Does adherence to U.S. dietary guidelines during pregnancy reduce exposure to over 50 contemporary and understudied chemicals?

Diana Pacyga, MS, PhD
Postdoctoral Trainee
Department of Epidemiology | University of North Carolina at Chapel Hill
Data Analysis Center | ECHO Program

ECHO Discovery Series – June 2025

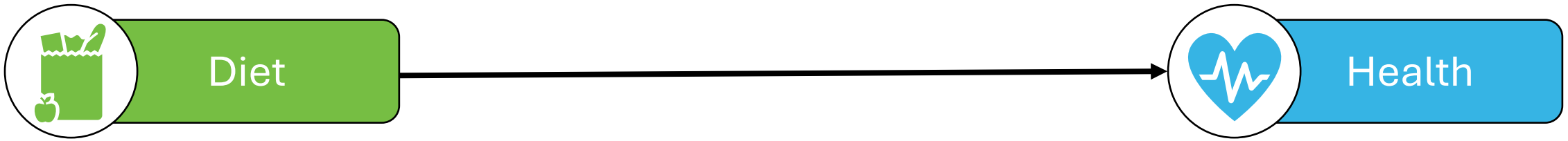
Acknowledgements

Conflicts: I have no conflicts to disclose.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health (NIH).

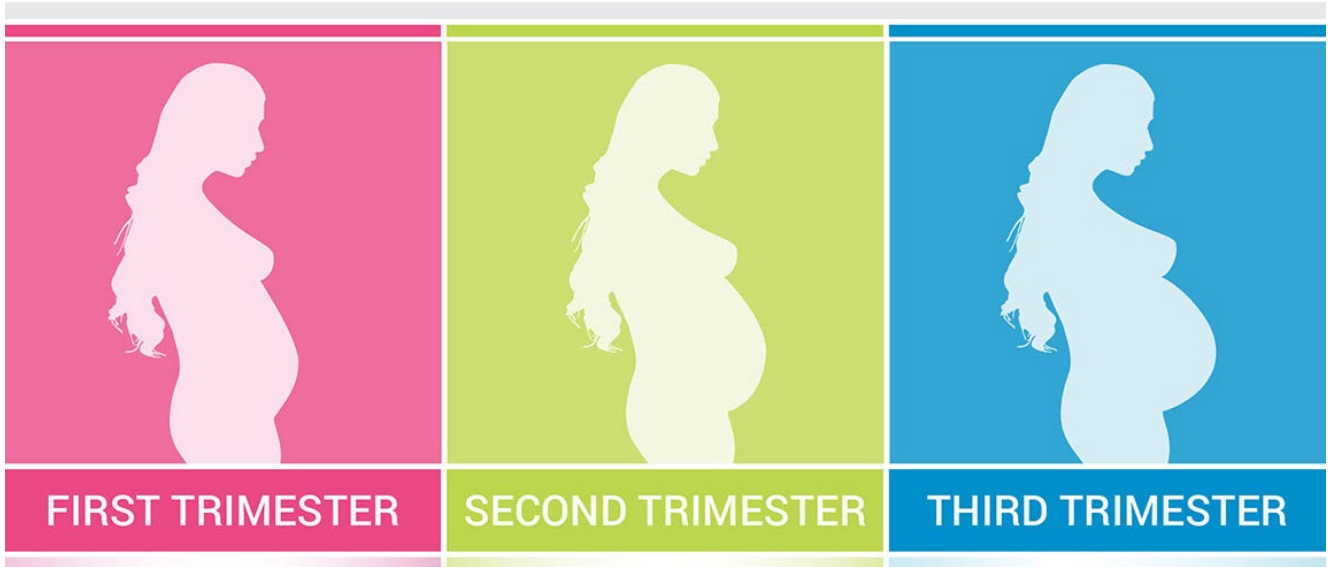
ECHO collaborators: Jessie Buckley, Tracey Woodruff, Deborah Bennett, Michael Bloom, Joseph Braun, Courtney Carignan, Caitlin Howe, Margaret Karagas, Kristen Lyall, John Meeker, Melissa Melough, Wei Perng, Christy Porucznik, Lesliam Quiros-Alcala, Zorimar Rivera-Nunez, Rebecca Schmidt, Rita Strakovsky, Ana Rosen Vollmar, Yeyi Zhu.

Mom’s diet in pregnancy shapes her and baby’s future health

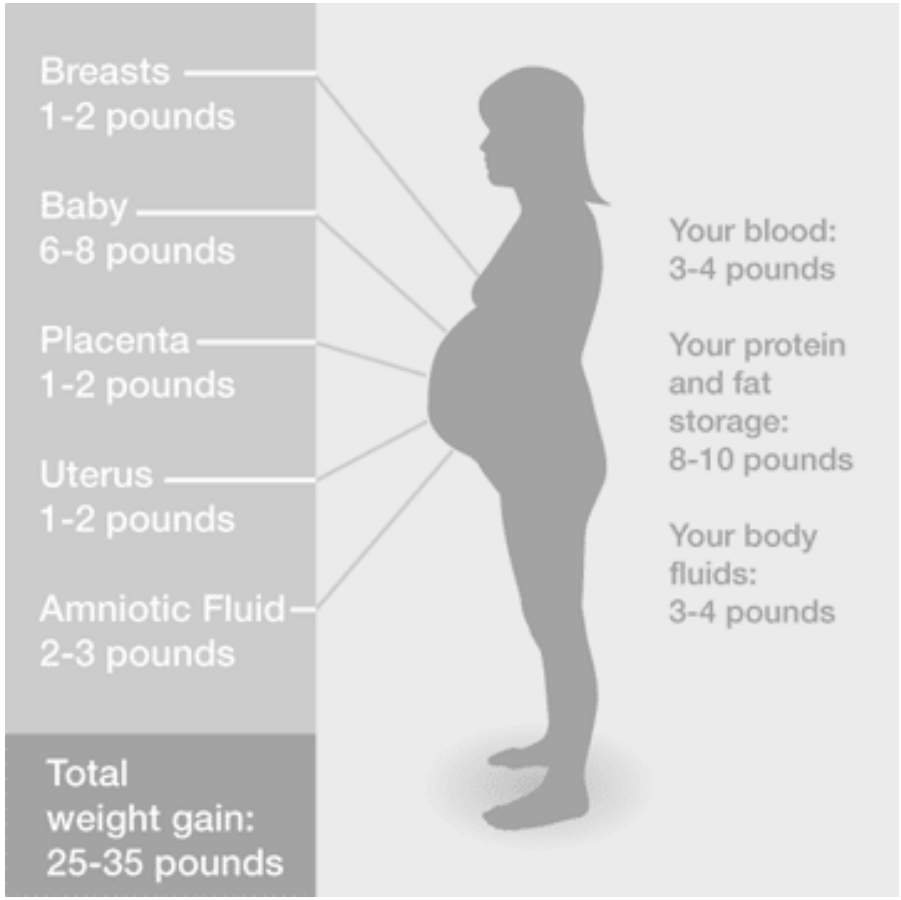


Pregnancy is a time of positive energy balance to support fetal growth and maternal health

Estimated change in calorie needs



+0 kcal/d **+340 kcal/d** **+452 kcal/d**



Dietary Guidelines for Americans, 2020-2025 (Chapter 5: Women Who are Pregnant or Lactating); Image from babyyourbaby.org

Dietary guidelines promote high quality diets to meet the increased energy and nutrient needs in pregnancy

Dietary Guidelines for Americans

Consume adequate amounts

Total vegetables, greens/beans

Total fruit, whole fruit

Total protein, seafood/plant protein

Whole grain

Total dairy

Fatty acids

Consume in moderation

Refined grains

Sodium

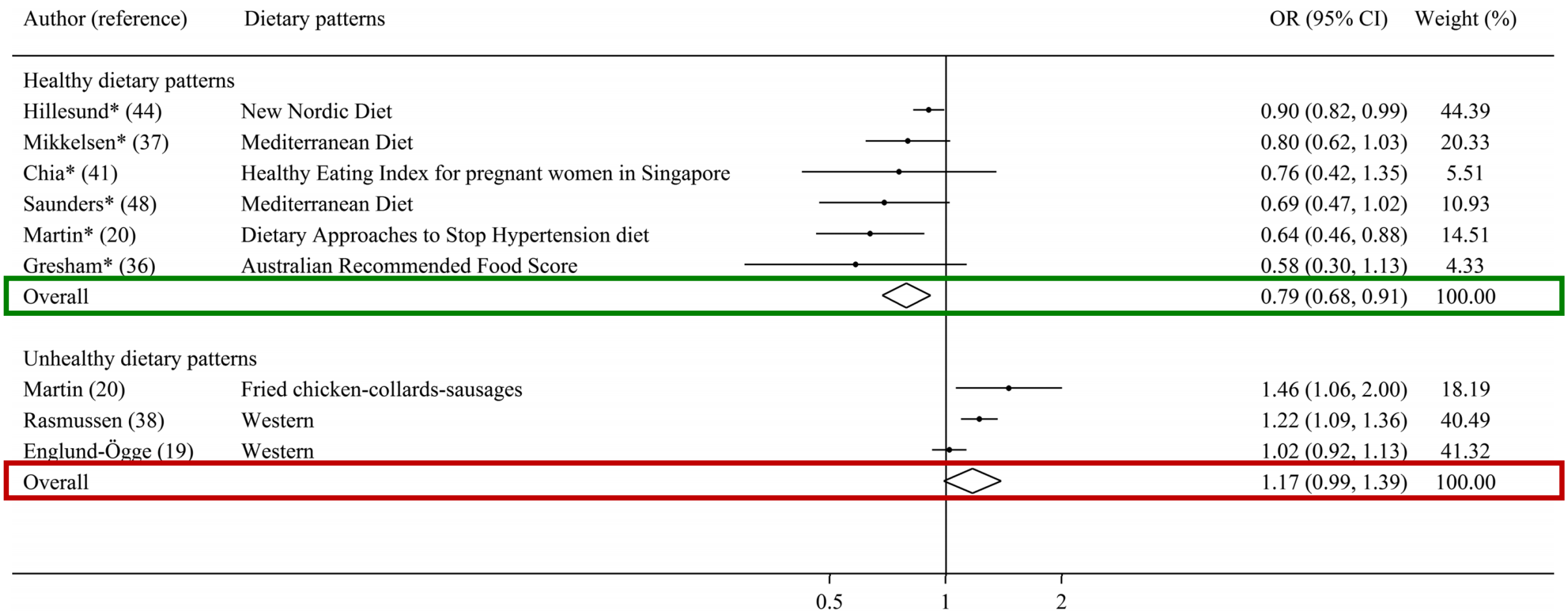
Saturated fats

Added sugar

+ prenatal vitamin for micronutrient needs that are difficult to meet through foods and beverages alone

Dietary Guidelines for Americans, 2020-2025 (Chapter 5: Women Who are Pregnant or Lactating)

Healthier dietary patterns are associated with favorable pregnancy outcomes, including lower odds of preterm birth



Chia *et al.*, *Advances in Nutrition*, 2019

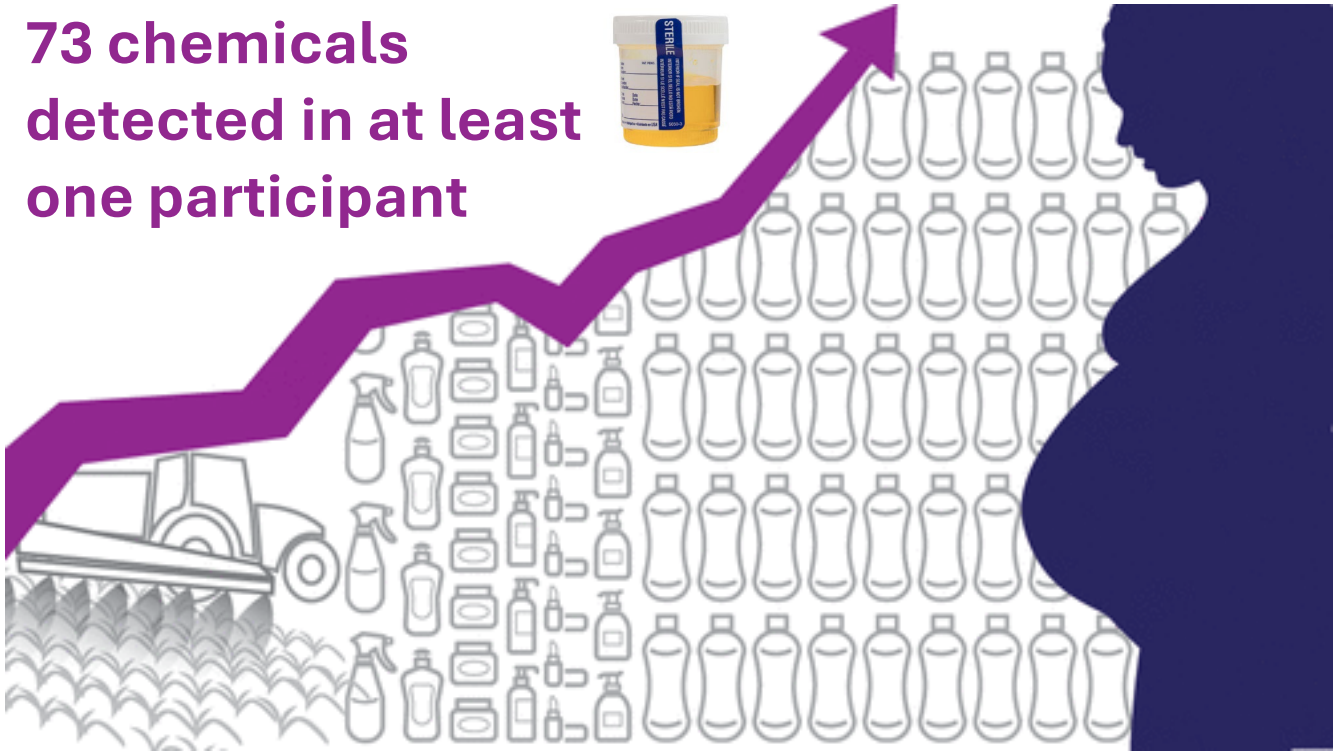
Diet is also a hidden source of chemicals

Pregnant women are exposed to many chemicals as shown in an ECHO pilot study

Phthalates

Bisphenols

73 chemicals detected in at least one participant

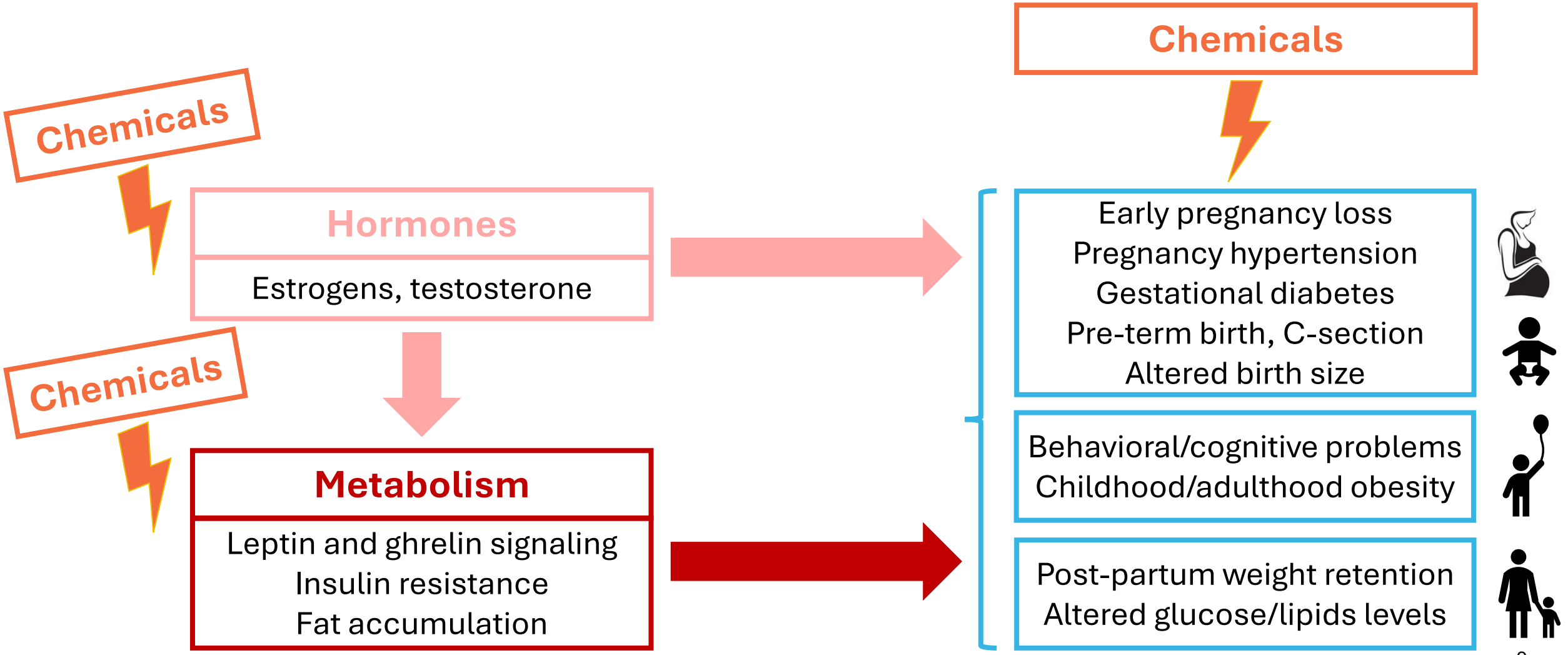


Pesticides

Polycyclic aromatic hydrocarbons (PAHs)

Buckley *et al.*, *Environmental Science & Technology*, 2022; Images from Microsoft 365 Library

Chemicals with endocrine and metabolic disrupting properties can impact maternal and child health



Strakovsky & Schantz, *Toxicological Sciences*, 2018; Warner *et al.*, *Reproductive Toxicology*, 2021; Pacyga *et al.*, *Environment International*, 2021

Most of our knowledge regarding chemicals in food comes from food monitoring and observational studies

Food monitoring studies test foods, while observational studies link food intake to exposure biomarkers

Food monitoring studies

- Monitor nutrient content and chemicals in specific food items over time
- Conducted by government agencies (e.g., FDA Total Diet Study) or independent laboratories

Observational studies

- Evaluate the relationship between self-reported food intake and chemical biomarkers
- Conducted in cohort studies with individuals from specific populations

Image from istockphoto.com

Current recommendations to reduce dietary chemical exposures are limited to a few classes

Reduce exposure to **phthalates**

Reduce exposure to **pesticides**

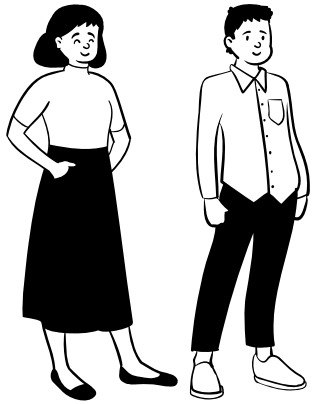
Images from healthyyouhealhtychildren.com and vectorstock.com

Dietary guidelines are in place to promote healthy diets, but do they protect against chemical exposure?

Bisphenols, phthalates, PAHs

Diet quality and exposure to endocrine-disrupting chemicals among US adults

Melissa M. Melough [a], Maricel V. Maffini [b], Jennifer J. Otten [c], Sheela Sathyanarayana [a c d]



PAHs

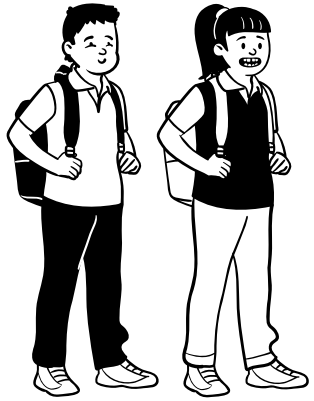
Diet, polycyclic aromatic hydrocarbons, and oxidative stress biomarkers in pregnancy: A Los Angeles pregnancy cohort

Kasey E. Yu [a], Sanjali Mitra [a], Qi Meng [a], Irish DelRosario [a], Sherin U. Devaskar [b], Carla Janzen [c], Peggy S. Sullivan [d], Liwei Chen [a], Michael Jerrett [e], Beate Ritz [a e]

PFAS

Dietary per- and polyfluoroalkyl substance (PFAS) exposure in adolescents: The HOME study

Harry Sultan [a b], Jessie P. Buckley [c], Heidi J. Kalkwarf [d e], Kim M. Cecil [d f], Aimin Chen [g], Bruce P. Lanphear [h], Kimberly Yolton [d], Joseph M. Braun [i]



Phthalates & replacements

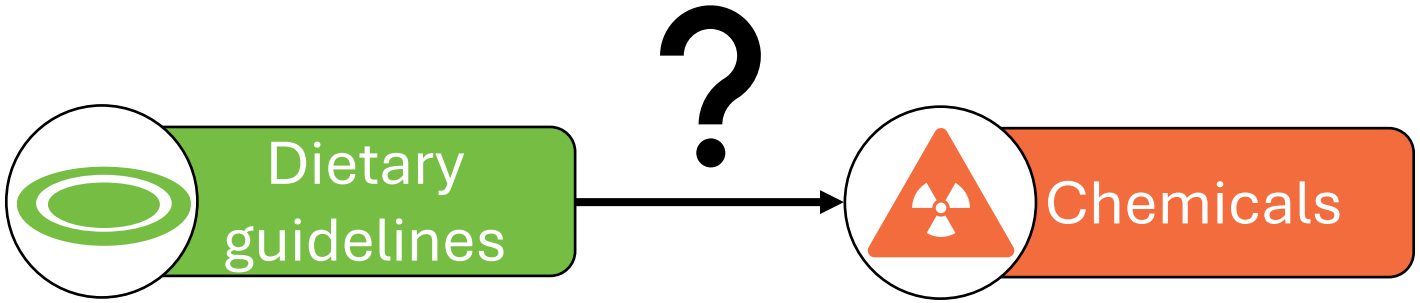
Exploring diet as a source of plasticizers in pregnancy and implications for maternal second-trimester metabolic health

Diana C. Pacyga [a b c], Luca Jolly [d e], Jason Whalen [f], Antonia M. Calafat [g], Joseph M. Braun [h], Susan L. Schantz [i j], Rita S. Strakovsky [a b]

Gap: No large-scale pregnancy study has evaluated diet and broad chemical exposure

Research questions

1. Is better adherence to the dietary guidelines associated with lower chemical exposures in pregnancy?
2. Which food components within the guidelines drive these associations?



ECHO
Environmental influences on Child Health Outcomes
A program supported by the NIH

Environmental influences on Child Health Outcomes

n = 6,107 (21 cohort sites)
Urine sent for chemical analysis

↓

n = 6,099 (21 cohort sites)
Available urine dilution data

↓

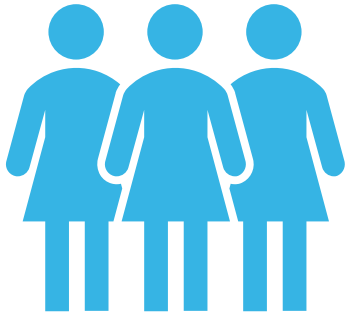
n = 1,515 (8 cohort sites)
Had diet data

↓

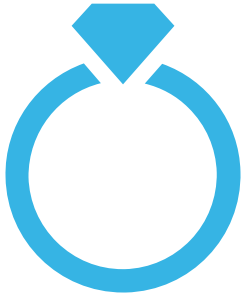
n = 1,487 (6 cohort sites)
Sites with n > 30 (2006-2020)

Characteristics of pregnant women (n = 1,487)

≥30 years old (47%)



NH White (40%)
NH Black (36%)



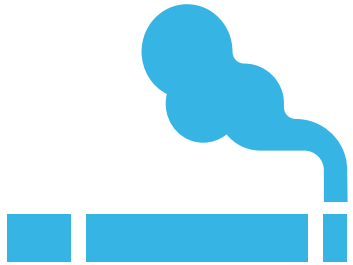
Married/partnered (70%)

College educated (63%)

BMI ≥ 25 kg/m^2 (57%)

≥ 1 prior birth (56%)

Consumed alcohol (20%)



Smoked (7%)

Healthy Eating Index (HEI-2015) measures adherence to the Dietary Guidelines for Americans

Mid-second trimester (median 21 weeks)

Food frequency questionnaire or 24-hour recall

- Scored out of 100 pts, higher score = better adherence
- Composed of 13 food/nutrient components

Consume adequate amounts

Total vegetables, greens/beans

Total fruit, whole fruit

Total protein, seafood/plant protein

Whole grain

Total dairy

Fatty acids

Consume in moderation

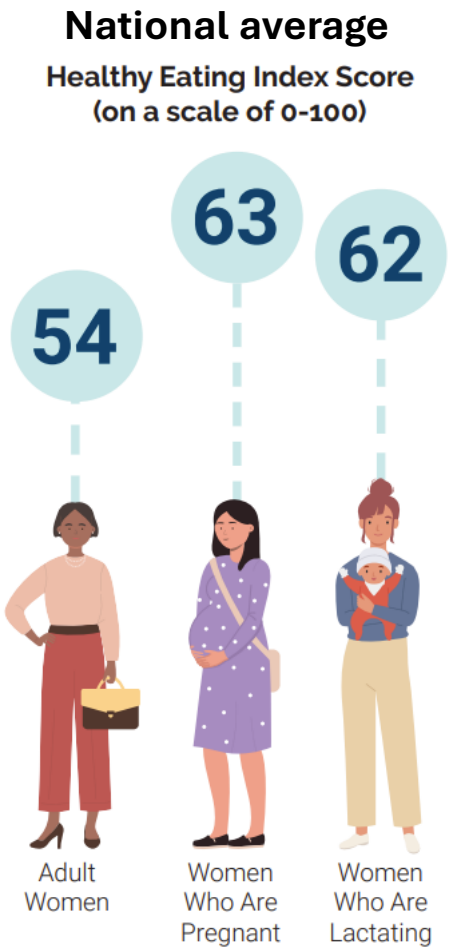
Refined grains

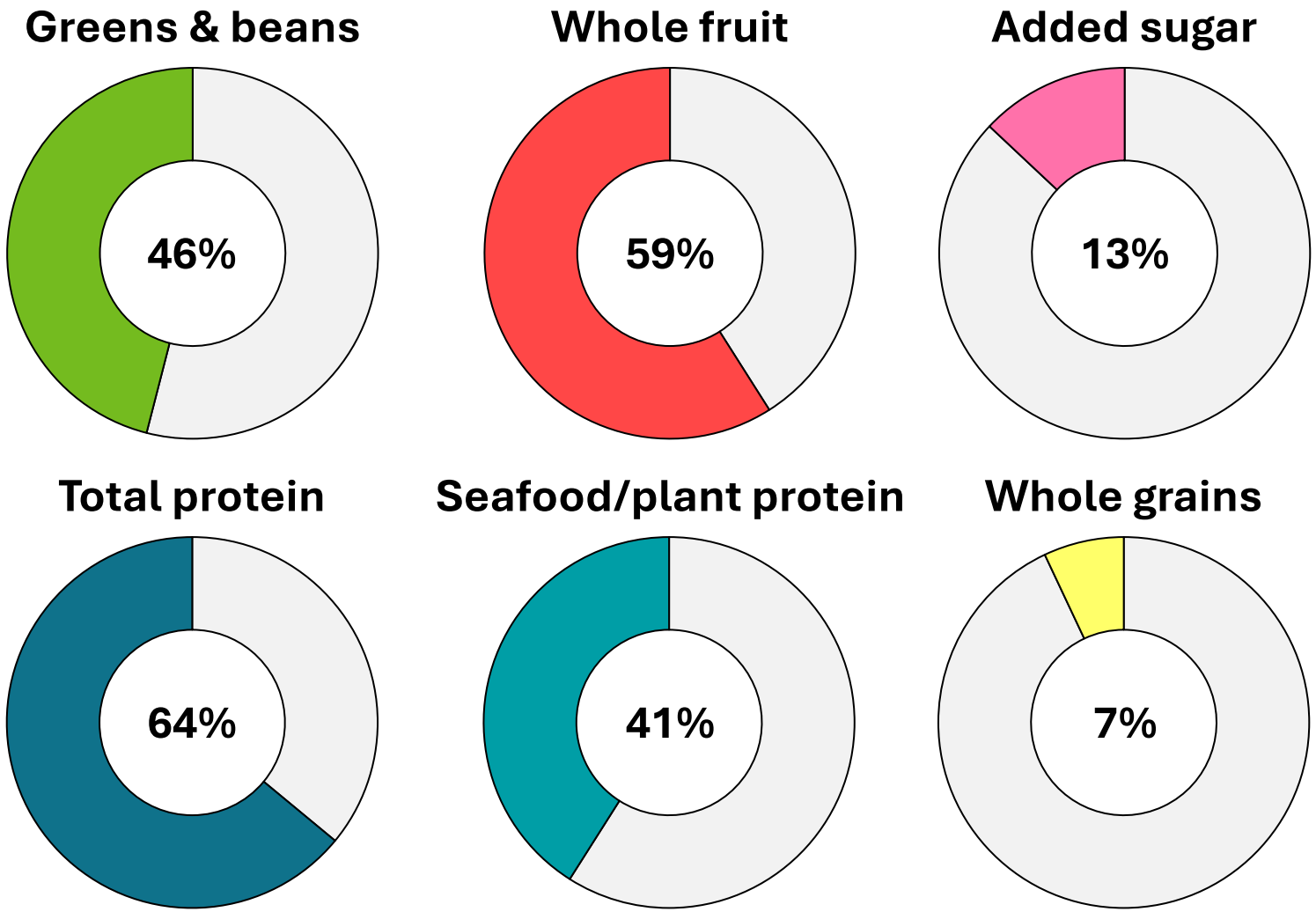
Sodium

Saturated fats

Added sugar

Mean HEI-2015 was 61 points (out of 100) with few women achieving maximum scores for individual components





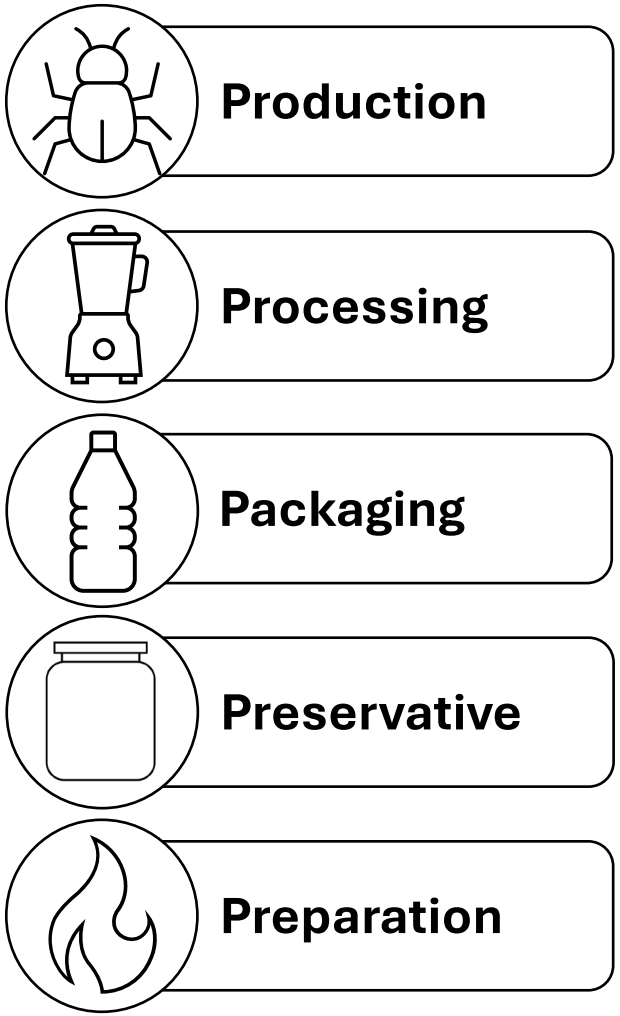
Dietary Guidelines for Americans, 2020-2025 (Chapter 5: Women Who are Pregnant or Lactating)

113 analytes were measured in urines capturing exposure to 10 chemical classes found in foods

Mid-second trimester (median 22 weeks)

One urine per participant

HHEAR Human Health Exposure Analysis Resource



20 insecticides

11 fungicides/herbicides

10 organophosphate esters

5 halogenated phenols

6 benzophenones

14 bisphenols

6 parabens

2 antimicrobials

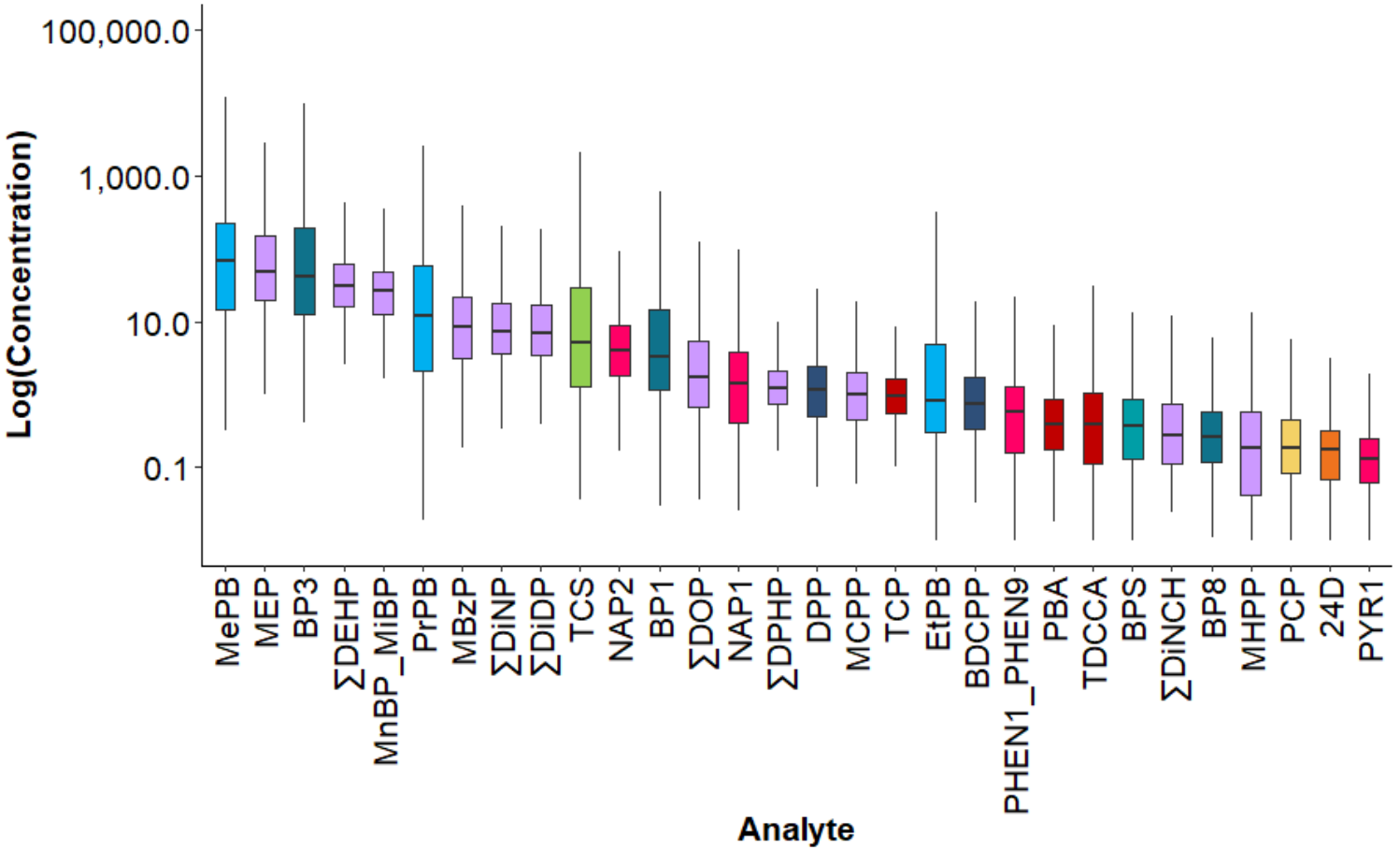
32 phthalates/alternatives

7 PAHs

35 analytes were detected in >70% of pregnant women reflecting widespread exposure to many chemicals

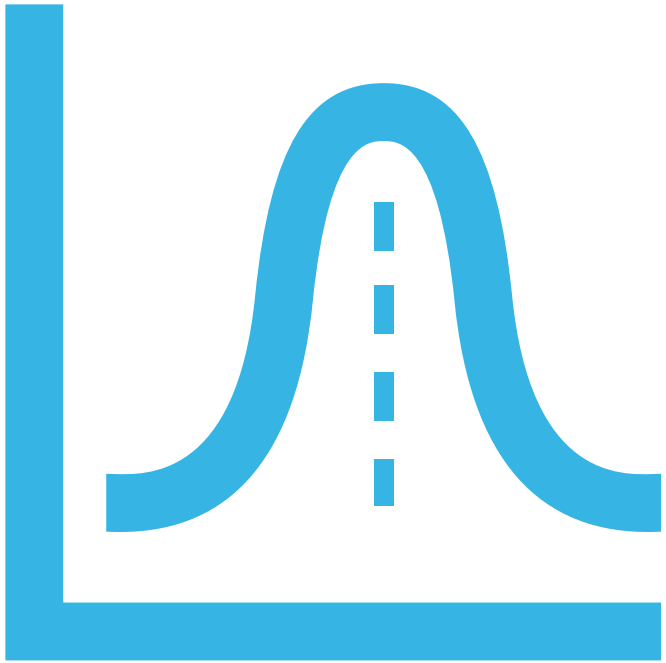
Detected in >70% of women

- 3 insecticides
- 1 fungicides/herbicides
- 2 organophosphate esters
- 1 halogenated phenols
- 3 benzophenones
- 1 bisphenols
- 3 parabens
- 1 antimicrobials
- 16 phthalates/alternatives
- 4 PAHs



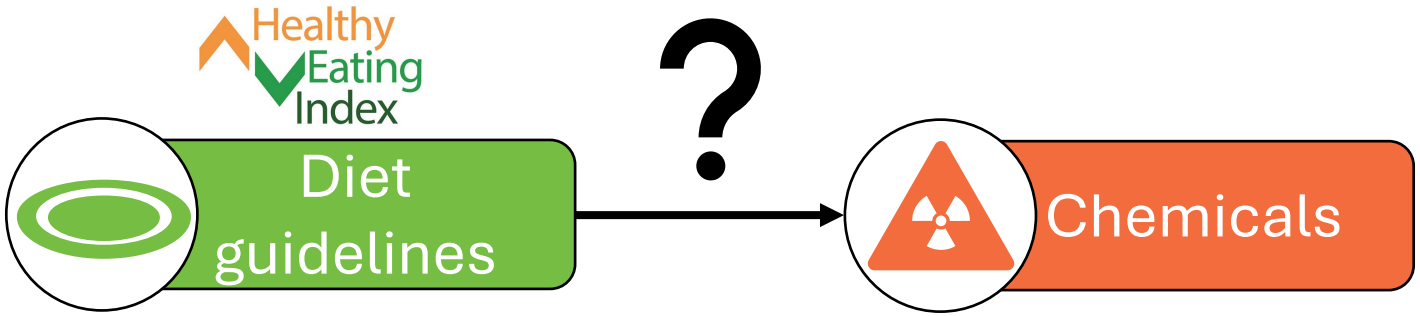
Statistical analysis

- Chemical biomarker levels were urine dilution-adjusted, ln-transformed
- Diet scores were modeled as untransformed, continuous variables
- Missing covariate data were multiply imputed where missing < 20%
  - Covariates: age, education, marital status, pre-pregnancy body mass index, alcohol use, tobacco use, and season of urine collection



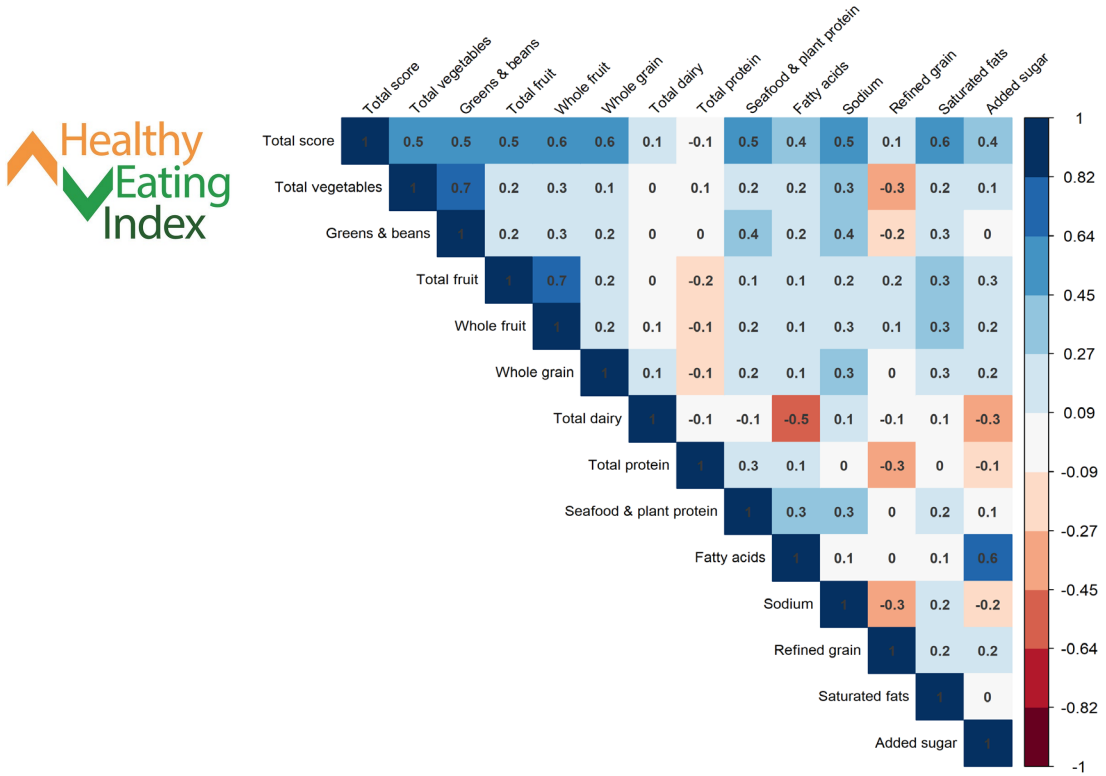
Statistical analysis

1. Is better adherence to the dietary guidelines associated with lower chemical exposures in pregnancy?
   - Bayesian linear mixed effects regression
   - Account for within cohort site clustering, including race/ethnicity and urine collection year

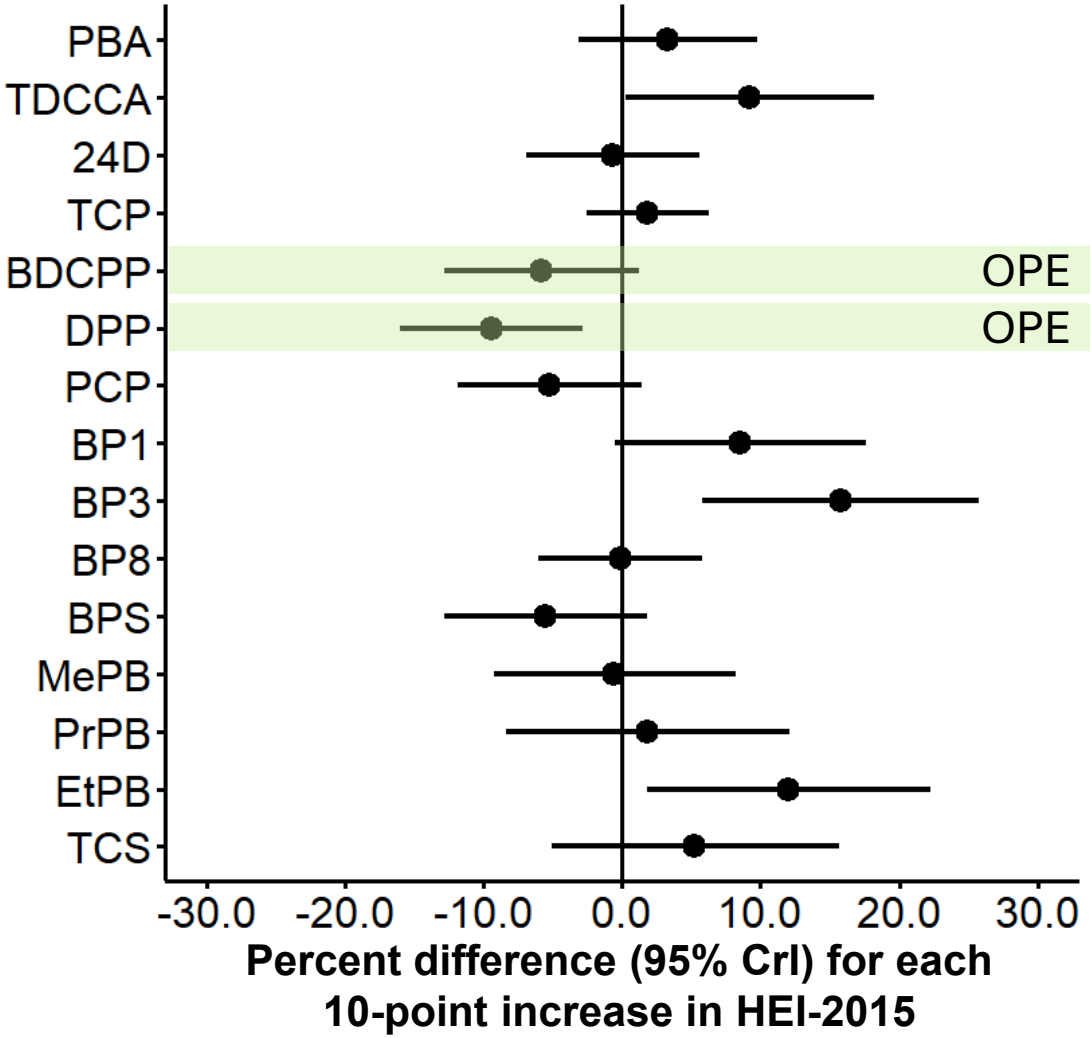


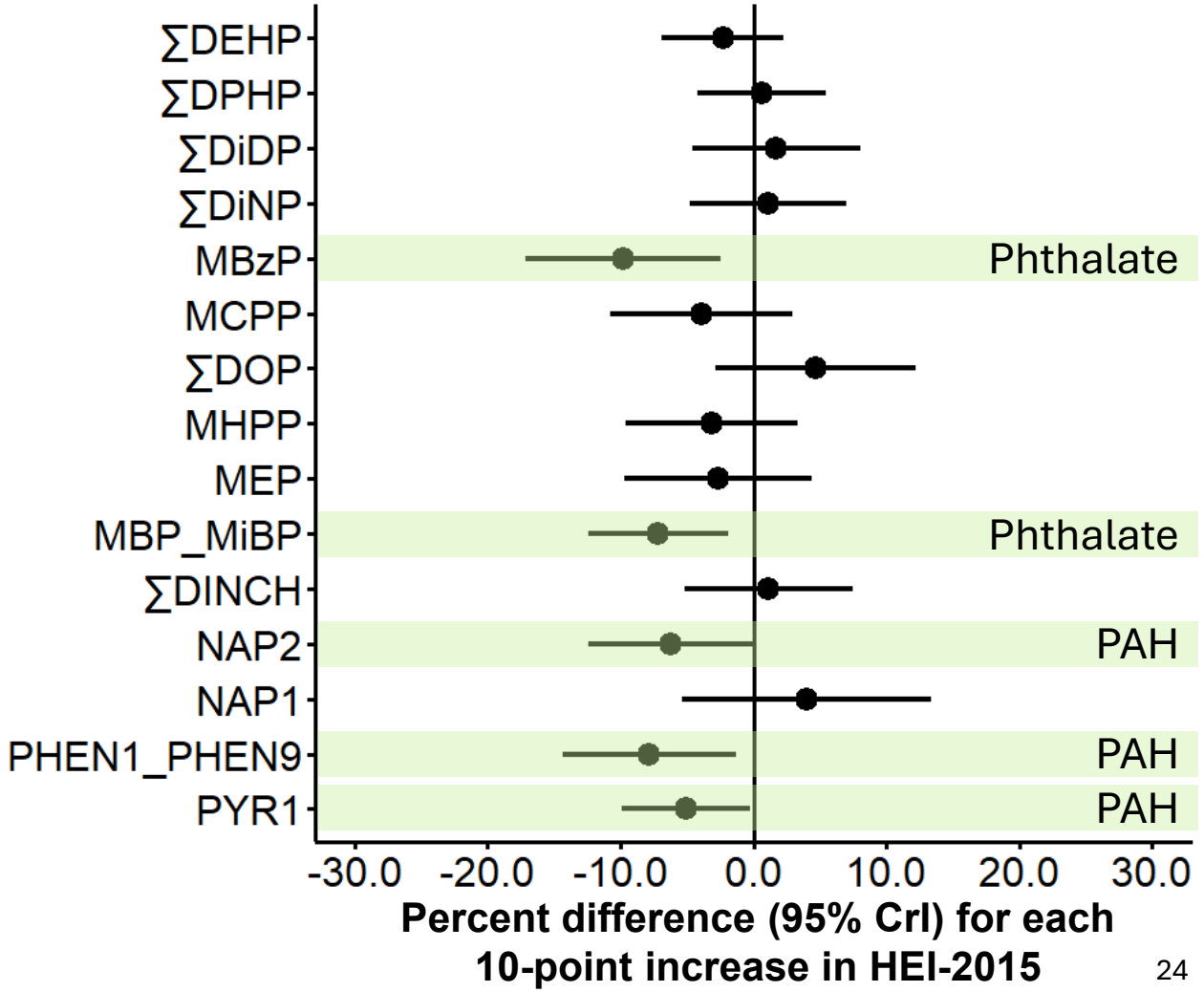
Statistical analysis

2. Which food components within the guidelines drive these associations?
   - Quantile-based g-computation
   - Incorporate multiple correlated HEI components in the same model



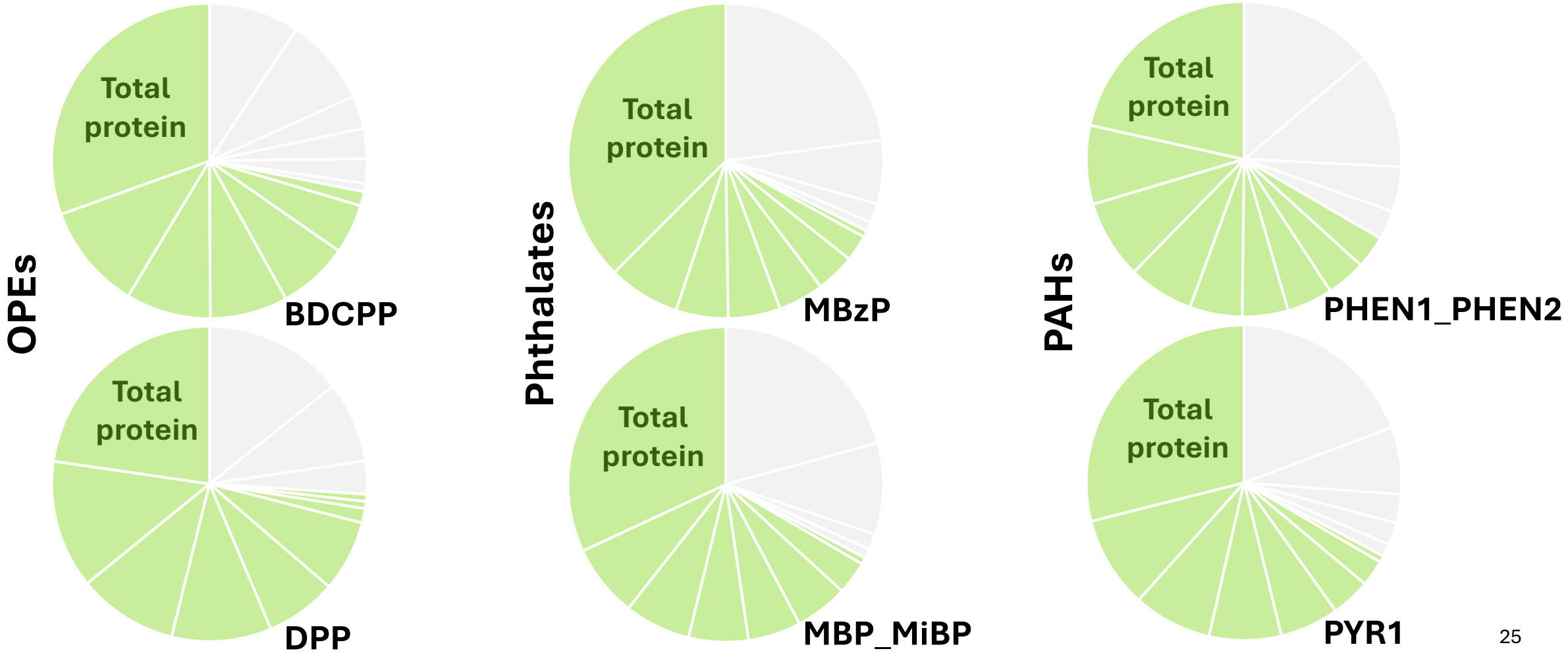
Higher HEI-2015 scores were associated with lower urinary levels of OPEs, phthalates, and PAHs





Inverse associations were consistently driven by higher consumption of total protein

Food components contributing to lower urinary chemical levels



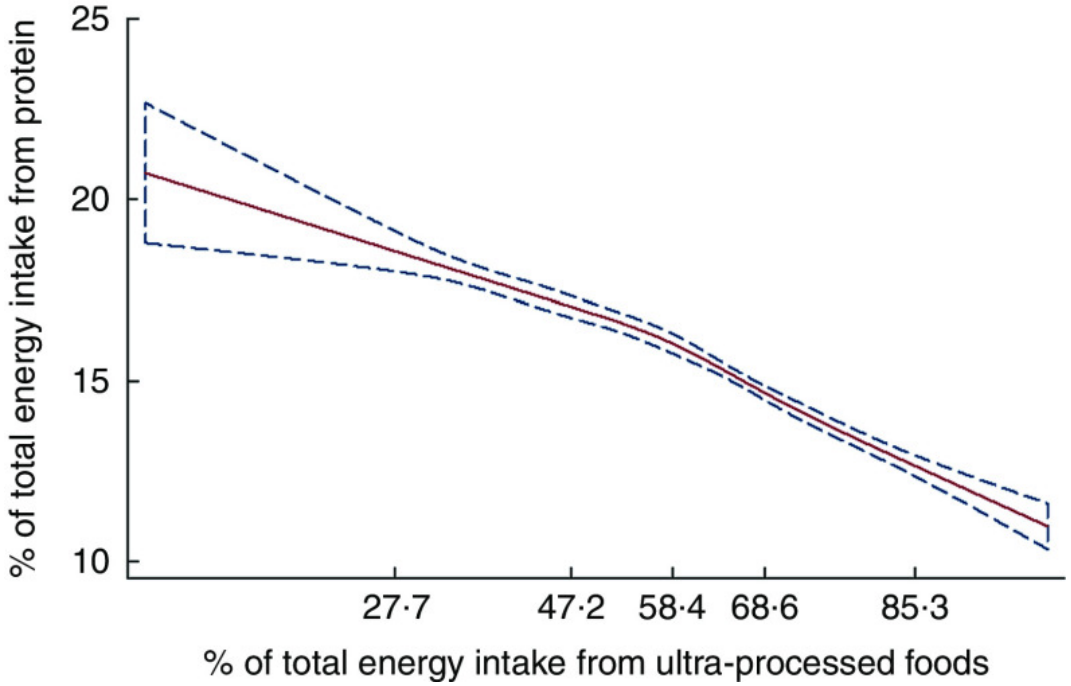
Meeting protein needs may be linked with lower intake of ultra-processed foods that are major sources of chemicals

OPEs, phthalates, & PAHs

Major sources: processed, packaged foods

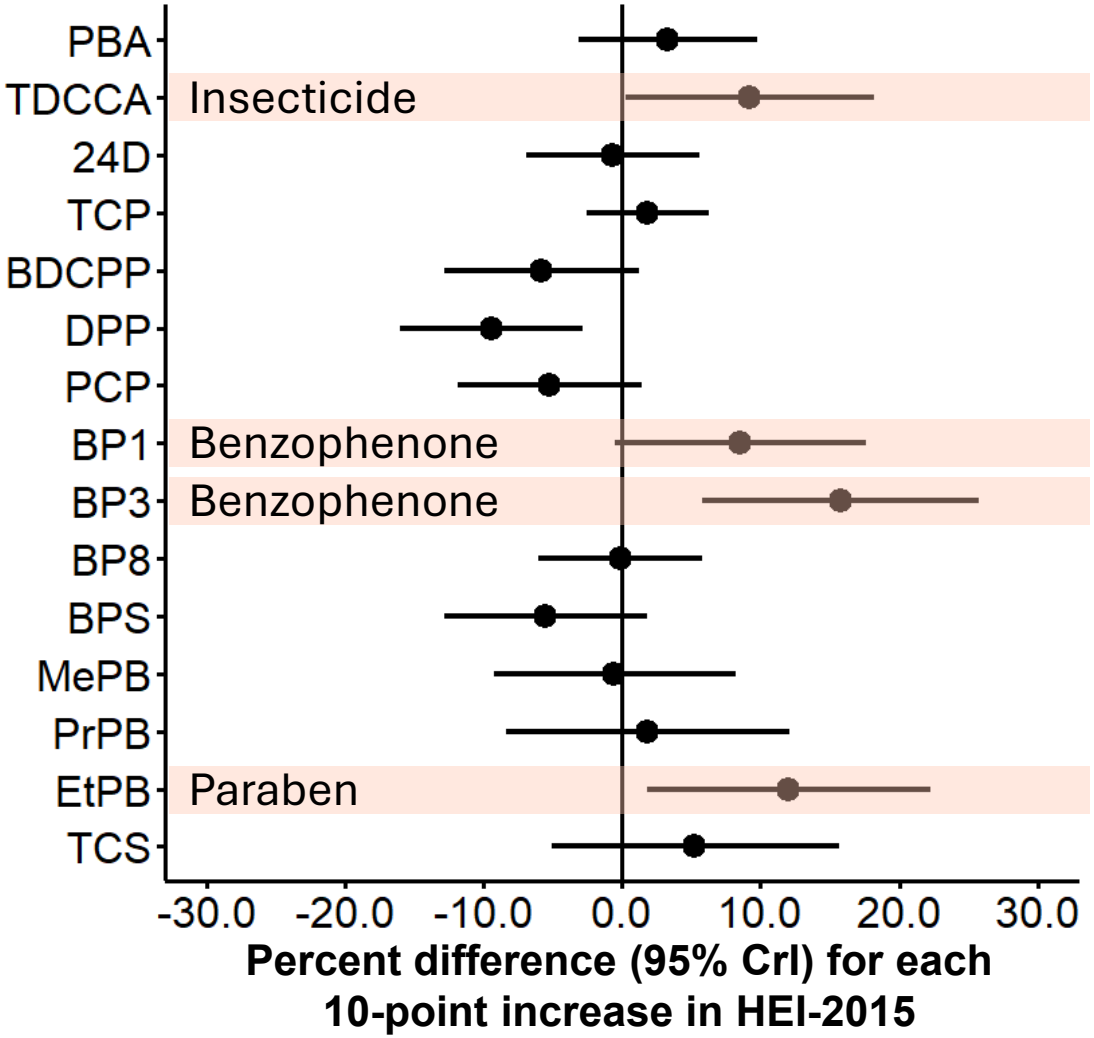
Ultra-processed foods, protein leverage and energy intake in the USA

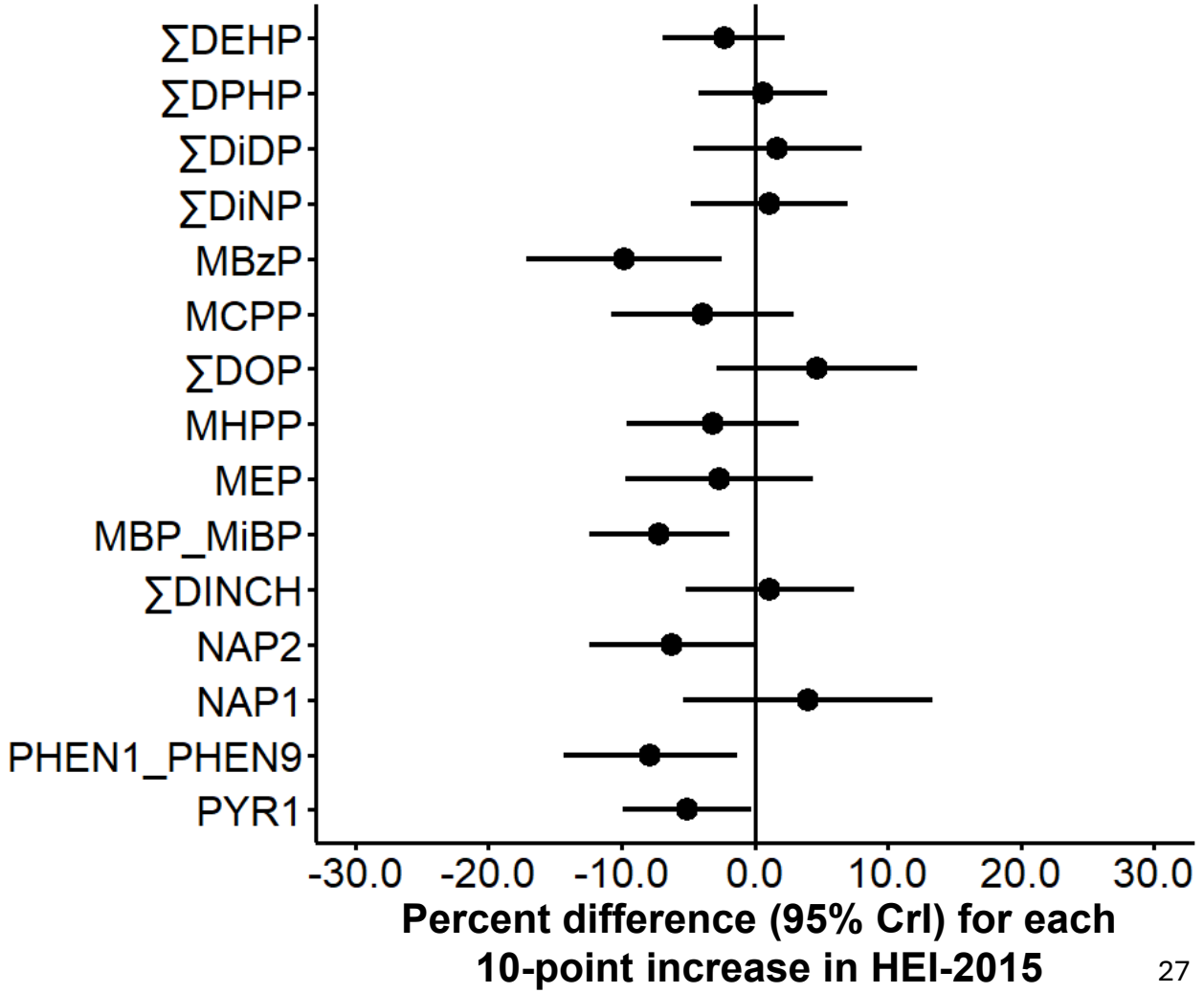
Euridice Martínez Steele[1,2], David Raubenheimer[3], Stephen J Simpson[3], Larissa Galastri Baraldi[1,2] and Carlos A Monteiro[1,2,*]



Kim *et al.*, *Environmental Research*, 2020; Buckley *et al.*, *Environment International*, 2019; Singh *et al.*, *Food Chemistry*, 2016; Image from News Medical Life Sciences.

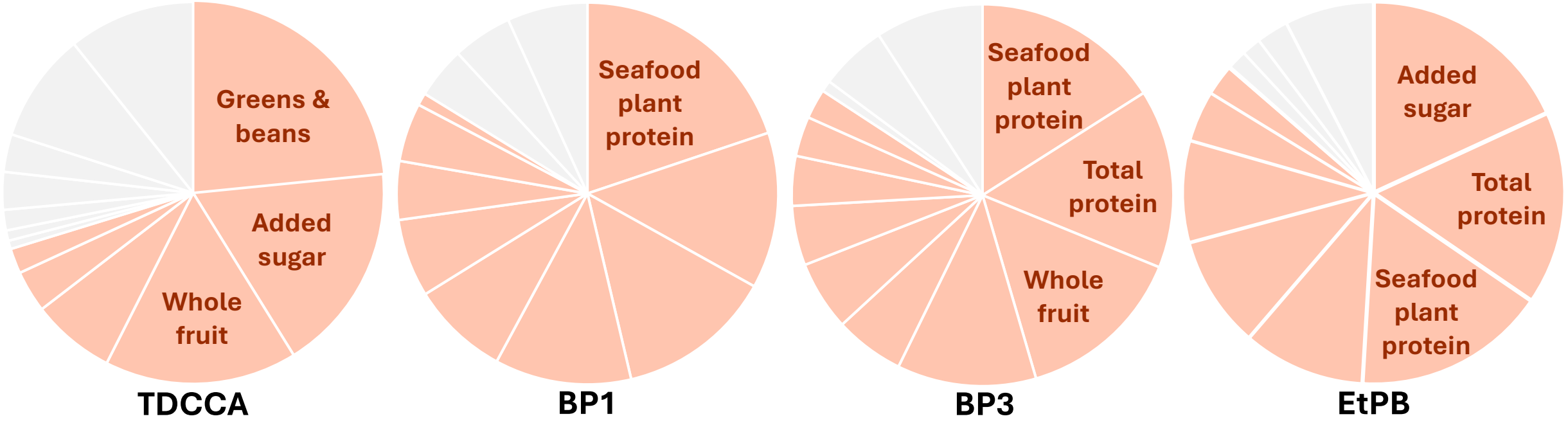
Higher HEI-2015 scores were associated with higher levels of insecticides, benzophenones, and parabens





Top food component contributors to positive associations varied by chemical class

Food components contributing to higher urinary chemical levels



Fresh produce contributes to insecticide exposure, but results with benzophenones and parabens are unexpected

Insecticide

Fresh produce

Benzophenones

Aquatic life, inks?

Paraben

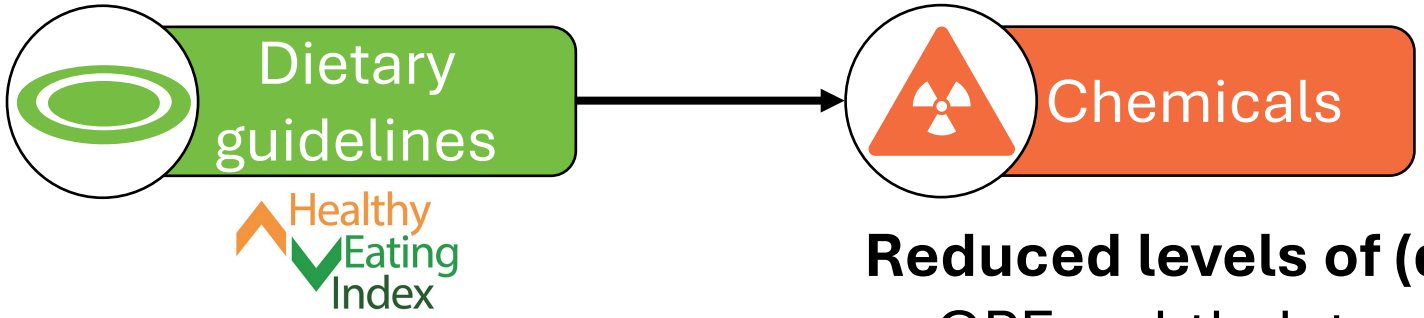
Food preservatives?

Major source: personal care products, cosmetics

Yao *et al.*, *Eco-Environment and Health*, 2024; Liao *et al.*, *Environmental Science & Technology*, 2013; Images from Microsoft 365 Library, Vecteezy, or Adobe Stock.

Summary of major findings

- Adherence to the dietary guidelines supports reduced exposure to some, but not all chemical classes



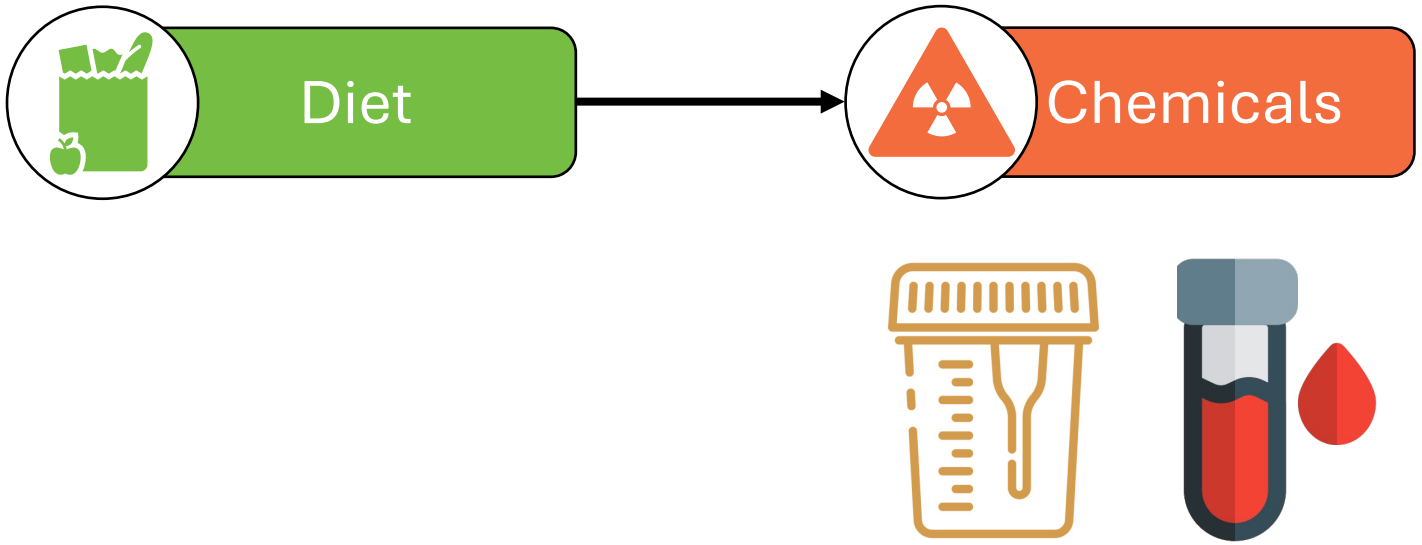
Reduced levels of (driven by total protein):

- OPEs, phthalates, PAHs

Increased levels of (driven by different foods):

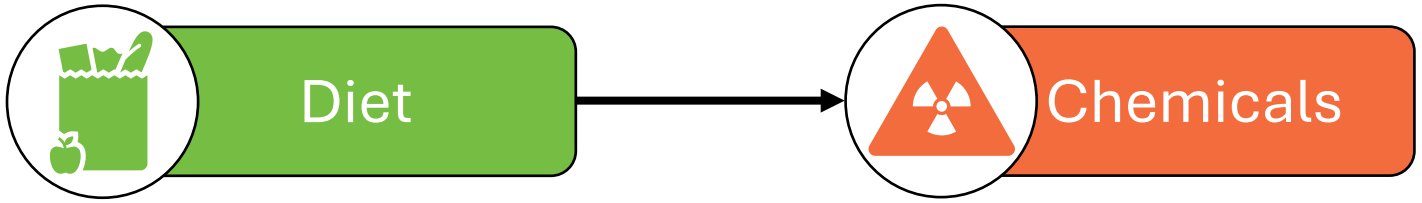
- Insecticides, benzophenones, parabens

Opportunities in ECHO:
Evaluating dietary exposure to other chemical classes



- Per- & polyfluoroalkyl substances
- Melamine and derivates
- Metals
- Organochlorine pesticides
- Polychlorinated biphenyls
- Polybrominated diphenyl ethers

Opportunities in ECHO
Investigating other aspects of diet like ultra-processed foods



Organophosphate esters

Urinary organophosphate ester concentrations in relation to ultra-processed food consumption in the general US population

Hyunju Kim [a], Casey M. Rebholz [a], Eugenia Wong [b], Jessie P. Buckley [a c]

Phthalates, Bisphenols

Ultra-processed food consumption and exposure to phthalates and bisphenols in the US National Health and Nutrition Examination Survey, 2013–2014

Jessie P. Buckley [a b], Hyunju Kim [c], Eugenia Wong [b], Casey M. Rebholz [b]

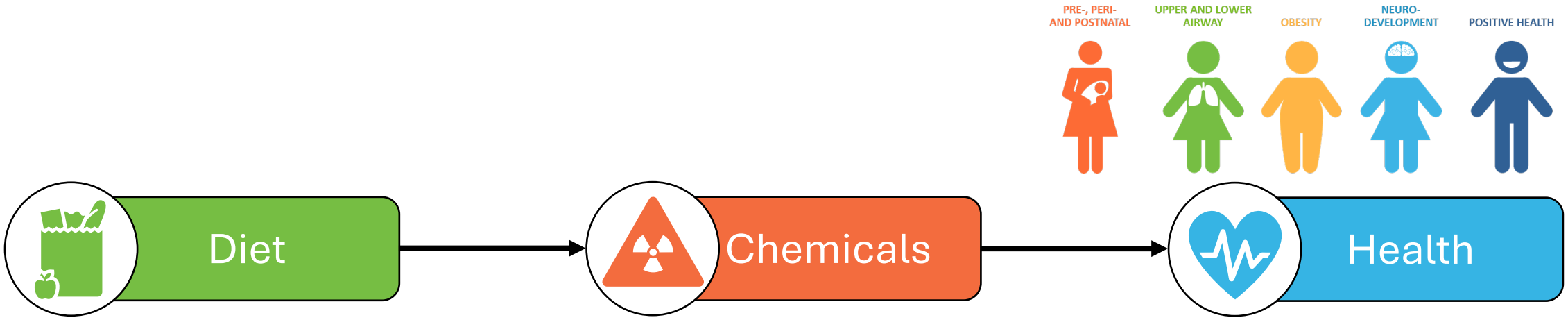
PFAS

Degree of food processing and serum poly- and perfluoroalkyl substance concentrations in the US National Health and Nutrition Examination Survey, 2003–2018

Diana C. Pacyga [a], Jessie P. Buckley [a], Euridice Martinez-Steele [b], Paige A. Bommarito [c], Kelly K. Ferguson [c], Danielle R. Stevens [c]

Image from News Medical Life Sciences

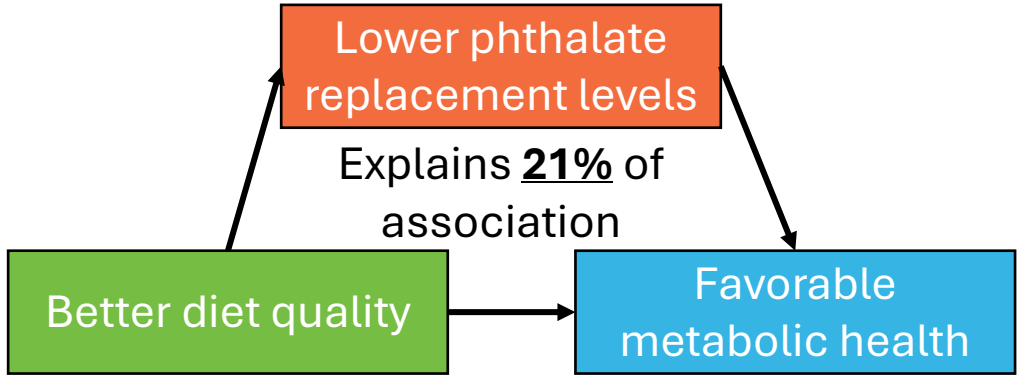
Opportunities in ECHO
Assess the health benefits of reducing chemicals from diet



Phthalates & replacements

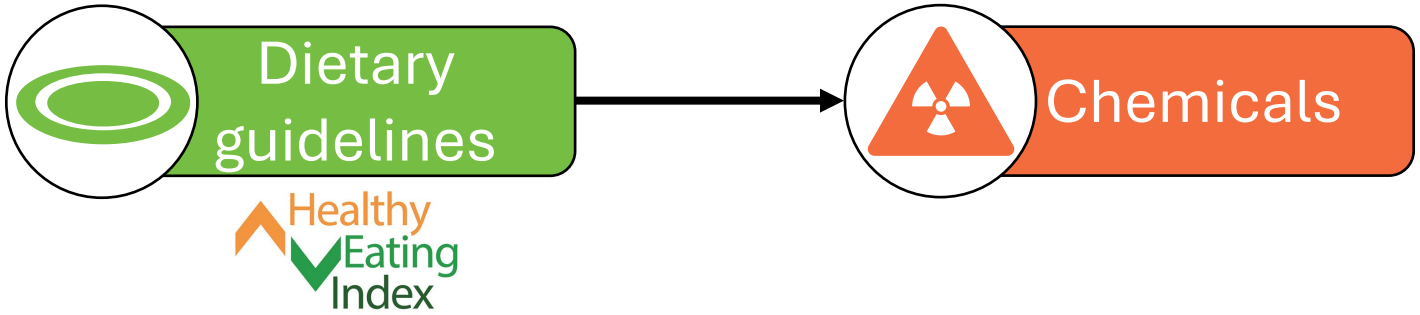
Exploring diet as a source of plasticizers in pregnancy and implications for maternal second-trimester metabolic health

Diana C. Pacyga [a b c], Luca Jolly [d e], Jason Whalen [f], Antonia M. Calafat [g], Joseph M. Braun [h], Susan L. Schantz [i j], Rita S. Strakovsky [a b]



Conclusions

- Adherence to the dietary guidelines supports reduced exposure to some, but not all chemical classes



- May be important to develop comprehensive guidelines that address nutrient needs and limit chemical exposures **OR**
- Reduce known endocrine and metabolic disrupting chemicals from the food supply

Thank you!

Contact me:
Diana Pacyga, pacygadi@unc.edu

Funding acknowledgement:
UNC UNITE T32ES007018