NASEM Webinar: Health Outcomes Associated with Nutrient Intake and Contaminant Exposure in Fish and Seafood

Impact of Nutrients and Contaminants in Human Milk on Growth and Development

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Breastfeeding Recommendations

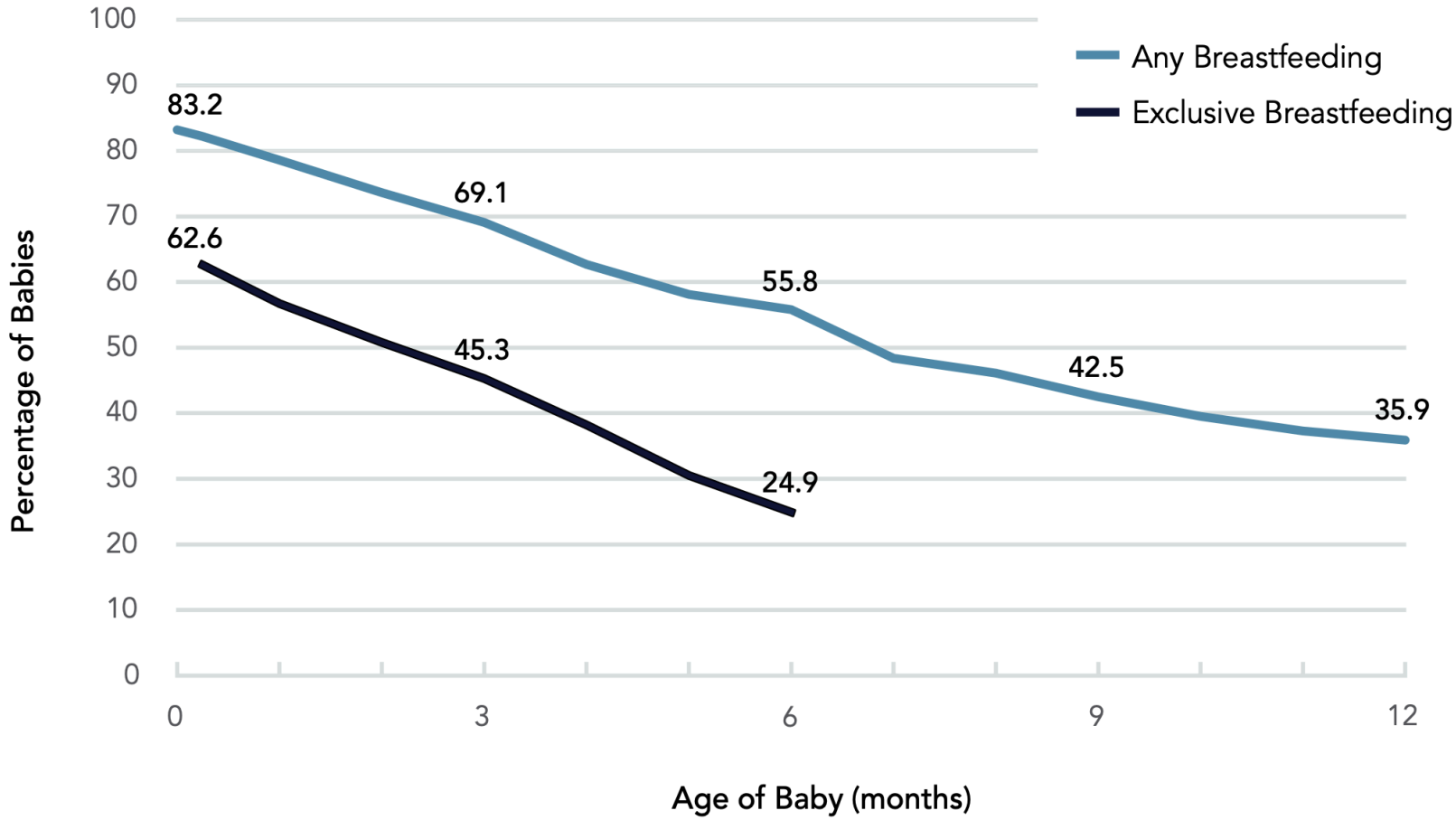
Exclusive breastfeeding for about 6 months, with appropriate complementary foods introduced at about 6 months and continued breastfeeding as long as mutually desired by mother and child for 2 years or beyond.

If 90% of infants fed according to recommendations:

- Reduce maternal deaths
- Reduce infant deaths
- Reduce medical costs by $3 billion per year

Meek JY, Noble L, Section on Breastfeeding. *Pediatrics*. 2022;150(1).
Bartick M et al. *Matern Child Nutr*. 2017 ;13(1):e12366.

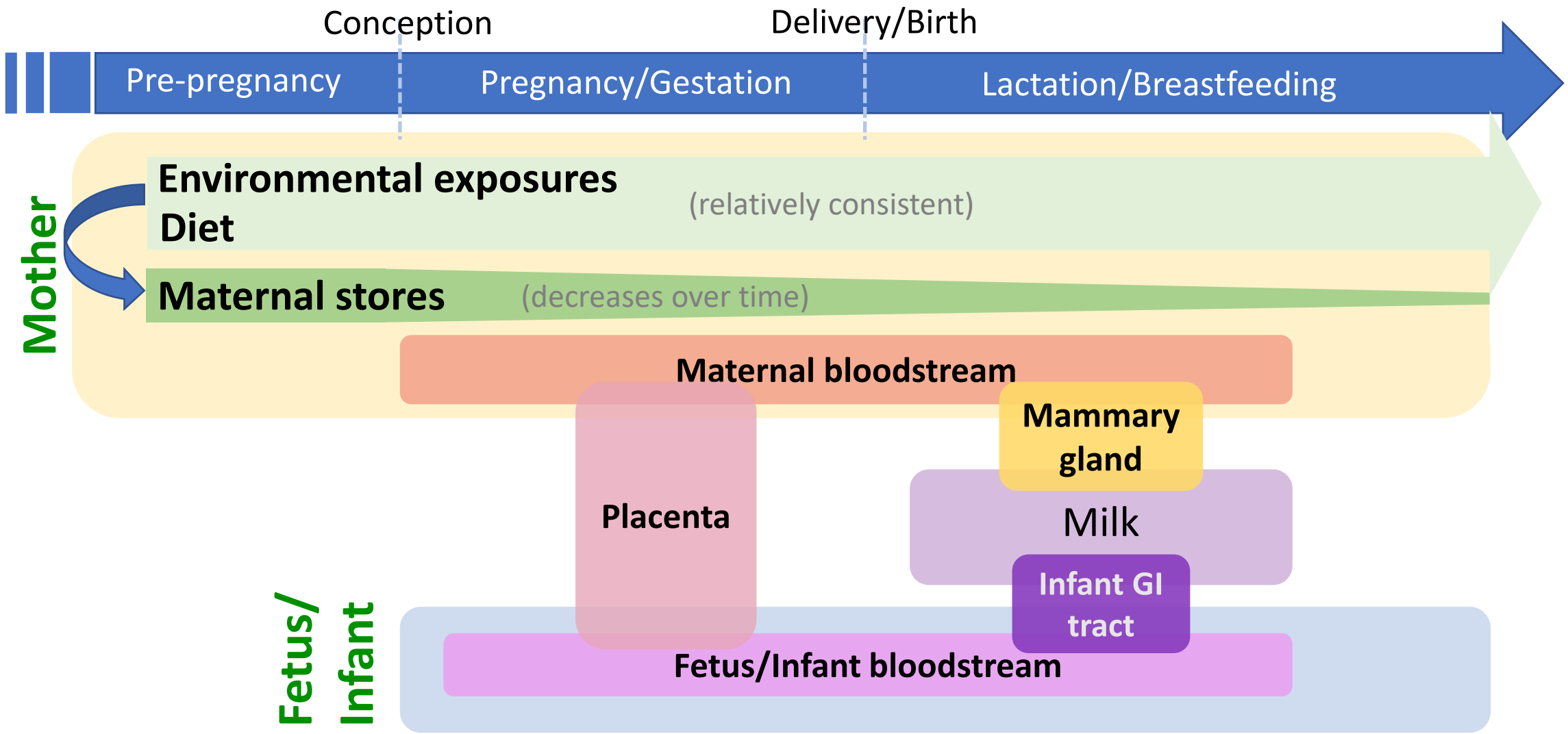
Any and Exclusive Breastfeeding in the US: Children Born in 2019



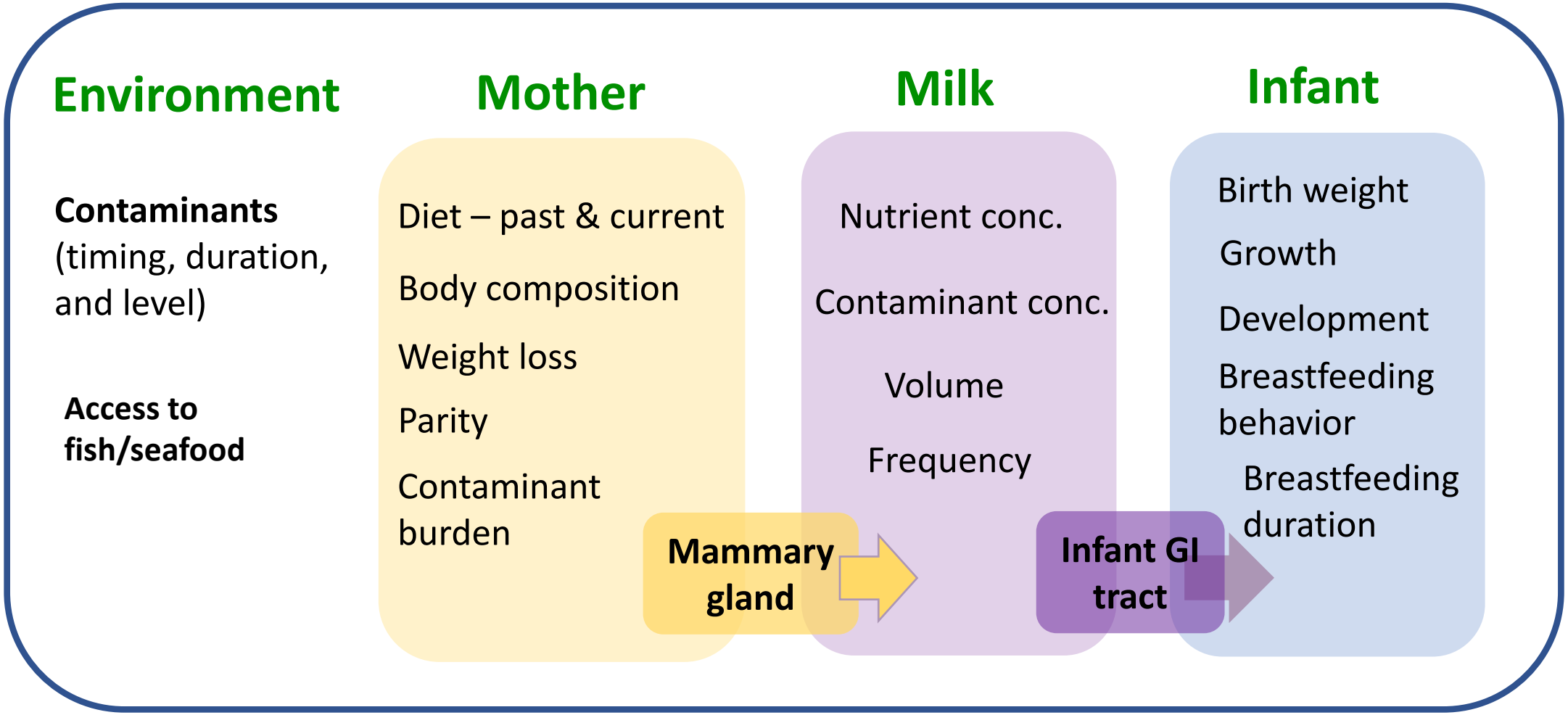
Breastfeeding Report Card, United States 2022. CDC.

Human milk (HM) composition

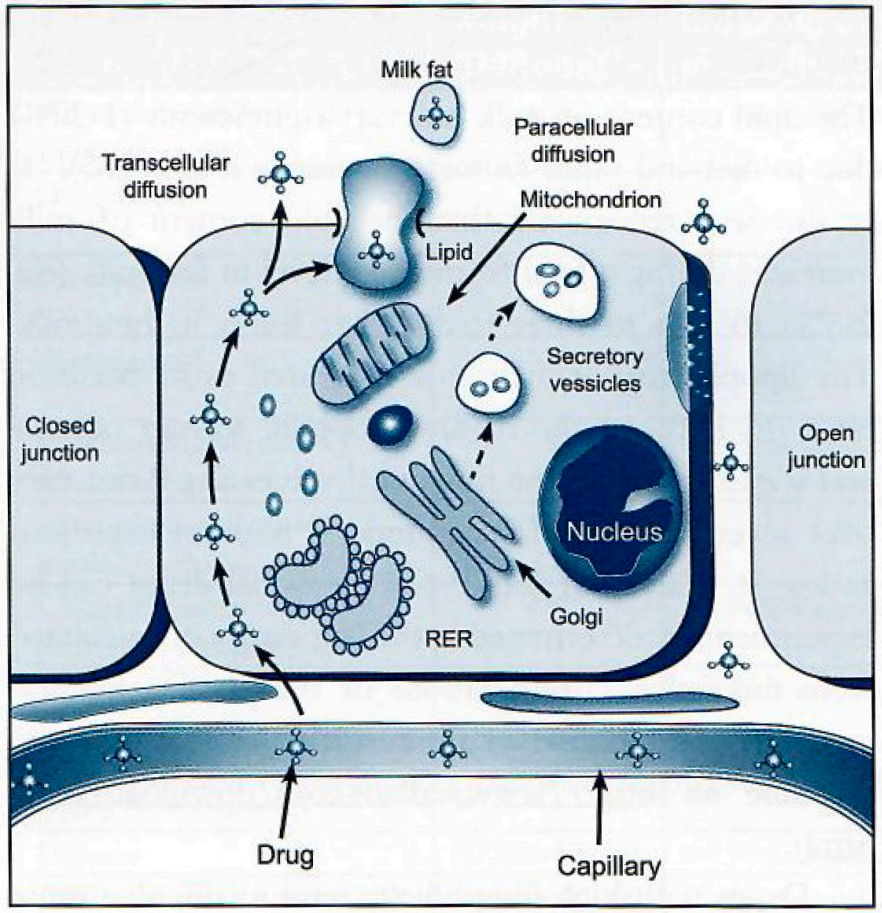
Transfer of substances to fetus/infant



Factors affecting HM content and transfer to infant



Mechanisms of entry into human milk



Hale & Hartmann's Textbook of Human Lactation. 2007.

Sources:

- Synthesized in lactocyte
- Transferred from maternal blood

Mechanisms:

- Paracellular diffusion – especially colostrum
- Passive transcellular diffusion
- Lipid droplets
- Secretory vesicles / exosomes

Affected by:

- Concentration in blood
- Characteristics of compound
  - Half-life
  - Molecular weight
  - Protein-binding

Macronutrient variability in human milk

Macronutrient	Proportion of energy in HM	Affected by Maternal Status	Affected by Maternal Diet	Comments
Carbohydrates	~40-45%	No	No	
Lactose		No	No	Lowest in colostrum
Oligosaccharides		No	No	Highest in colostrum
Proteins	~6%	No	No	Total concentrations similar in well- and undernourished
Amino acids		No	Yes	
Fat/Lipids	~50-55%	Yes	Affects type	Most variable macronutrient
Polyunsaturated FAs		Yes	Yes	
Saturated FAs		Some	Some	Type of FAs affected by maternal diet and BMI
Monounsaturated FAs		Some	Some	
Cholesterol		No	No	

Fats are also where contaminants are stored

Dror & Allen. 2018. *Adv Nutr.*

Docosahexanoic acid (DHA)

DHA crucial during lactation and infancy

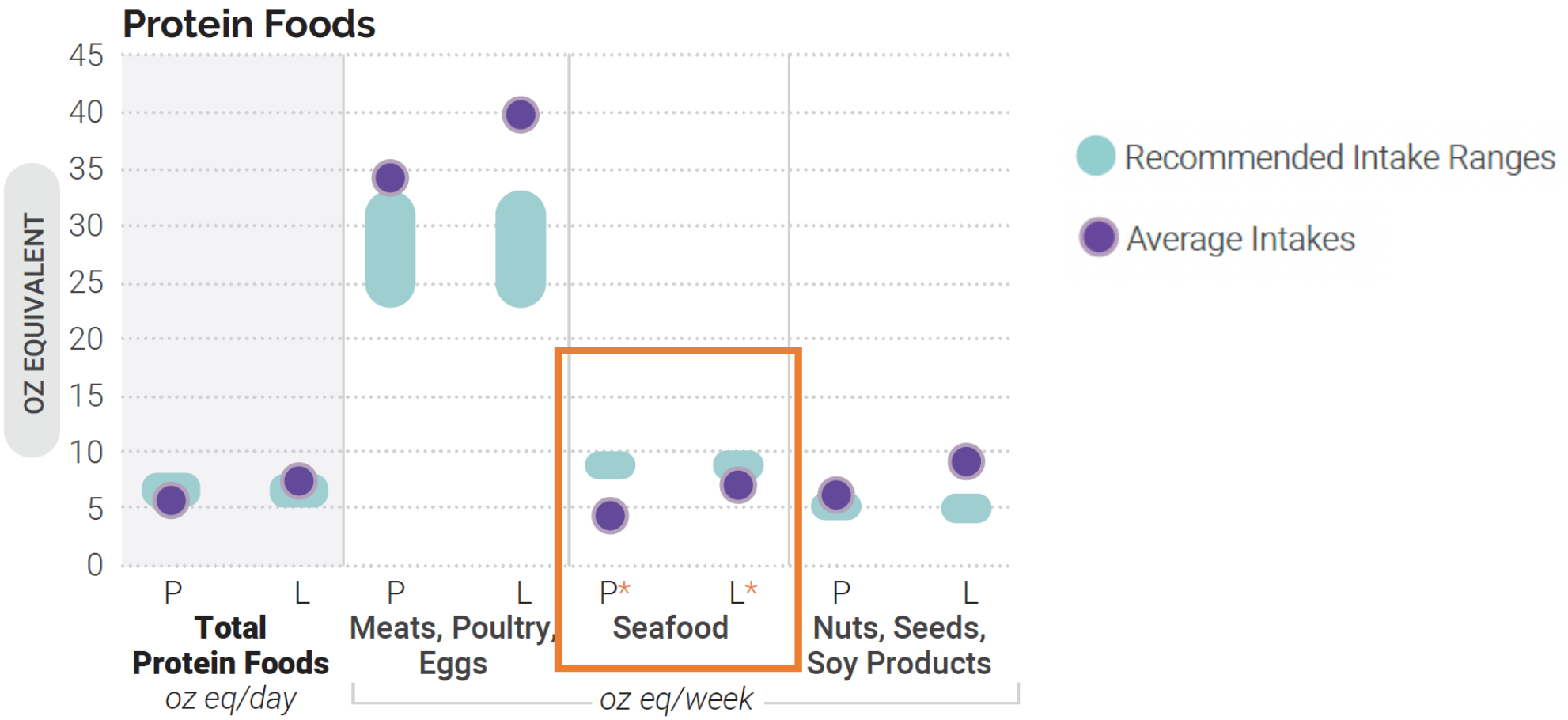
- DHA deposited in brain from late gestation through 1st year
  - Neuronal membrane flexibility
  - Neuronal transmission
  - Neurogenesis and neuronal growth
  - Retina development

Recommendation:

- Dietary Guidelines for Americans recommend lactating women consume 8 and 12 oz of fish per week (low mercury types)

Meldrum S and Simmer K. *Ann Nutr Metab* 2016;69(suppl 1):23-28.; Dietary Guidelines for Americans, 2020-2025.

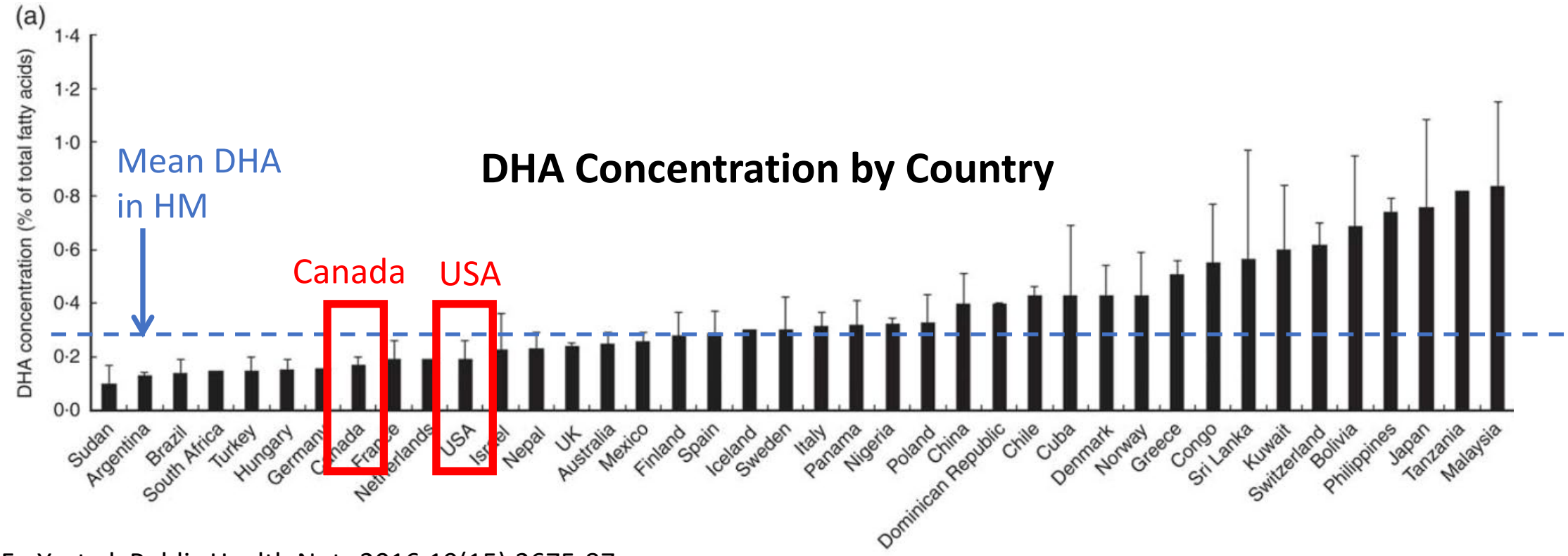
Seafood and fish intake low among pregnant and lactating women in U.S.



Dietary Guidelines for Americans, 2020-2025.

DHA in human milk worldwide

- 78 studies, 3746 individuals, 4163 HM samples
- Mean DHA 0.37 (SD 0.11) % of total fatty acids
- North America region lowest DHA concentrations



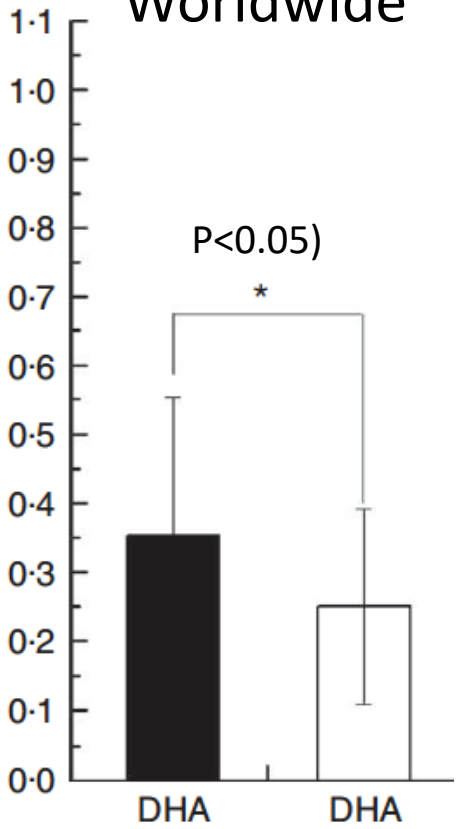
Fu Y, et al. Public Health Nutr 2016;19(15):2675-87.

Breast milk DHA by access to marine foods

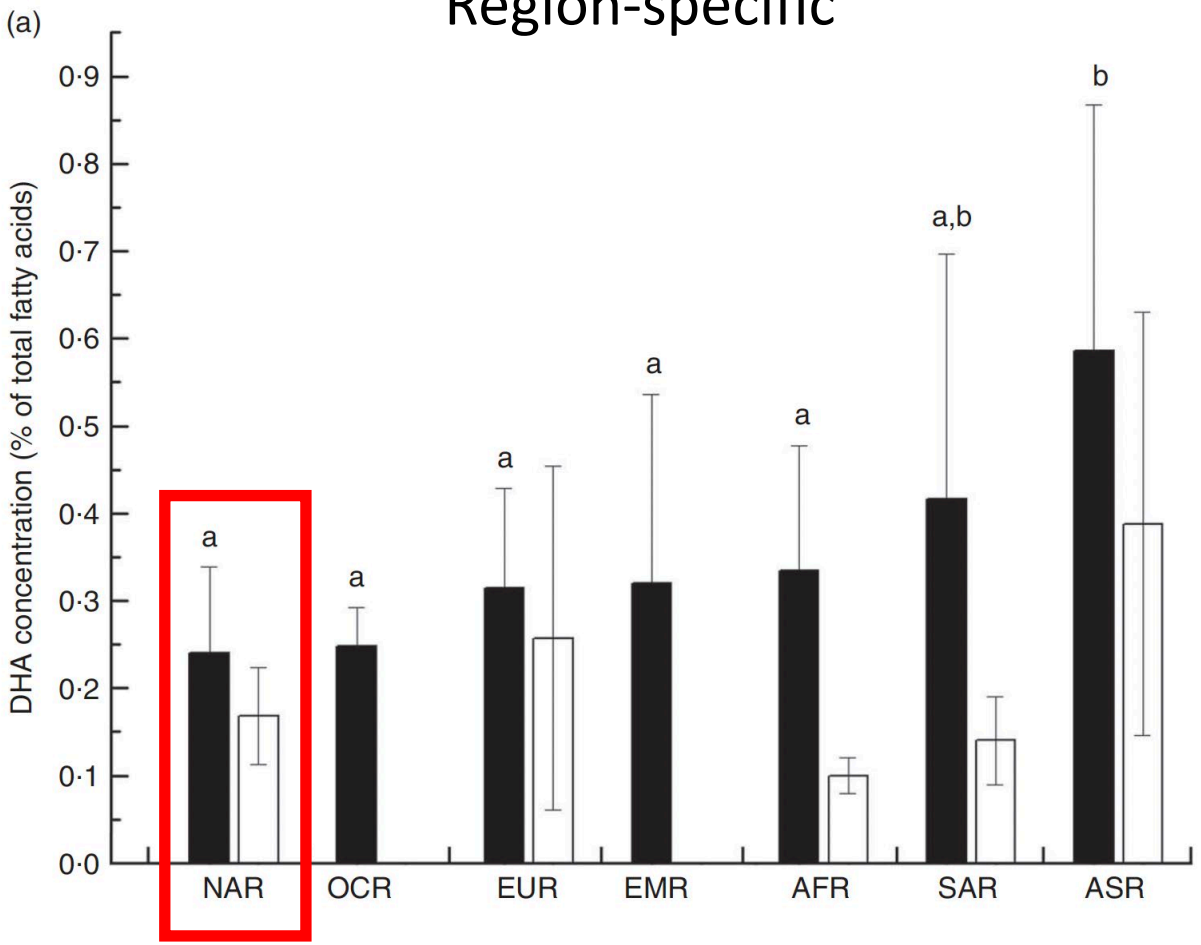
DHA concentrations in HM by access to marine foods

marine access
no marine access

Worldwide



Region-specific



Fu Y, et al. Public Health Nutr 2016;19(15):2675-87.

DHA concentration of human milk

- Fatty acid content of HM variable with diet
- Habitual intake vs current intake
- DHA in HM reported as % total fatty acids
- Total amount of fat in milk varies substantially
- Amount DHA infant receives from HM unclear
- Infant formulas: 0.2% to 0.96% fatty acids as DHA (no beneficial effects or harms of DHA in infant formula)

NASEM. *Scanning for New Evidence on Nutrient Content of Human Milk.* https://doi.org/10.17226/25943.
Bzikowska-Jura A, et al. *Nutrients* 2019;11(7).
Jasani B, et al. *Cochrane Database Syst Rev*. 2017;3(3):Cd000376.

Fish Consumption during Lactation and Infant Growth and Development

Seafood Intake during lactation & infant outcomes

- "All articles assessed maternal seafood intake during pregnancy and no articles assessed seafood exposure during lactation."

- "No evidence is available to determine the relationship between maternal seafood intake during lactation and neurocognitive development in the child. (Grade: Grade not assignable)."

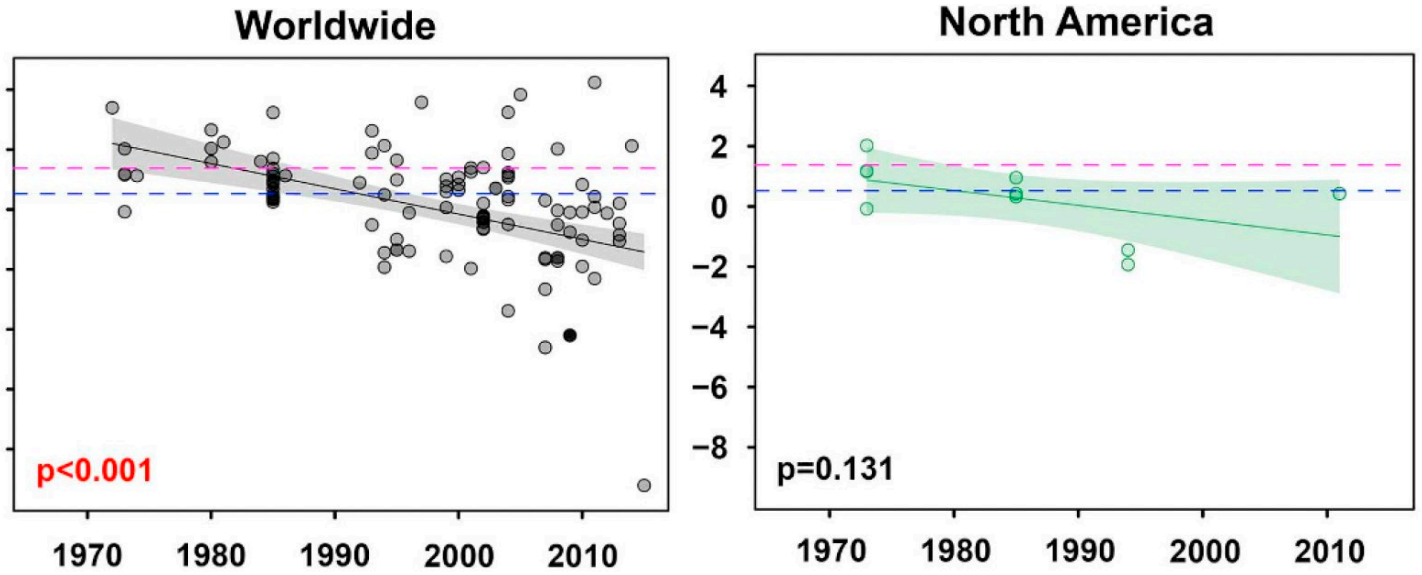
Snetselaar L, et al. *Seafood Consumption during Pregnancy and Lactation and Neurocognitive Development in the Child: A Systematic Review*. July 2020. U.S. Department of Agriculture, Food and Nutrition Service, Center for Nutrition Policy and Promotion, Nutrition Evidence Systematic Review. Available at: https://doi.org/10.52570/NESR.DGAC2020.SR0502

Contaminants in Human Milk

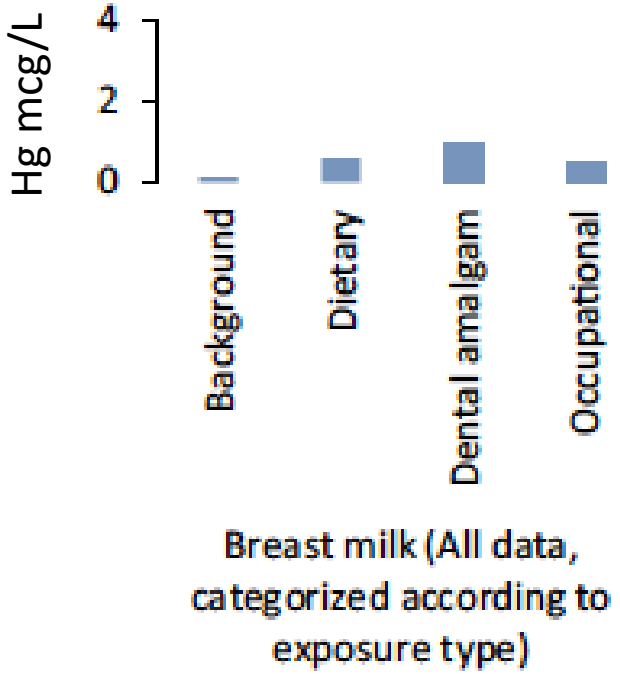
Mercury
PFAS
POPs

Mercury in human milk worldwide

Total mercury concentrations in human milk



HM Hg levels by exposure type



Sharma et al. *Environ Int* 2019;125:300-19.

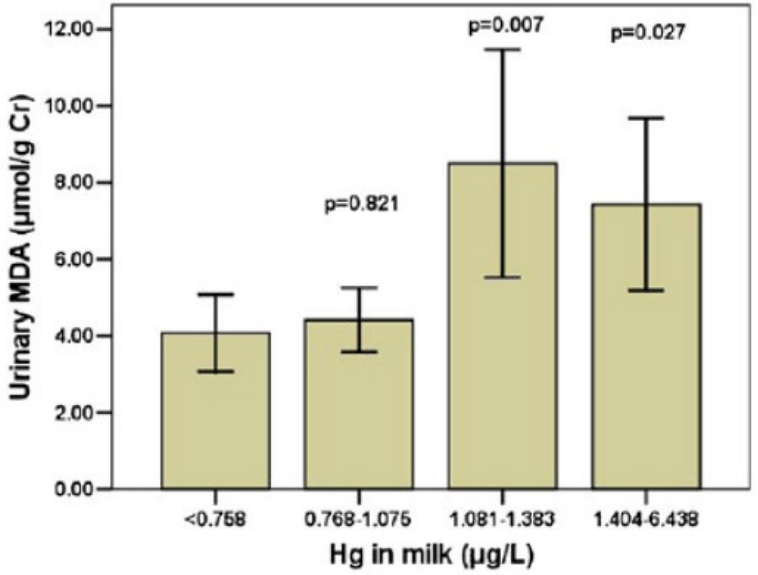
Mercury in human milk – infant development

- No association detected between mercury exposure through human milk and cognitive outcomes in infants
- Italian cohort study
  - n=606 children and their mothers
  - Exposures: Hg in maternal hair, cord blood, breast milk; Fish intake measured by food frequency questionnaire, assessment of 22 fish species
  - Outcome: Bayley Scales of Infant and Toddler Development-III at 18 mo
  - No associations between HM mercury level and infant development
  - No associations between fish intake and development
  - No report of BF exclusivity or duration

Valent et al. J Epidemiol 2013;23(5):360-370.
Sharma et al. *Environ Int* 2019;125:300-19.

Mercury in human milk – oxidative stress

- HM mercury associated with increased oxidative stress biomarkers
- Urinary oxidative stress biomarkers (n=155 mothers + infants, Saudi Arabia)
  - HM mercury associated with infant urinary malondialdehyde
- Biomarkers in HM (n=108, Mexico)
  - HM [Se], [Hg], and fish/shellfish intake all correlated with GST activity
  - No infant data collected



Al-Saleh I, et al. *Biol Trace Elem Res*. 2013;153:145-154.

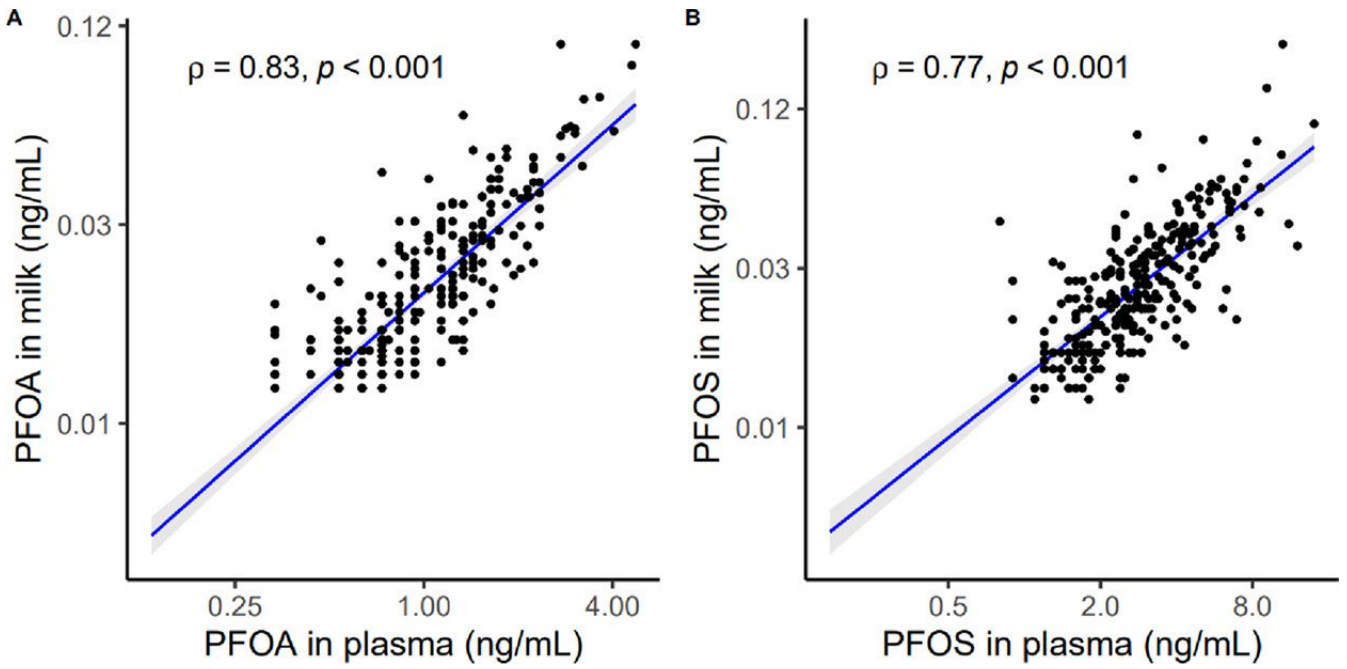
Sharma et al. *Environ Int.* 2019;125:300-19.
Al-Saleh I, et al. *Biol Trace Elem Res*. 2013;153:145-154.
Gaxiola-Robles R, et al. *Nutr Hosp.* 2014;30(2):436-46.

Contaminants in Human Milk

Perfluoroalkyl substances (PFAS)

Plasma and human milk PFAS correlated

- N=294, New Hampshire Birth Cohort
- Maternal plasma 28wk gest
- HM collected at 6 wk postpartum
- Maternal plasma-to-milk ratio
  - 0.02 PFOA
  - 0.01 PFOS
- No data on intake/maternal exposure source



Spearman correlation of PFOA and PFOS between maternal plasma and milk. (n=294)

Criswell RL, et al. *Environ Sci Technol* 2023;57:463-472.

Fish as source of PFAS in human milk

- N=184, birth cohort in Eastern Slovakia
- “Colostrum” samples day 4 or 5 postpartum
- Food frequency questionnaire (96-item) during delivery hospitalization – calculated quantity (g/d) of foods consumed
- Fresh/frozen fish consumption strongest predictor

Multivariable determinants of ”colostrum” PFOS and PFOA

Determinant	PFOS % change (pg/mL)	*P*-value	PFOA % change (pg/mL)	*P*-value
Parous	-39.8	0.002	-40.4	-40.4
Birth interval >18mo	39.4	0.04	41.6	41.6
Fresh/frozen fish consumption (per 50g/d)	100.6	0.001	54.9	54.9
Birthweight (per 100g)	-2.3	0.02	--	
Fresh fruit/veg (100 g/d)	-4.7	0.02	--	

Jusko TA, et al. *Environ Sci Technol* 2016;50(13):7152-7162.

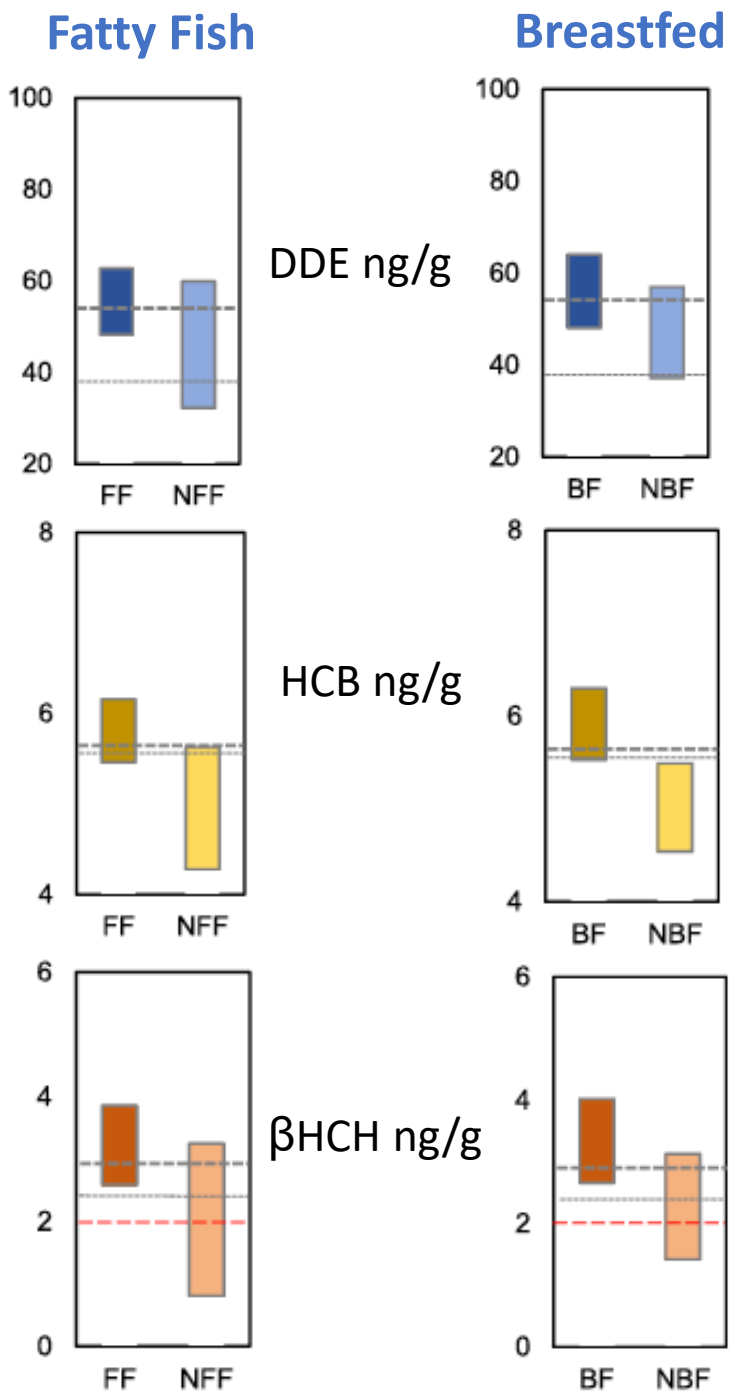
Contaminants in Human Milk

Persistent Organic Pollutants (POPs)

Fish intake and POPs in HM

- N=206, primiparous mothers in Belgium
- HM samples 3 to 8 weeks postpartum
- Diet assessed by “structured questionnaire”
- Maternal age and BMI associated with higher POPs
- Fatty fish major determinant of HM POP concentration
- Mother’s receipt of HM as infant determinant of HM POP concentration

Contaminant burden from infancy resulted in higher contaminants in own breast milk

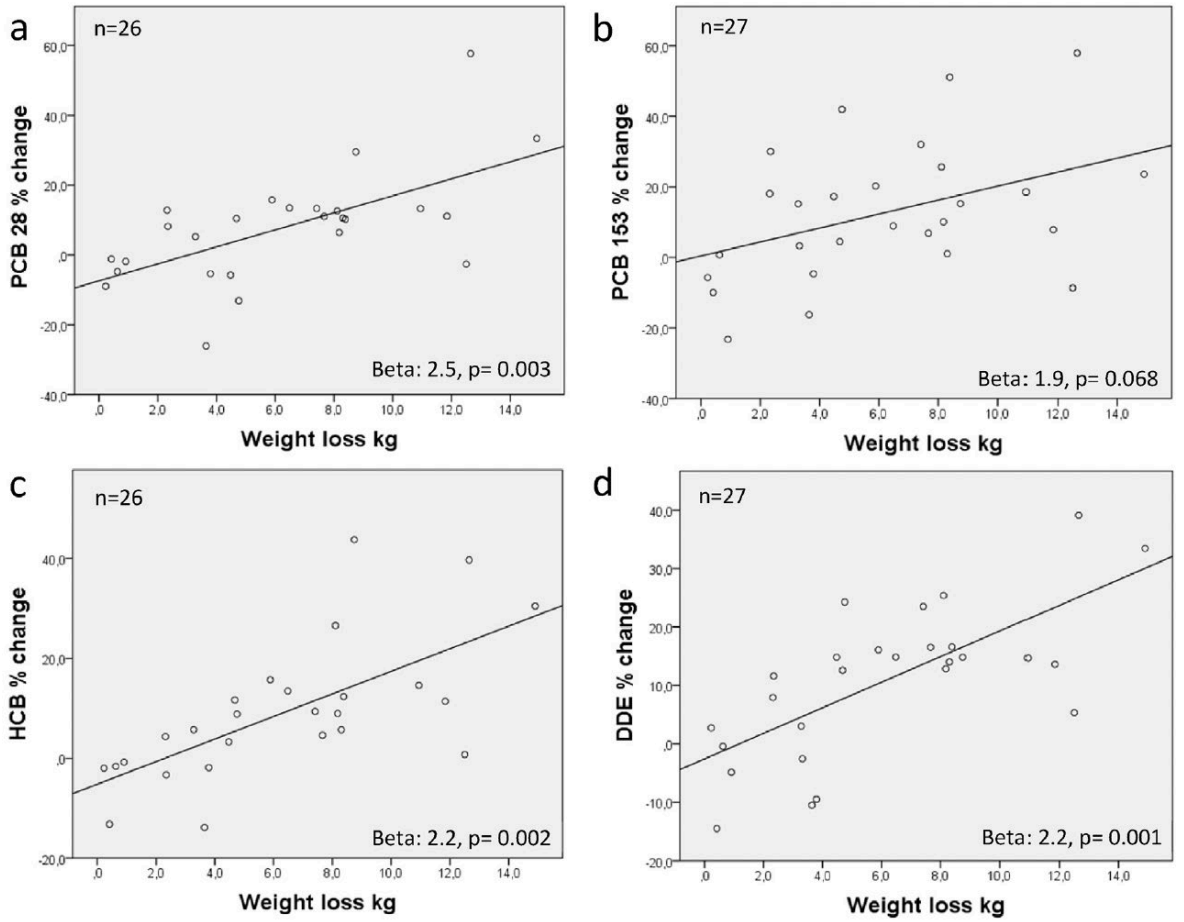


Aerts R, et al. *Environ Int* 2019;131:104979.

Maternal weight loss impacts POPs in HM

- N=32, Postpartum weight loss trial in Sweden (LEVA)
- Baseline 12 wk, follow-up 24 wk
- Milk samples analyzed for POPs
- Infant HM intake estimated
- POPs in HM increased 2-2.4% per percent maternal weight loss
- Absolute intake remained stable
- Intake per kg body weight decreased 17-22%

Weight loss and percent change in POP concentration in HM



Lignell S, et al. *Chemosphere* 2016;159:96-102.

Maternal weight loss impacts POPs in HM

Increased

Decreased

Substance	n	Change in concentration from ~12wk to ~24wk (ng/g lipid)	*P*-value
Women who lost weight			
PCB 28	26	0.05 ± 0.16	0.168
PCB 153	27	3.2 ± 6.9	0.043
HCB	26	0.72 ± 1.1	0.117
DDE	27	7.8 ± 20	0.057
Women who did not lose weight			
PCB 28	5	-0.11 ± 0.10	0.060
PCB 153	5	-2.8 ± 2.5	0.066
HCB	5	-1.1 ± 0.93	0.056
DDE	5	-7.5 ± 5.7	0.025

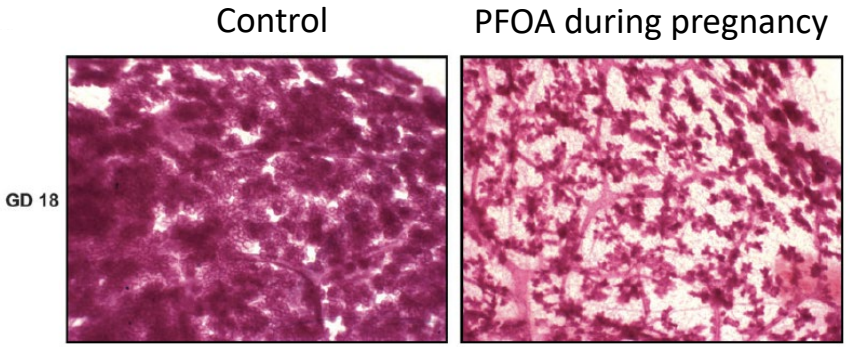
Lignell S, et al. *Chemosphere* 2016;159:96-102.

Impact of Contaminants in HM on development and growth

NO DATA

Contaminants affect lactation

- Epidemiologic evidence:
  - PFAS associated with shorter breastfeeding duration
  - DDT associated with shorter breastfeeding duration
  - PCBs – mixed evidence
  - Phthalates – mixed evidence
- Animal studies:
  - PFOA: impaired mammary gland development, altered milk protein gene expression
  - BPA: accelerated mammary gland development, reduced protein synthesis and milk yield

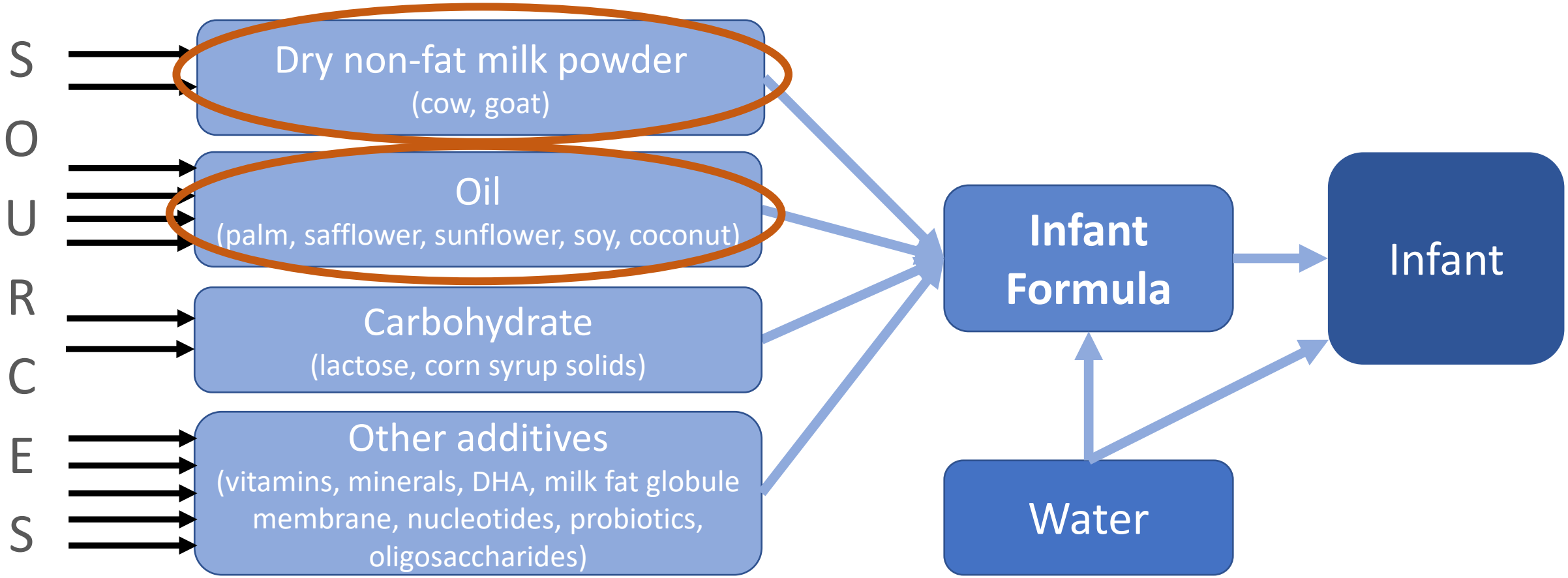


White SS, et al. *Toxicol Sci.* 2007;96(1):133-44.

Criswell R, et al. *Curr Opin Endocrinol Diabetes Obes.* 2020;27(6):388-395.

Infant Formula exposure to contaminants

Screening for PFAS and POPs not required



Dabeka RW, McKenzie AD. *Food Addit Contam Part B Surveill*. 2012;5(1):65-9.

Human milk composition and contaminants

Summarizing the research

Research Gaps

- Infant outcomes frequently not collected
- Limited data on nutrients other than DHA from fish/seafood in HM
- Design
  - Single HM sample typically collected / analyzed
  - Lack measurements of maternal plasma, HM, and infant plasma
  - Few longitudinal designs
- Execution
  - Maternal diet frequently not reported or adequately reported
  - HM concentrations reported with no context of volume consumed, or duration of breastfeeding
- Populations studied
  - Few studies in U.S. or Canada

Conclusions

- Both concentration and volume of HM needed to estimate exposure
- DHA in human milk clearly linked to fish/seafood consumption
- Lack data on other nutrients from fish/seafood in HM
- Most contaminants not assessed in diet
- Contaminants may negatively affect ability to breastfeed
- Lack data on infant outcomes from exposure through HM

- Consuming no fish does not eliminate contaminant risk
- Substantial risks associated with not breastfeeding

Thank you!

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