Investigating associations between maternal multiple nutrient deficiencies and breast milk nutrients using samples from Ariaal women in northern Kenya

Masako Fujita, Associate Professor of Anthropology

Overview
The positive health impacts of breastfeeding on children are well established (1, 2). Among breastfed children, however, morbidity and mortality vary considerably (1, 3). Variation in the nutrient or immune contents in milk may contribute to these differences. The existing literature is inconclusive as to the effects of maternal malnutrition on breast milk nutrient contents (4). This may be due, in part, to the covert nature of some aspects of maternal nutrition, such as micronutrient deficiencies, that may not be captured by a global measure such as Body Mass Index (4, 5), typically utilized to quantify maternal nutrition. Inclusion of specific aspects of maternal nutrition may help clarify nutritional influences on maternal nutrient delivery to milk. In food-insecure environments, breastfeeding mothers may also suffer concurrent subclinical (asymptomatic) deficiencies in multiple micronutrients without exhibiting overt signs of malnutrition. The impact of concurrent multiple maternal nutrient deficiencies (e.g. iron deficiency and vitamin A deficiency) may differ from the impact of a single nutrient deficiency. This introduces further complexity for understanding the variation of milk content attributable to maternal nutrition.

This project will investigate associations between maternal multiple nutrient deficiencies and breast milk nutrients using archival data and sample specimens from Ariaal women in northern Kenya (n=205). This research will take place in the Biomarker Laboratory for Anthropological Research of Michigan State University. The laboratory houses cryogenically archived human milk specimens originally donated in 2006 by Ariaal mothers residing in agro-pastoral communities of northern Kenya. Due to the remoteness, poor soil productivity of the arid lands, and prevailing drought in the Horn of Africa, anemia and night-blindness, indicative of iron/vitamin A deficiencies, were prevalent (6). Analyses done in the laboratory using maternal anthropometric data and blood specimens that accompanied the milk specimens indeed revealed high prevalence of chronic energy deficiency, iron-deficiency, vitamin A deficiency, and folate or vitamin B₁₂ deficiency (7-10).

Furthermore, a substantial number of mothers were concurrently deficient in multiple nutrients; out of 205 mothers, for whom data are complete, thirty mothers had two concurrent deficiencies and eight mothers had three concurrent deficiencies, as summarized in Table 1 (Fujita, unpublished document). In the existing literature, very few studies have investigated multiple nutrient deficiencies in individuals of reproductive age. By statistically evaluating associations between maternal multiple nutrient deficiencies and breast milk nutrients, the proposed project has the potential to contribute to multiple fields concerned with maternal child nutrition, human lactation biology, and human milk content variation in ecological settings.
**Table 1** Number of mothers with concurrent nutritional deficiencies by deficiency type

<table>
<thead>
<tr>
<th>Deficiency Type</th>
<th>CED &amp; FeD</th>
<th>CED &amp; VAD</th>
<th>CED &amp; VB&lt;sub&gt;9/12&lt;/sub&gt;D</th>
<th>FeD &amp; VAD</th>
<th>FeD &amp; VB&lt;sub&gt;9/12&lt;/sub&gt;D</th>
<th>VAD &amp; VB&lt;sub&gt;9/12&lt;/sub&gt;D</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>n =</td>
<td>15</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>30</td>
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</table>

b. Three concurrent deficiencies

<table>
<thead>
<tr>
<th>Deficiency Type</th>
<th>CED, FeD &amp; VAD</th>
<th>CED, FeD &amp; VB&lt;sub&gt;9/12&lt;/sub&gt;D</th>
<th>FeD, VAD &amp; VB&lt;sub&gt;9/12&lt;/sub&gt;D</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>n =</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

Abbreviations: CED chronic energy deficiency (BMI <18.5 kg/m<sup>2</sup>), VAD vitamin A deficiency (serum retinol <1.05 µmol/l), FeD iron deficiency (dried blood spot soluble transferrin receptor >5 unit), VB<sub>9/12</sub>D folate or vitamin B<sub>12</sub> deficiency (serum homocysteine >15 µmol/l)

<sup>1</sup> Total mothers evaluated: N=205

**Project Activities:**

**Literature search, Data generation, and Statistical analysis**

The postdoctoral researcher will participate in the following activities.

1. A systematic search of existing literature on human milk vitamin B<sub>12</sub> (or an alternative content/contents; see below) variation: This is to summarize the expected concentration range for human milk, and to obtain the background information on its relationship with maternal nutrition and health.

2. Assays of the archived milk specimens to determine vitamin B<sub>12</sub> concentrations: For this activity, an economical commercial ELISA kit will be utilized. The postdoctoral researcher will have an opportunity to learn the principle of ELISA technology and assay quality control evaluation. If the proposed assay work is not acceptable under the African Futures Program, or due to a budgetary limitation, it can be replaced by another milk content, such as milk folate (binding-protein, FOLR1) or lactoferrin (protein with immunological function which may be related to maternal iron status), data for which may be available to the project.

3. Statistical evaluations of the associations of milk data with maternal nutrient deficiencies: Tentatively, this will be based on a multivariate regression analysis approach, adjusting for influences of other variables such as age, infant characteristics, dietary characteristics, and socioeconomic status. Regression models will test a set of hypotheses derived from the maternal buffering hypothesis (11, 12). The core idea behind this hypothesis is that human lactation biology, specifically maternal delivery of nutrient contents to milk, has evolved to buffer milk against mild-to-moderate nutritional stress (routine occurrence in evolutionary history) but not against severe malnutrition (evolutionarily novel condition). Therefore, milk nutrient content may be unchanged in the presence of a single subclinical nutrient deficiency but may decrease in the presence of concurrent multiple deficiencies.
Dissemination of Research Findings
The postdoctoral researcher will participate in writing journal manuscripts and conference presentations to disseminate project outcomes. The target journal and conference venue will be determined at an early stage of the project.

Grant Proposal Development and Writing
Subsequently, the postdoctoral researcher and PI will write a research grant proposal for a new project that is both relevant for the postdoctoral researcher’s home country and PI’s research interest, building on the findings from the proposed project. National Science Foundation or National Institute of Health of the United States may be a possible target grant agency.

Timeline

<table>
<thead>
<tr>
<th>Activity</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
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<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
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<tr>
<td>Lit search; pretests, assays, QC</td>
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<tr>
<td>Stats; manuscript writing &amp; revising</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Dissemination &amp; grant development</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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</table>

Summary of Research Engagement Opportunities for the Fellow
- Systematic and focused literature search for an annotated bibliography
- Human milk assays for a nutrient content biomarker using ELISA technology
- Assessment of assay data validity and reliability
- Formulation of testable hypotheses using theoretical framework and empirical information
- Statistical analysis of data for summary and hypothesis testing
- Journal article submission
- Conference presentation
- Development of a new grant proposal

Budget
- Vitamin B$_{12}$ ELISA kit 8 kits\(^1\) $5,032
- Lab supplies and quality control specimens\(^2\) 968
- Result Dissemination\(^3\) 2,000
- Domestic conference travel for the Fellow 1,000

Total $9,000

\(^1\) Price based on quote # BULK3777G (4/26/19) Novus Biological Catalog #NBP2-60196-1Kit
\(^2\) Include PPE, tips/tubes, lab water, vit B$_{12}$ controls (sigma-Aldrich V2876-1G), assay S&H
\(^3\) Publication fees and/or conference registration
References


5. Gangopadhyay NN, Moldoveanu Z and Stephensen CB; Vitamin A deficiency has different effects on immunoglobulin A production and transport during influenza A infection in BALB/c mice. *Journal of Nutrition* 1996;126(12):2960-7.


Masako Fujita  
Curriculum vitae

Department of Anthropology  
328 Baker Hall, 655 Auditorium Road  
Michigan State University  
East Lansing, MI 48824  
Phone: (517) 353-7174  
Fax: (517) 432-2363  
Email: masakof@msu.edu  
Homepage: http://anthropology.msu.edu/author/fujitam/  
ORCID: 0000-0001-9173-6678

ACADEMIC POSITIONS

2015-present  Associate Professor, Department of Anthropology, Michigan State University
2008-2015  Assistant Professor, Department of Anthropology, Michigan State University

EDUCATION

2008  Ph.D. Anthropology, University of Washington, Seattle, Washington  
Dissertation: An epidemiological and evolutionary investigation of mother-offspring vitamin A transfer. Advisor: Dr. Bettina Shell-Duncan
2005  M.A. Anthropology, University of Washington
2003  M.A. Anthropology, University of Victoria, British Columbia, Canada  
Thesis: Sedentarization, seasonality, and economic differentiation: maternal diet and health in Ariaal-Rendille communities in northern Kenya. Advisor: Dr. Eric Roth
1999  B.A. Anthropology, University of Victoria, British Columbia, Canada

AREAS OF SPECIALIZATION

Maternal diet, nutrition, infection, inflammation, and anemia in the environments of high infectious disease load and food insecurity; human milk contents; sex biases in infant feeding in polygynous systems; droughts and famine; reproductive ecology; human ecological immunology; evolutionary medicine; life-history theory; parental investment theory; biomarker methods

HONORS, AWARDS, AND FELLOWSHIPS

2016  US Department of Education National Resource Center Program Course Development Grant awarded via MSU African Studies Center, $3,000.
2010  US Department of Education Title IV Curriculum Development Grant awarded via MSU Center for Advanced Study in International Development (CASID), $1,500.
2008-2010  Social Sciences and Humanities Research Council of Canada Postdoctoral Fellowship (awarded but declined)
2007-2008  University of Washington (UW) Graduate School Dissertation Fellowship
2007  Canadian Association for Physical Anthropology Davidson Black Award
2002-2005  Social Sciences and Humanities Research Council of Canada Doctoral Fellowship
1999-2001  University of Victoria (UVic) Faculty of Graduate Studies Dean’s Scholarship
1996-1998  UVic Entrance Scholarship; President’s Scholarships
1996  North Island College (British Columbia, Canada) BC Tel Award; Dean’s Honour Roll
RESEARCH GRANTS


2016-2018  PI. Effects of maternal nutrition and infant gender on breastmilk antibodies and micronutrients. National Science Foundation (NSF), Biological Anthropology Senior Award, $120,000.


2016  PI. Strategic Partnership Travel Funds for research development in Kilimanjaro, Tanzania. MSU African Studies Center and Anthropology, $3,860.

2015-2016  PI. Exploring nutritional and immunological correlates of maternal anemia and possible impacts on breast milk quality in rural Kenya. MSU Provost Undergraduate Research Initiative Award, $4,000.

2015  PI. Feasibility study for iron status dried blood spot assay. MSU Provost Undergraduate Research Initiative Summer Award, $1,634.

2014-2015  PI. The Impact of Coping Strategies for Food Insecurity and Health Outcomes. MSU Provost Undergraduate Research Initiative Award, $1,366.

2013-2014  PI. Food Insecurity, Coping Strategy, Nutrition and Immune Health among Ariaal Mothers in Kenya: An Exploratory Study. MSU Provost Undergraduate Research Initiative Award, $2,000.

2009-2013  PI. A Longitudinal Study of Mother-Offspring Vitamin A Transfer in Northern Kenya. (for Prolactin analysis). MSU College of Social Science Faculty Initiative Fund, $3,640.


2010-2011  PI. Travel Support for a Prospective Visiting Scholar, Mr. Philip Ndemwa of the Centre for Public Health Research, Kenya Medical Research Institute. MSU CASID, US$4,000 (Awarded but declined for schedule conflict).

2010  PI. Research Development in Para, Brazil. MSU CASID Research Initiative Travel Grant, $2,943.

2009  PI. A Longitudinal Study of Mother-Offspring Vitamin A Transfer in Northern Kenya. MSU CASID International Development Research Initiation Grant, $4,000.

2006-2008  PI (with Dr. Bettina Shell-Duncan). An Evolutionary Perspective on Mother-Offspring Vitamin A Transfer. NSF Dissertation Improvement Grant, US$12,000.

2006-2008  PI. An Evolutionary Perspective on Mother-Offspring Vitamin A Transfer. Wenner-Gren Foundation for Anthropological Research, US$25,000 (Grant # 7460).


**PUBLICATIONS**

**Peer-reviewed Journal Articles**


**Book Chapters**


**Technical Reports**


Data


Published Abstracts in Peer-reviewed Journals


**PRESENTATIONS**

*Conference Presentations*


22. Bignall E, Paredes Ruvalcaba N, **Fujita M.** 2019. During drought in northern Kenya, mothers with iron deficiency anemia were younger, but not of low socioeconomic status. University Undergraduate Research and Arts Forum. MSU.


12. Apland A, **Fujita M**. 2015. Folate Receptor 1 (FOLR1) adjusted for hormonal status serves as a marker of folate nutrition. Undergraduate Research Symposium of the *American Association of Physical Anthropologists*, St. Louis, MO.

11. **Fujita M**, Yun-Jia Lo, Baranski J, Brindle E. 2014. In endemically vitamin A deficient northern Kenya, undernourished mothers allocate a higher proportion of blood vitamin A to breastmilk than better-nourished mothers, with effects moderated by the lactation hormone prolactin. Podium presentation, annual meeting of the *Canadian Association for Physical Anthropology*, Fredericton, Canada.


Invited Presentations


4. Fujita M. 2011. Understanding why vitamin A in breastmilk declines when children need it the most: data from a northern Kenyan community. Human Development Initiative Seminar Series, MSU.

3. Fujita M. 2010. Maternal vitamin A status in northern Kenya. Invited speaker, Epidemiology 200 A Multi-disciplinary Approach to Problems in Global Public Health and Epidemiology, Department of Epidemiology, College of Human Medicine, MSU.


Professional Service

Journal Manuscripts Reviewed

- American Journal of Clinical Nutrition
- American Journal of Human Biology
- American Journal of Physical Anthropology
- Ann NY Acad Sci
- Anthropologica (The Journal of the Canadian Anthropology Society)
- Current Zoology
- Evolution and Human Behavior
- Food and Foodways
- Health, Risk & Society
- Human Ecology
- Human Nature
- Journal of Nutrition
- Nutrition: the International Journal of Applied and Basic Nutritional Sciences
- Pediatric Research
- PLoS ONE

Other Professional Service

- 2017 Ad Hoc Reviewer, National Science Foundation Biological Anthropology Program
- 2016 Reviewer, American Society for Nutrition Scientific Sessions
- 2012 – 2016 Member, Program Committee for the 2013, 2014, 2015, and 2016 annual meetings of the American Association of Physical Anthropologists
- 2012 Faculty Mentor for the American Association of Physical Anthropologists Undergraduate Symposium, Portland, Oregon (Mariana Rendon)
- 2009 Co-chair, Symposium on the Evolutionary Biology of Primate Lactation at the 78th Annual Meeting of the American Association of Physical Anthropologists

Expert Consultations

- 2009 – 2010 Key external expert for the WHO Micronutrients Unit, Geneva, Switzerland
- 2006 – 2007 Performance evaluation of a portable fluorometer for the Micronutrient Initiative
- 2006 Workshop on enzyme immunoassay principle and method for capacity building for the
Centre for Public Health Research Laboratory, Kenya Medical Research Institute

2006 Workshop on improving dietary intake of vitamin A for northern Kenyan mothers (with Antonella Lobura of the Food for the Hungry International, Marsabit, Kenya)

2005 Product label review for retinol-binding protein ELISA kit, PATH, Seattle

2004 Technology transfer of C-reactive protein enzyme immunoassay from Northwestern University to the University of Washington

**UNIVERSITY/DEPARTMENT SERVICE**

2008 – present Core Faculty, Center for Advanced Study of International Development, MSU
2008 – present Core Faculty, African Studies Center, MSU
2008 – present Core Faculty, Center for Gender in Global Context, MSU
2017 – present Member, Hearing Board, MSU College of Social Science
2016 – present Chair, Graduate Curriculum and Programs Committee, MSU Anthropology
2019 Judge for University Undergraduate Research and Arts Forum (UURAF), MSU
2016 Member, Graduate Curriculum and Programs Committee, MSU Anthropology
2016 Member, Foreign Language and Area Studies Fellowship Selection (FLAS) Review Committee, MSU African Studies Center
2011 – 2015 Member, Faculty Advisory Committee, MSU Anthropology
2015 Judge for UURAF, MSU
2015 Member, FLAS Review Committee, MSU African Studies Center
2014 – 2015 Advisor for MSU College of Social Science Dean’s Assistantship scholar (A. Apland)
2014 Referee, Gendered Perspectives on International Development Working Papers, MSU Center for Gender in Global Context
2012 – 2014 Member, Forensic Anthropology Faculty Search Committee, MSU Anthropology
2010 Judge for the Provost
2009 – 2011 Member, Graduate Curriculum and Programs Committee, MSU Anthropology
2009 Grant Reviewer, Office of the Vice President for Research and Graduate Studies
2009 Member, African Language Work Group, MSU African Studies Center
2008 – 2009 Member, Admissions Committee, MSU Anthropology
2005 – 2007 Advisory Board for the Biodemography Core of the Center for Studies in Demography and Ecology, University of Washington

**STUDENT THERSES AND DISSERTATION GUIDANCE COMMITTEES SERVED (C=current)**

<table>
<thead>
<tr>
<th>Name (Alphabetical Order)</th>
<th>Role</th>
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<tbody>
<tr>
<td>Bird, Catherine</td>
<td>PhD Committee Member</td>
</tr>
<tr>
<td>Bodnar, MaryKate</td>
<td>First-Year Advisor</td>
</tr>
<tr>
<td>Boffi, Emilia</td>
<td>PhD Committee Member</td>
</tr>
<tr>
<td>Colas, Kelly</td>
<td>PhD Committee Member</td>
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<tr>
<td>Gordon, Linda</td>
<td>First-Year Advisor</td>
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<tr>
<td>Guay, Evan</td>
<td>PhD Committee Member</td>
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<tr>
<td>Hurst, Carolyn</td>
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<tr>
<td>Karim, Tazin</td>
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<td>Kutch, Libbey (C)</td>
<td>PhD Committee Member</td>
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<tr>
<td>Michel, Amy</td>
<td>MA Committee Member</td>
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<tr>
<td>Paredes Ruvalcaba, Nerli (C)</td>
<td>First-Year Advisor; PhD Committee Chair</td>
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</table>
Perlman, Sabrina (C) First-Year Advisor; PhD Committee Chair
Rovin, Kimberly PhD Committee Member
Vollner, Jennifer PhD Committee Member

**STUDENTS SUPERVISED IN LABORATORY (C=CURRENT)**

**Name (Alphabetical Order)**
- Apland, Allison (Anthropology/History): Professorial Assistant, CSS Dean’s Scholar
- Baranski, Janine (Biomedical Laboratory Diagnostics): Professorial Assistant
- Bignall, Emma (Anthropology): Volunteer (C)
- Cameroamortegui, Felipe (Osteopathic Medicine): Medical Student Researcher
- Carpenter, Kelsey (Anthropology): Volunteer
- Castro, Pamela (Osteopathic Medicine): Medical Student Researcher
- Corbitt, Mary (Animal Science): Undergraduate Laboratory Intern
- DellBene, Erin (Anthropology/Physiology): Undergraduate Research Assistant
- Kyla Cools (Anthropology): Volunteer
- Paredes, Nerli (Anthropology): Graduate Research Assistant; NSF Doctoral Fellow (C)
- Perlman, Sabrina (Anthropology): Graduate Research Assistant
- Rendon, Mariana (Microbiology and Molecular Genetics): Undergraduate Research Assistant
- Rife, Alexis (Anthropology): Undergraduate Research Assistant
- Saetern, Quexteen (Anthropology): Undergraduate Research Assistant (C)
- Sass, Savanna (Anthropology): Undergraduate Research Assistant
- Singleton, Sabrina (Anthropology): Undergraduate Research Assistant
- Stone, Jonah (Anthropology/Human Biology): Undergraduate Research Assistant
- Yabes, Izzy (Neuroscience): Undergraduate Research Assistant
- Tran, Tin (Anthropology/BioChem, Grinnell College): 2019 Summer Research Opportunity Scholar

**COURSES TAUGHT**
- Biocultural Evolution (ANP 840)
- Quantitative Methods in Anthropology (ANP 846)
- Nutrition in Biocultural Perspective (ANP 892)
- Human Adaptability (ANP 443)
- Intro to Physical Anthropology (ANP 206, formerly ANP 202)
- Time Space Change in Human Society (ISS 220, Integrative Studies in Social Science)

**PROFESSIONAL MEMBERSHIPS**
- American Association of Physical Anthropologists
- Canadian Association for Physical Anthropology
- Human Biology Association

**CITIZENSHIPS AND LANGUAGES**
- Japanese Citizen, US Permanent Resident, Canadian Landed Immigrant
- Native speaker of Japanese, Fluent in English, Basic French, Basic Swahili