

BIOGRAPHICAL SKETCH

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NAME: Nancy F. Krebs

eRA COMMONS USER NAME (credential, e.g., agency login): KREBS.N

POSITION TITLE: Professor of Pediatrics

EDUCATION/TRAINING (*Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.*)

INSTITUTION AND LOCATION	DEGREE	Completion Date	FIELD OF STUDY
Iowa State University, Ames, IA	BS w/ honors	05/1973	Family Environment
University of Maryland, College Park, MD	MS	12/1979	Nutrition Science
University of Colorado School of Medicine	MD w/ honors	05/1987	Medicine
University of Colorado School of Medicine	Internship & Residency	06/1990	Pediatrics
University of Colorado School of Medicine	Fellowship	06/1993	Pediatr GI & Nutr

A. PERSONAL STATEMENT

My primary research interests have extended from detailed metabolic studies employing stable isotope methodologies across the life cycle, to large scale RCT of supplements and/or food-based interventions. The focus of these studies has been to define dietary **micronutrient requirements** and to characterize homeostasis, including metabolic regulation and **adaptation to different diets and physiologic states**, in normal infants, in healthy adults, and in pregnant and lactating women. I have extensive experience directing intervention trials to monitor and evaluate growth and development in infants and toddlers. I direct the ongoing ancillary analyses of the **preconception maternal nutrition intervention** trial ("Women First," WF) conducted in 4 low resource countries. Outcomes include those of public health interest plus extensive maternal (and infant) phenotyping, e.g. metabolomics, microbiome and epigenetic profiles. My research laboratory extensively employs mass spectrometry (ICP-MS) to measure **stable isotope tracers and multi-element mineral analyses** in biological and food samples, and we conduct multiple ELISA's for biomarkers of nutritional status.

Since our first investigation in 2013 of the effects of different **complementary foods** on infants' **microbiota** profile, I have collaborated on multiple RCT in infants and young children. Investigations in Denver over the past two decades have documented the impact of maternal phenotype (including **obesity**) on human milk composition and production, infant nutrient intakes, growth and body composition. Past and current interventions reflect extensive collaborations among the investigators on the current NORC application and include modifications of types of complementary foods to evaluate effects on growth, adiposity, nutritional status, microbiome, and sleep.

On the basis of the **food-specific compounds** (FSC) identified in the Metabolomics of Foods R01, I led the design of the small clinical trial to prospectively evaluate detection of FSC in foods, and in participants' biospecimens (timing corresponding to consumption) and to link these to health indicators. A complementary clinical trial examined effects of salmon consumption on inflammation in pre-diabetic adult participants.

My program has emerging interest in mitigation of the adverse effects of **heat stress in pregnancy**, emanating directly from secondary analyses from the WF trial. We reported striking findings from the WF Pakistan site of the adverse impact of heat stress on fetal growth and placental gene expression, effects that were lessened in women randomized to the preconception nutrition arm. Additionally, unpublished preliminary

analyses link high ambient temperatures in pregnancy with risk of anemia and systemic inflammation, and with high incidence of neonatal microcephaly in the southwest coastal area of Guatemala.

Current and recent funding relevant to this application:

1. NIH/NICHD 2UG1HD076474-11 (MPI Krebs/Asturias) 08/07/2023 – 07/31/2030

Leveraging the Global Network to implement health interventions to improve maternal and child outcomes in a rapidly changing environment

Global Network (GN) participation involves common protocols with other GN member sites, including maternal-newborn health registry, prevention of postpartum iron deficiency, effects of heat stress in pregnancy.

Role: Contact PI

2. NIH/NIDDK R01 DK126710-03 (Tang) 02/01/21 – 01/31/26

Dietary influence on infant growth and the gut microbiota

Objective of this project is to establish how infant diet with different protein-rich foods impact growth trajectories and gut microbiota development. Role: Co-I

3. National Cattlemen's Beef Association (Krebs) 01/2022 – 09/2024

Beef with or without fruits & vegetables in a Westernized diet: a metabolomics perspective

Project is an RCT, controlled feeding trial that examines the effects of adding phytochemical-rich fruits and vegetables (Mediterranean pattern) to a diet containing daily intake of beef. Role: PI

4. University of California San Francisco (McDonald) 01/01/20 – 09/30/24

Study of multi fortified salt among women of reproductive age in India

The primary goal is to evaluate nutritional impact of multiply fortified salt for improvement of micronutrient status among nonpregnant women of reproductive age in India. Role: Co-I

5. NIH/NIDDK T32 DK007658-32 (Krebs) 07/01/21 – 06/30/26

Institutional Training Program in Nutrition

The goal of this training program in nutrition is to train the next generation of physician scientists and basic researchers who are committed to the prevention of disease and health promotion through careers in human nutrition. Role: PI

6. NIH/NIDDK 5R01DK113957-05 (Krebs, Reisdorph, Campbell MPI) 07/01/18-3/31/25 (NCE)

Predicting health outcomes of Mediterranean diet via metabolomics of foods and biospecimens

Objective is to connect unique molecular signatures in foods from a Mediterranean-style diet to the same food-specific signatures in biological fluids, and to link signatures to beneficial health indicators.

Role: Contact PI

Completed Research Support

1. Bill & Melinda Gates Foundation/Global Dev't Grant (Krebs/Hambidge) 11/15/12 – 06/30/21

Women First Preconception Maternal Nutrition: The objective was to determine the benefits on fetal and offspring growth (birth-2 years) in austere environments of commencing daily multiple micronutrient fortified lipid based nutrition supplement ≥ 3 mo prior to conception compared to initiation of same supplement at 12 wk gestation. Role: Co-PI

Selected Relevant Citations

1. Hambidge KM, Westcott JE, Garcés A, Figueroa L, Goudar SS, Dhaded SM, Pasha O, Ali SA, Tshetu A, Lokangaka A, Derman RJ, Goldenberg RL, Bose CL, Bauserman M, Koso-Thomas M, Thorsten VR, Stolka K, Das A, McClure EM, **Krebs NF** on behalf of the Women First Preconception Trial Study Group. A multi-country randomized controlled trial of a maternal nutrition supplement-initiated preconception versus early gestation: The Women First Trial. *Am J Clin Nutr*. 2019 Feb 1;109(2):457-469. doi: 10.1093/ajcn/nqy228. PMID: 30721941
2. Shankar K, Ali SA, Ruebel ML, Jessani S, Borengasser SJ, Gilley SP, Jambal P, Yazza DN, Weaver N, Kemp JF, Westcott JL, Hendricks AE, Saleem S, Goldenberg RL, Hambidge KM, **Krebs NF**, Maternal nutritional status modifies heat-associated growth restriction in women with chronic malnutrition. *PNAS*

Nexus, 2023 Jan;2(1):pgac309. doi: 10.1093/pnasnexus/pgac309. eCollection 2023 Jan. PubMed PMID: 36744021; PubMed Central PMCID: PMC9896899.

3. Hill EB, Reisdorph RM, Rajery SR, Michel C, Khajeh-Sharafabadi M, Doenges KA, Weaver N, Quinn K, Sutliff AK, Tang M, Borengasser SJ, Frank DN, O'Connor LE, Campbell WW, **Krebs NF**, Hendricks AE, Reisdorph NA. Salmon Food-Specific Compounds and Their Metabolites Increase in Human Plasma and Are Associated with Cardiometabolic Health Indicators Following a Mediterranean-style Diet Intervention. *J Nutr.* 2023; PMID: 37918675

B. POSITIONS, SCIENTIFIC APPOINTMENTS, AND HONORS

- 2014-2018 Vice-Chair, Academic Affairs, Dept of Pediatrics; (Assoc Vice-Chair- 2018-present)
- 2005- Professor (with tenure), Dept. Pediatrics UCD-SOM, Denver, CO
- 1998-2023 Head, Section of Nutrition, Dept. of Pediatrics, UCD-SOM, Aurora, CO
- 1998-04 Associate Professor, Depts. of Pediatrics, & Preventive Medicine & Biometrics, UCSOM
- 1993- Medical Director, Dept of Clinical Nutrition, Children's Hospital Colorado, Aurora, CO
- 1993-98 Assistant Professor, Depts. of Pediatrics & Preventive Medicine, UCSOM, Denver, CO

Other Experience and Professional Contributions and Memberships

- 2023 - NICHD, "ADVANTAGE": Agriculture and Diet: Value Added for Nutrition Translation / Adaptation in a Global Ecology", Work Group 1 (Climate & Health Outcomes), Co-Chair
- 2022- National Academies of Sciences, Engineering, Medicine. Standing Committee for the Review of the Dietary Reference Intake Framework
- 2020-21 NICHD, Breastmilk Ecology: Genesis of Infant Nutrition (BEGIN); Work Group Chair
- 2020-23 FAO/WHO Expert Group on Nutrient Requirements for Children Aged 0-36 months
- 2019 NIDDK, T32/35 Review Panel, Nov 2019, 2021, 2022
- 2019 NIH Infectious, Reproductive, Asthma and Pulmonary Conditions [IRAP], Study Section, Feb
- 2018 NICHD Strategic Planning Working Group, Oct 2018
- 2017-18 Chair, Maternal, Perinatal, & Pediatric Research Interest Section, Am Society for Nutrition
- 2017 NIH Nutrition Research Thought Leader Panel, June 2017
- 2015 Invited participant, NICHD, Global Health Consultation Meeting, "Intersection of Child Neurodevelopment, Nutrition, and Inflammation in Low Resource Settings."
- 2015- Technical Expert Collaborative (TEC), USDA-HHS Dietary Guidance Development Project for Infants and Toddlers from Birth to 24 Months and Women Who are Pregnant (B-24/PW)
- 2006-13 Chair, Promotions & Tenure Committee, Dept of Pediatrics, UCSOM
- 2012-13 Dietary Guidelines B-24 Federal Steering Comm, Workshop Planning Committee & Working Group
- 2010-16 BOND (Biomarkers of Nutrition for Development), Nutrient (Zn) Expert Panel, NICHD
- 2007-11 NIDDK-DDK-C Special Review Sub-committee for Digestive Diseases & Nutrition
- 2003-07 Food and Nutrition Board, National Academy of Sciences
- 2003-06 Co-Chair, Task Force on Obesity, American Academy of Pediatrics
- 2001-05 Chair, Committee on Nutrition, American Academy of Pediatrics (CON member 1997-2001)

Honors:

- 2024 Goalkeeper Champion, Gates Foundation
- 2023 Jean-Pierre Habicht Lifetime Achievement in Global Nutrition Research Award, ASN
- 2022 Agnes Higgins Award, March of Dimes
- 2019 Fellow, American Society for Clinical Nutrition
- 2016 Robert Suskind and Leslie Lewinter-Suskind Pediatric Nutrition Lifetime Achievement Award, ASN
- 2015 Roland Weinsier Award for Excellence in Medical Nutrition Education, American Society for Nutrition
- 2013 Golden Stethoscope Award for Clinical Teaching, UCSOM
- 2010 Samuel J. Fomon Nutrition Research Award, American Academy of Pediatrics
- 1998-99 Physician Nutrition Specialist Award, American Society for Clinical Nutrition
- 1993, 1996, 1997, 1998, 2009: Excellence in Teaching Award, Univ. of Colorado School of Medicine

C. CONTRIBUTIONS TO SCIENCE

1. **Definition of Zinc Requirements in Pregnant and Lactating Women and Infants:** From an early RCT in lactating women, I described the dramatic longitudinal decline in the zinc concentrations in human milk,

independent of maternal diet or status. This premise has been upheld in subsequent reports in women with widely divergent diets and in a broad range of settings, resulting in breastfed infants' vulnerability to deficiency by ~ 6 months of age and dependence on zinc containing complementary (weaning) foods. This biological reality explains a substantial portion of the high prevalence of zinc deficiency in infants and young children worldwide. Stable isotope studies have been foundational to define zinc requirements.

- a) **Krebs NF**, Reidinger CJ, Hartley S, Robertson AD, Hambidge KM. Zinc supplementation during lactation: Effects on maternal status and milk zinc concentrations. *Am J Clin Nutr* 61:1030-6, 1995.
- b) **Krebs NF**, Reidinger CJ, Miller LV, Hambidge KM. Zinc homeostasis in breastfed infants. *Pediatr Res* 39:661-5, 1996. DOI: 10.1203/00006450-199604000-00017
- c) **Krebs NF**, Westcott JE, Culbertson DL, Sian L, Miller LV, Hambidge KM. Comparison of complementary feeding strategies to meet zinc requirements of older breastfed infants. *Am J Clin Nutr*, 2012; 96: 30-35. PMCID: PMC3374732.
- d) Young BE, Heinrich R, Borman LL, Long J, Pinney S, Westcott J, **Krebs NF**. Effect of pooling practices and lactation stage on the energy, zinc, and hormone concentrations of donor human milk pools. *J Pediatr*, 2019 Nov;214:54-59. doi: 10.1016/j.jpeds.2019.07.042. Epub 2019 Sep 23. PMID: 31558278

2. **Confirmation of Impact of Nutrition Interventions on Pregnancy and Infant Outcomes:** The “1000 days” is a critical window for fetal and infant growth and development, with vulnerability for undernutrition and micronutrient deficiencies that contribute to adverse pregnancy outcomes, including the small vulnerable newborn, and with enduring effects on child growth. We have undertaken investigations on the impact of micronutrient supplements and complementary foods on infant growth, including RCT in US and in low resource settings. Observations of limited effects of food-based approaches (animal source foods and fortified foods) on linear growth and stunting in low resource settings laid the foundation for earlier and more comprehensive interventions to improve post-natal growth, including the 4-country preconception maternal nutrition supplementation trial (multiple micronutrients), Women First (see Section A).

- a) **Krebs NF**, Mazariegos M, Chomba E, et al. Randomized controlled trial of meat versus multi-micronutrient-fortified cereal in infants and toddlers in settings with high stunting rates. *Am J Clin Nutr*, 2012, 96:840-847.
- b) Hambidge KM, Bann CM, McClure EM, Westcott JE, Garcés A, Figueroa L, Goudar SS, Dhaded SM, Pasha O, Ali SA, Derman RJ, Goldenberg RL, Koso-Thomas M, Somannavar MS, Herekar V, Khan U, **Krebs NF**. Maternal characteristics affect fetal growth response in the Women First Preconception Nutrition Trial. *Nutrients*. 2019 Oct 21;11(10). pii: E2534. PMCID: PMC6835723.
- c) Castillo-Castrejon M, Yang IV, Davidson EJ, Borengasser SJ, Jambal P, Westcott J, Kemp J, Garces A, Ali SA, Figueroa L, Hambidge KM, **Krebs NF**, Powell TL. Preconception lipid-based nutrient supplementation in two low-resource countries results in distinctly different IGF-1/mTOR placental responses. *J Nutr* 2021; 151: 556–569. PMCID: PMC7948206
- d) **Krebs NF**, Hambidge KM, Westcott JL, Garcés AL, Figueroa L, et al. Birth length is the strongest predictor of linear growth status and stunting in the first 2 years of life after a preconception maternal nutrition intervention: the children of the Women First trial. *Am J Clin Nutr*. 2022 Jul 6;116(1):86-96. PMCID: PMC9257468.

3. **Demonstrated Impact of Distinct Complementary Feeding Patterns on Infants' Growth:** Recognition of the period of older infancy (6-12 mo) as critical for meeting zinc and iron needs led to RCTs in Denver to examine the impact of different protein sources on infant growth, body composition and microbiota.

- a) **Krebs NF**, Westcott JE, Butler N, Robinson C, Bell M, Hambidge KM. Meat as a first complementary food for breastfed infants: feasibility and impact on zinc intake and status. *J Pediatr Gastroenterol Nutr* 42:207-214, 2006.
- b) Mazariegos M, Hambidge KM, Westcott JE, Solomons NW, Raboy V, Das A, Goco N, Kindem M, Wright LL, **Krebs NF**. Neither a zinc supplement nor phytate-reduced maize nor their combination enhance growth of older Guatemalan infants. *J Nutr* 140:1041-1048, 2010.
- c) Tang M, Anderson V, Hendricks AE, **Krebs NF**. Different growth patterns persist at 24 months in formula-fed infants randomized to consume a meat- or dairy-based complementary diet from 5 to 12 months. *J Pediatr*, 2019;206:78-82.
- d) Tang M, Ma C, Weinheimer-Haus EM, Robertson CE, Kofonow JM, Berman JM, Waljee A, Zhu J, Frank DN, **Krebs NF**. Different gut microbiota in U.S. formula-fed infants consuming a meat vs. dairy-

based complementary foods: a randomized controlled trial. *Front Nutr.* 2023; 26;9:1063518. PMCID: PMC9909089

4. **Demonstrated Links Between Diet, Microbiota (MB), Inflammation:** We have documented the profound effects of infant and maternal diets and phenotype on the MB; of intestinal inflammation on nutrient utilization; of maternal nutrition on placental function. Our Denver laboratory-based work in conjunction with trials in low resource settings has built capacity for collection, processing, shipping, and analyses of multiple biospecimen types, and has contributed fundamental understanding of global public health challenges. With this experience, we have provided considerable technical support for expanded scope for multiple trials in the Global Network.
- a) **Krebs NF**, Sherlock LG, Westcott J, Culbertson D, Hambidge M, Feazel LM, Robertson CE, Frank DN. Effects of different complementary feeding regimens on iron status and enteric microbiota in breastfed infants. *J Pediatr* 2013; 163: 416-423, e4.
 - b) Esamai F, Liechty E, Ikemeri J, Westcott JE, Kemp JF, Culbertson D, Miller LV, Hambidge KM, **Krebs NF**. Zinc absorption from micronutrient powder is low but is not affected by iron in Kenyan infants. *Nutrients* 2014 Dec; 6(12):5636-51.
 - c) Tang M, Weaver NE, Frank DN, Ir D, Robertson CE, Kemp JF, Westcott J, Shankar K, Garces AL, Figueroa L, Tshetu AK, Lokangaka AL, Goudar SS, Somannavar M, Aziz S, Saleem S, McClure EM, Hambidge KM, Hendricks AE, **Krebs NF**, and the Women First Study Group. Longitudinal reduction in diversity of maternal gut microbiota during pregnancy is observed in multiple low-resource settings: Results from the Women First Trial. *Frontiers in Microbiology*, 13 (2022). PMCID: PMC9376441.
 - d) Odiase E, Frank DN, Young BE, Robertson CE, Kofonow JM, Davis KN, Berman LM, **Krebs NF**, Tang M. The gut microbiota are affected by feeding type and are associated with growth status in exclusively breastfed and formula-fed US infants. *J Nutrition*, 2023; 153: 2543-2772. <https://doi.org/10.1016/j.tjnut.2023.07.009>.
5. **Investigations of early origins of childhood obesity:** I led the development of policy guidelines on obesity prevention and assessment for the American Academy of Pediatrics. I have collaborated on several studies examining the fetal and early post-natal origins of childhood obesity, including investigations of effects of maternal metabolic health on human milk production and composition, and on the effects of infant complementary feeding on growth.
- a) Young BE, Levek C, Reynolds RM, Rudolph MC, MacLean P, Hernandez TL, Friedman JE, **Krebs NF**. Bioactive components in human milk are differentially associated with rates of lean and fat mass deposition in infants of mothers with normal vs elevated BMI. *Pediatric Obesity*, 2018; doi:10.1111/ijpo.12394.
 - b) Young BE, Patinkin Z, Palmer C, de la Houssaye B, Barbour LA, Hernandez T, Friedman JE, **Krebs NF**. Human milk insulin is related to maternal plasma insulin and BMI: but other components of human milk do not differ by BMI. *Eur J Clin Nutr.* 2017 Jun;21(6):1367-1376. doi: 10.1038/ejcn.2017.75. PMID: 28513622
 - c) Rodel RL, Farabi SS, Hirsch NM, Heiss KP, McNair B, Hernandez TL, **Krebs NF**, Barbour LA, Young BE (2021) Human milk imparts higher insulin exposure in infants born to women with Type 2 Diabetes Mellitus. *J Mat-Fetal Neo Med (IJMF)*, 2022 Dec;35(25):7676-7684. PubMed PMID: 34465258.
 - d) Gilley SP, Harrall KK, Friedman C, Glueck DH, Cohen CC, Perng W, Sauder KA, **Krebs NF**, Shankar K, Dabelea D. Association of Maternal BMI and Rapid Infant Weight Gain With Childhood Body Size and Composition. *Pediatrics*, 2023;151(5). doi:10.1542/peds.2022-059244. PubMed PMID: 37016999.

Complete List of Published Work (>350) in My Bibliography:

<https://www.ncbi.nlm.nih.gov/myncbi/nancy.krebs.1/bibliography/public/>