nutritional Sciences, The Pennsylvania State University, University Park, PA, United States

<sup>4</sup>Geisinger Obesity Institute, Geisinger, Danville, PA, United States

<sup>5</sup>Erasmus Medical Center, Generation R Study, University Medical Center Rotterdam, Rotterdam, Netherlands

<sup>6</sup>Bureau of Women, Infants, and Children, Pennsylvania Department of Health, Harrisburg, PA, United States

<sup>7</sup>Institute for Healthy Childhood Weight, American Academy of Pediatrics, Wilmington, DE, United States

<sup>8</sup>Maternal and Family Health Services, Wilkes-Barre, PA, United States

<sup>9</sup>Department of Pediatrics, Penn State College of Medicine, Hershey, PA, United States

<sup>10</sup>Department of Public Health Sciences, Penn State College of Medicine, Hershey, PA, United States

<sup>11</sup>Department of Population Health Sciences, Geisinger, Danville, PA, United States

## Corresponding Author:

Samantha MR Kling, PhD, RD  
Evaluation Sciences Unit, Division of Primary Care and Population Health  
Department of Medicine, School of Medicine  
Stanford University  
1265 Welch Rd x216  
Stanford, CA, 94305  
United States  
Phone: 1 605 726 3392  
Email: [skling@stanford.edu](mailto:skling@stanford.edu)

## Abstract

**Background:** Socioeconomically disadvantaged newborns receive care from primary care providers (PCPs) and Women, Infants, and Children (WIC) nutritionists. However, care is not coordinated between these settings, which can result in conflicting messages. Stakeholders support an integrated approach that coordinates services between settings with care tailored to patient-centered needs.

**Objective:** This analysis describes the usability of advanced health information technologies aiming to engage parents in self-reporting parenting practices, integrate data into electronic health records to inform and facilitate documentation of provided responsive parenting (RP) care, and share data between settings to create opportunities to coordinate care between PCPs and WIC nutritionists.

It is feasible to use advanced health information technology strategies to collect patient-reported data and share these data between multiple providers.

- Pediatricians and WIC nutritionists shared data
- WIC nutritionists were more likely to use data and document RP care to coordinate care
- Differences in visit schedules requires flexibility

# WEE Baby Care Findings - Early Healthy Lifestyles risk screening tool



**Reduced obesogenic risk behaviors:** The patient-centered, care-coordinated responsive parenting intervention reduced obesogenic feeding and sleep risk behaviors among WIC-enrolled mother–infant dyads.

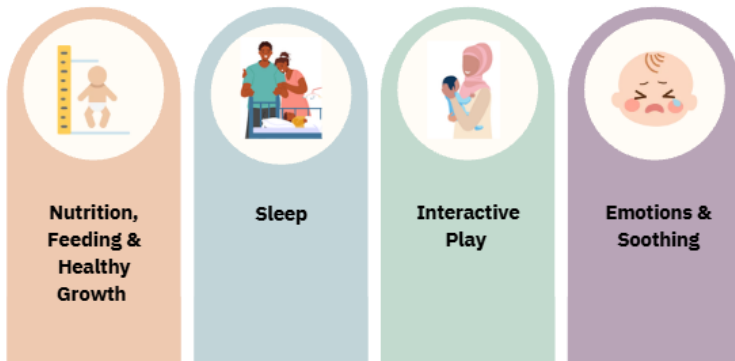
**Identified infants at risk for later obesity:** The Early Healthy Lifestyles risk screening tool identified modifiable obesogenic behaviors associated with later infant weight outcomes, supporting its potential for early, tailored obesity-prevention counseling.

# ENRICH: Responsive Parenting Initiatives for Reducing Obesity during Childhood



- Who: Mother-infant dyads in home-visiting programs
- When: Birth to 24 months
- What: Responsive parenting versus standard care
- Delivered by: Trained home visitors in the home

Specific topics will include:



**Study ongoing, more to come!**

# The field-level evidence

## TOPCHILD

- Across 17 RCTs (N = 9,128; 8 countries), early parent-focused interventions did not meaningfully reduce child BMI z-score at age 2

## Across families and multiple interventions...

What works?

For whom?

Under what conditions?

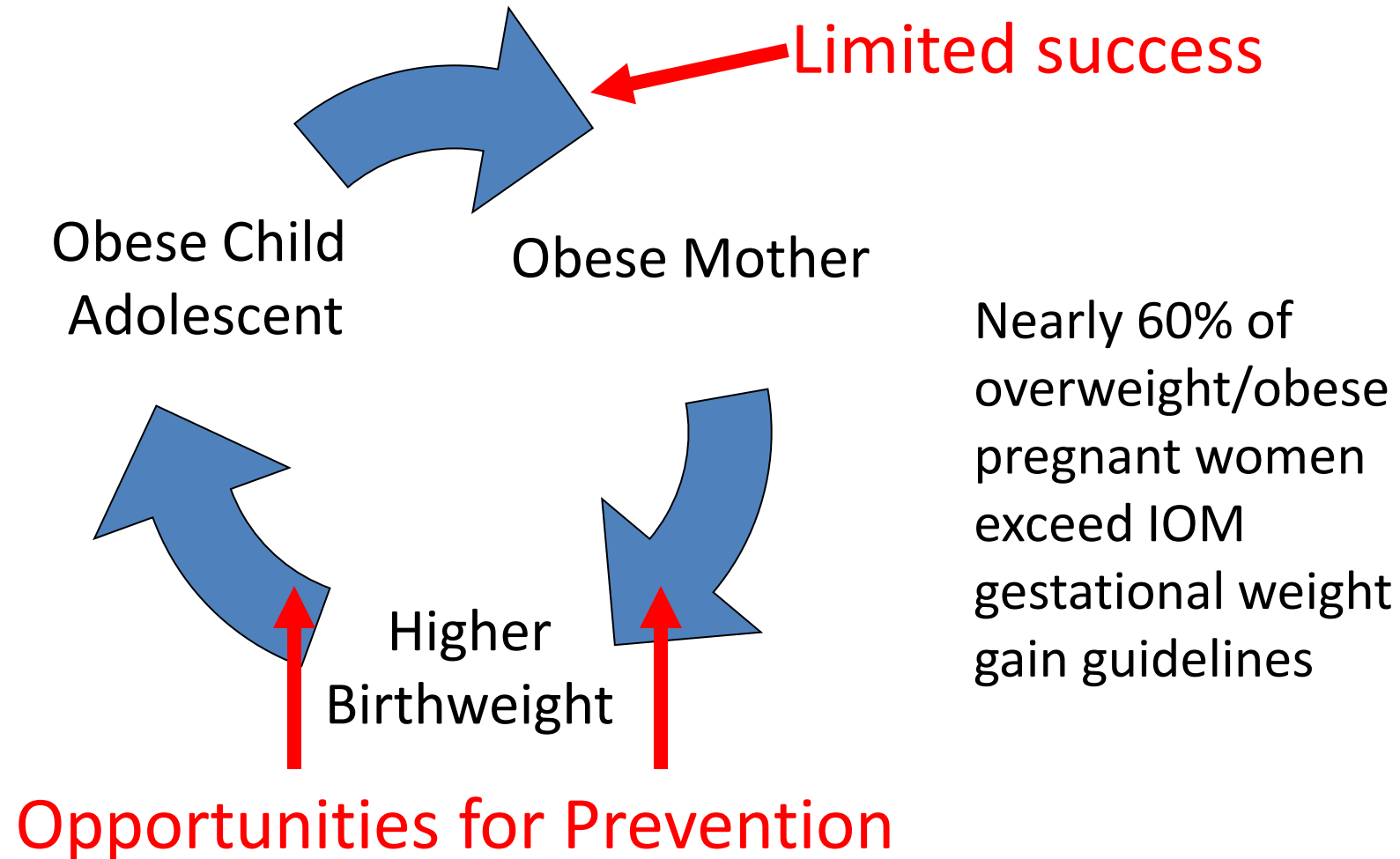
Can effects be sustained?

# Another “too late” moment

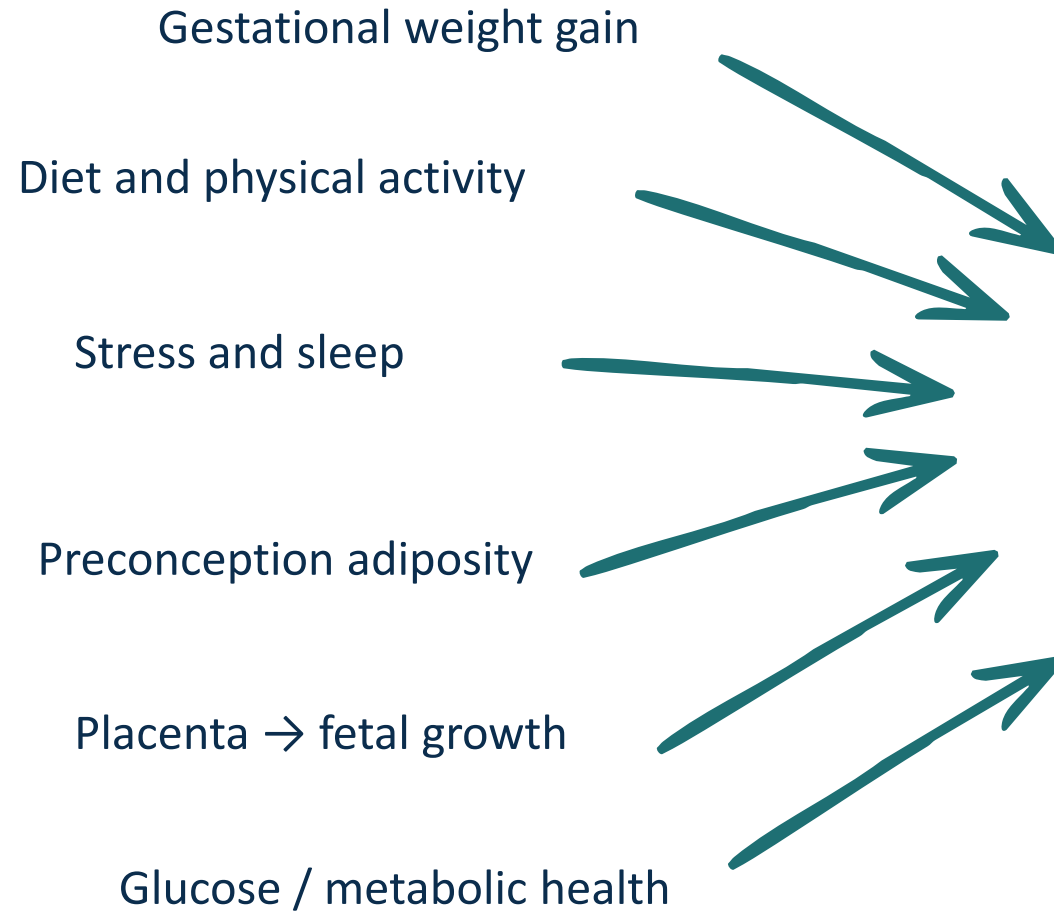
What if birth is already too late?

**Age 5 → Preschool → Infancy → Pregnancy**

# Intergenerational effects on obesity: Opportunities for prevention

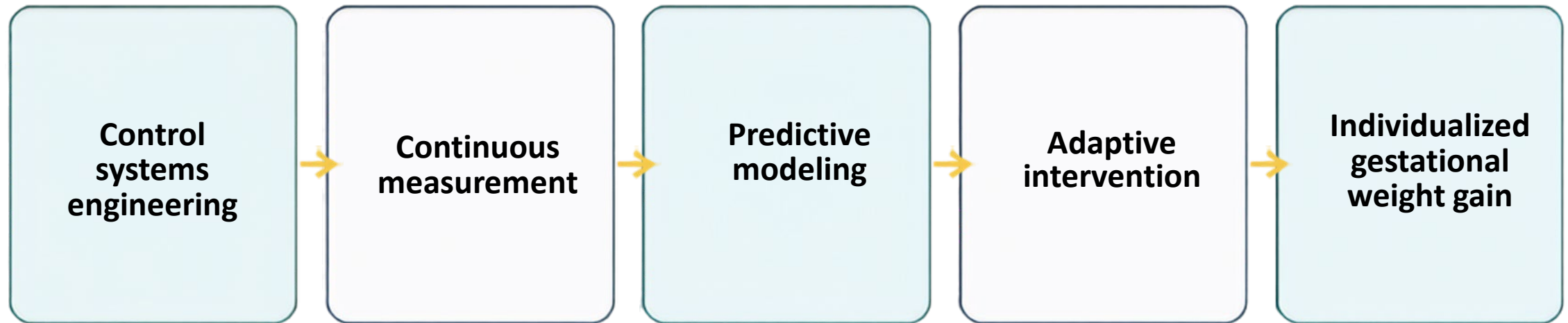


# Maternal obesity is not one exposure



# An unexpected turn

Instead of one-size-fits-all behavioral intervention:



# “Baseline” Intervention



## Featured Evidence/ Baby's Health

Emails highlighting key topics of how mom's behaviors impact baby (sleep, brain development, food preferences)

## Baby Fun Facts

Emails on baby's growth each week (e.g., baby is big as a lime this week" and "your baby can now suck her thumb")

## Goals-Action Plans

Action plans, self-selected goals + we set target goals for them (e.g., PA guidelines, target food groups)

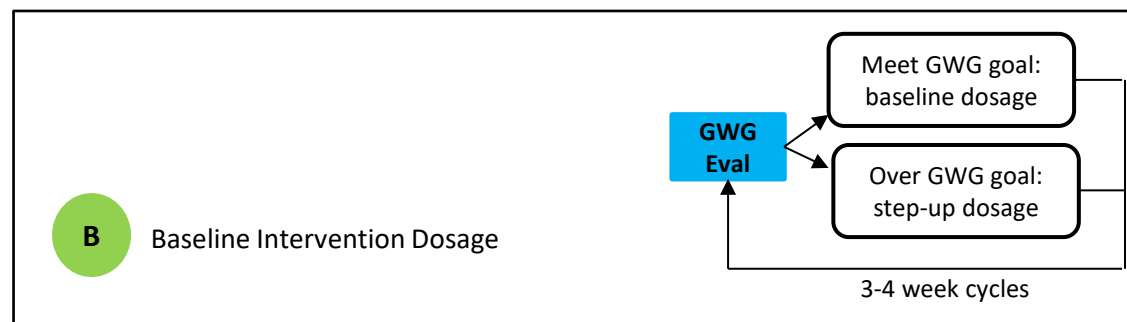
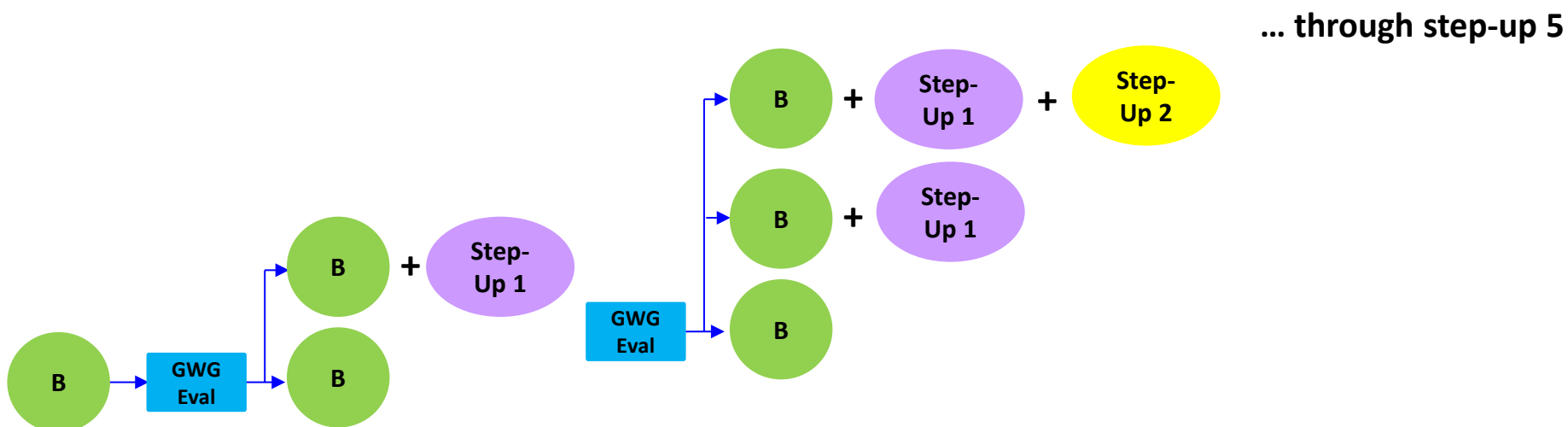
## Self-Monitoring

mHealth tools behavior tracking, feedback on prior week's eating/exercise, text/email reminders

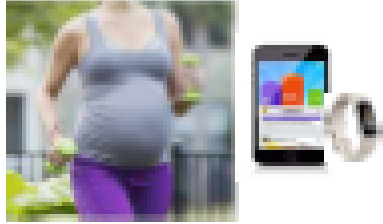
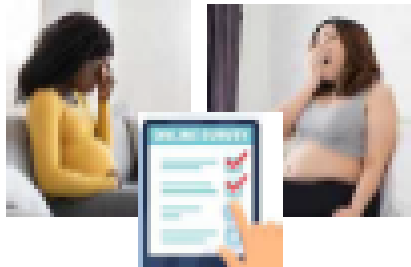
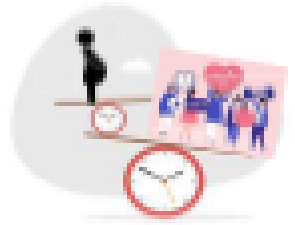
## Education\*

Plotting GWG goals, benefits of regulating GWG/healthy eating/PA/moving more, sleep hygiene, mood





# Key Findings from Preparation Phase: HMZ 1.0

|                                                                                   |                                                                                   |                                                                                     |                                                                                     |                                                                                     |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
|  |  |  |  |  |
| 21% lower GWG                                                                     | INT group sustained PA kcal while CON decreased                                   | CON had 3 times higher EI kcal than INT                                             | INT better motivation and sleep behaviors than CON                                  | HMZ manual dosage change process was too slow                                       |

INT = intervention group, CON = control group

# What we thought vs. what we know

| What we thought                        | What the science taught us                                                             |
|----------------------------------------|----------------------------------------------------------------------------------------|
| Obesity prevention starts in childhood | Risk trajectories emerge much earlier                                                  |
| Focus on children's eating             | Focus on development of self-regulation and impacts of sleep and child characteristics |
| Tell parents what to feed              | Change how parents respond                                                             |
| Intervene on the child                 | Intervene on the parent–child, family systems                                          |
| A successful trial is the goal         | Translation and sustainment matter                                                     |
| Birth is the beginning                 | Maternal health may begin the story earlier                                            |

# The next generation of prevention

- More precise, adaptive interventions- shift from identifying risk factors to identifying *who responds to what, when, and why*.
- Systems-based - Study parenting and the broader environment as an integrated system.
- Expand the field to children historically underrepresented in obesity research—including children with special health care needs
- Prioritize implementation and scalable interventions that work in real-world pediatric care.

**Not simply preventing obesity—but promoting healthy development.**

# The Child Health Research Center

Transforming discoveries into lifelong wellbeing for children and communities.

Learn about CHRC

*Our mission is to enhance the health and well-being of children, families, and their communities through research, interdisciplinary collaboration, and robust community partnerships*

jsavage@psu.edu

VISIT OUR WEBSITE



FOLLOW US ON

LinkedIn



# Q&A

## **Be the Reason Kids Greaux Healthy**

### Annual Childhood Obesity Conference



**Pennington Biomedical  
Research Center**  
Louisiana State University

Pennington Biomedical  
**Greaux  
Healthy** 

# **Thank you for investing in our children's future!**