OMB No. 0925-0001 and 0925-0002 (Rev. 10/2021 Approved Through 09/30/2024)

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
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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 & 06/1990 Pediatrics

 Residency

University of Colorado School of Medicine Fellowship 06/1993 Pediatr GI & Nutr

****A. PERSONAL STATEMENT**** As a physician scientist, my primary research interests and experience relate to maternal and infant nutrition. My work has extended from detailed stable isotope studies of trace mineral (viz., zinc and iron) homeostasis across the life cycle, to large scale RCT of nutrition supplements and/or food-based interventions, in settings across 4 continents and nearly a dozen countries. The broad focus of these studies has been to define micronutrient requirements and to characterize adaptation to different diets and physiologic states, e.g., infancy, pregnancy, lactation, and various disease and inflammatory states. I have directed multiple intervention trials to monitor and evaluate growth and development in infants and toddlers exposed to different diets and nutrient intakes. I directed the multi-country Global Network (GN) studies of complementary feeding (“First Bites”, 2006-2012) and the preconception maternal nutrition intervention trial (“Women First”, WF), co-led with Dr. KM Hambidge, 2012-2019) conducted in 4 sites of the GN. The WF trial extended from pre-pregnancy through 24 months and included multiple public health outcomes (birth anthropometry, postnatal infant/child stunting rates, neurodevelopment) plus extensive maternal and infant phenotyping, e.g., nutritional status, human milk composition, metabolomics, microbiome and epigenetic data.

 My investigations in Denver have documented the impact of maternal phenotype on human milk composition and production, infant nutrient intakes and growth. Past and current interventions modify types of complementary foods to evaluate effects on growth, adiposity, nutritional status, microbiome, and sleep.

 As a founding member-site of the GN, our team, currently including Drs. Mazariegos, Figueroa, and Garces, and Ms. Westcott, has contributed to virtually all common protocols, and has published GN and non-GN supported studies in global health and nutrition. The addition of Dr. Asturias to our team in the current GN cycle, with his extensive expertise in infectious diseases, vaccinology and heat stress in low resources settings, extends our engagement with Guatemala and strongly aligns with priorities of the GN. I have visited 6 of the current 7 GN sites and have collaborated with all of the teams currently in the GN. The proposed intervention trial to mitigate the adverse effects of heat stress emanates directly from secondary analyses, led by Dr. Shankar, from the WF trial and from epidemiologic data from the GN maternal newborn health registry (see publications below). The scientific premise of the proposed trial – that the adverse effects of heat stress on fetal growth and obstetric outcomes can be mitigated by improved maternal nutrition, aspirin and cooling strategies - is robustly supported by our published findings, by preclinical data, and by epidemiologic data.

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 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 regulate growth trajectories and gut microbiota development. Role: Co-I

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

***Institutional Training Program in Nutrition***

The primary 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

**4. University of California San Francisco (McDonald) 01/01/20 – 03/31/24
*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

**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 Citations:

1. Shankar K, Ali SA, Ruebel ML, Jessani S...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. PMCID: PMC9896899
2. Shankar K, Jackson K, Westcott JL, Saleem S…Wylie BJ, Goldenberg RL, Thorsten VR, McClure EM, Krebs NF. Associations between ambient temperature and pregnancy outcomes from three South Asian sites of the Global Network Maternal Newborn Health Registry: A retrospective cohort study. BJOG, 2023, 00:1–10. DOI: 10.1111/1471-0528.17616.

3. Hambidge KM, Westcott JE, Garcés A, Figueroa L…Stolka K, Das A, McClure EM, **Krebs NF** and the Women First Study Group. A multicountry randomized controlled trial of comprehensive maternal nutrition supplementation initiated before conception: the Women First trial. *Am J Clin Nutr*, 109: 457-469, 2019. PMCID: PMC6367966

**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- 2023 Medical Director, Dept of Clinical Nutrition, Children's Hospital Colorado, Aurora, CO

 1993-98 Assistant Professor, Depts. of Pediatrics & Preventive Medicine, UCSOM, Denver, CO

2006-present

 **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 member1997-2001)

**Honors:**

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.
2. **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.
3. **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
4. **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.
5. Hambidge KM, Miller LV, Mazariegos M, Westcott JE…Goco N, Hartwell T, Wright L, **Krebs NF**. Up-regulation of zinc (Zn) absorption matches increases in physiological requirements for Zn in women on high or moderate phytate diets during late pregnancy and early lactation. *J Nutr*, 2017;147:6: 1079-1085 PMCID: PMC5443465.
6. **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).
7. **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.
8. 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.
9. 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
10. **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.
11. **Demonstrated Impact of Distinct Complementary Feeding Patterns on Infant 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.
12. **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 Gastroenter Nutr* 42:207-214, 2006.
13. 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.
14. 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.
15. 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
16. **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.
17. 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.
18. Long JM, Mondal P, Westcott JE, Miller LV, Islam MM, Ahmed M, Mahfuz M, Ahmed T, **Krebs NF.** Zinc absorption from micronutrient powders is impaired in Bangladeshi toddlers at risk for environmental enteric dysfunction (EED) and may increase dietary zinc requirements. *J Nutr*, 2019;149:98–105. PMCID: PMC6377437
19. Tang M, Weaver NE, Frank DN, Ir D, Robertson CE, Kemp JF, Westcott J, Shankar K, Garces AL, Figueroa L, Tshefu 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.
20. 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 .

1. **Diverse Topics in Maternal and Infant Health:** As Director of our T32 Post-doctoral Training Program in Nutrition and as former K24 awardee, I have demonstrated a strong commitment to mentorship of young investigators, MD’s and PhD’s, including several from international settings. With active mentoring and the opportunities provided by the multi-site RCT and infrastructure of the GN, many junior investigators have published findings of interest to themselves and to the global health community.
2. Ali SA, Khan U, Saleem S, **Krebs NF**, Hambidge KM, Westcott JE, Goldenberg RL, McClure EM, and Pasha O. Challenges of implementing ‘Women First’ (Preconception maternal nutrition)’ study in a rural study site of Pakistan along with innovative strategies. *Nutr Metab Insights*. 2019; 21:1178638819852059. PMCID: PMC6611011
3. Garces A, Perez W, Harrison MS, Hwang KS, Nolen TL, Goldenberg RL, Patel AB, Hibberd PL, Lokangaka A, Tshefu A, Saleem S, Goudar SS, Derman RJ, Patterson J, Koso-Thomas M, McClure EM, **Krebs NF**, Hambidge KM. Association of parity with birthweight and neonatal death in five sites: The Global Network's Maternal Newborn Health Registry study. *Reprod Health*. 2020;17(Suppl 3):182. PMCID: PMC7745358
4. Figueroa L, Garces A, Hambidge KM, McClure EM, Moore J, Goldenberg R, **Krebs NF**. Prevalence of clinically evident congenital anomalies in the Western highlands of Guatemala. *Reprod Health*. 2020 Nov 30;17(Suppl 2):153. PMCID: PMC7708098.
5. Manasyan A, Salas AA, Nolen TL, Chomba E, Mazariegos M, Tshefu A, Saleem S, Naqvi F, Hambidge KM, Goco N, McClure EM, Wallander JL, Biasini FJ, Goldenberg RL, Bose CL, Koso-Thomas M, **Krebs NF**, Carlo WA. Diagnostic accuracy of ASQ for screening of neurodevelopmental delays in low resource countries. *BMJ Open, 2023;13:e065076.* PMCID: PMC10230914

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

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