

sightandlife

A FURTHER
DECADE OF
HELPING
TO DRIVE THE
GLOBAL NUTRITION
AGENDA
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35

CELEBRATING OUR
35TH ANNIVERSARY

YEARS

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Cover photo from the first issue of *Sight and Life* magazine published in 2011. Publication of the ground-breaking *Lancet* Series on maternal and child nutrition was to follow 2 years later.



Welcome

Ten years ago, introducing issue 1/2011 of *Sight and Life* magazine, I concluded with the observation that “the magazine is produced not for us but for you, the reader.”

In the intervening decade, nothing has required that sentence to be changed. Since celebrating our 25th anniversary in 2011, we have continued to combine scientific rigor with accessibility, publishing evidence-based findings and opinions about some of the most influential developments shaping the global nutrition agenda. It has always been our ambition to remain ahead of the curve in an arena that continues to experience tremendous change. Our readers can assess the degree to which we have succeeded by revisiting the contents of this special 35th anniversary issue and exploring the up-to-the-minute reflections of their respective authors.

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“It has always been our ambition to remain ahead of the curve”

.....

Creating this anniversary issue

In deciding how to shape this issue of the magazine, we were guided by a number of considerations. Reasons of space precluded us from republishing a huge number of contributions that might easily have taken their place among these pages. Reasons of clarity encouraged us to republish just one contribution from each year since 2011. Considerations of continuity prompted us to select the work of authors who are still active in the field in which they worked when we published their original contributions. We also felt it inappropriate to select any material penned by members of the *Sight and Life* team itself. By this means, and through considerable reading, reflection and discussion, we arrived at the selection that makes up this anniversary issue. I am all too aware of the many outstanding contributions that we were obliged to leave out of this issue, and would like to express my deep appreciation to all the contributors who have made the past decade of *Sight and Life*

magazine possible, whether or not their work appears in the present publication.

Our contributors

To the contributors whose work is republished here, a special word of thanks is of course due. It was decided to republish the original articles verbatim, without any updates, additions or corrections, but to supplement the republished pieces with a personal perspective written from the vantage point of 2021. This allows each writer, or team of writers, to reflect on the significance of the original work and the import of new findings that may have been gathered since that work first appeared in print. I very much hope that the resulting issue therefore functions as much more than a showcase for the cutting-edge scientific thinking we have published during the past 10 years; I hope it provides our readers with a compelling view of some of the key issues that we as a nutrition community must tackle in the years ahead, and that it also outlines some of the important tools and methodologies that are now available for the purposes of addressing those challenges.

Milestones

Ten years ago saw the founding of the Scaling Up Nutrition (SUN) Movement, which has done so much to bring the global nutrition community together in ways that would have been previously unimaginable. Our infographic on pages 8–9 charts some of the key moments in the global nutrition agenda of the past 10 years, mapping these against some of the key milestones that *Sight and Life* itself has attained, including the inauguration of the *Sight and Life* Global Nutrition Research Institute at Johns Hopkins University, our re-establishment as an independent Swiss foundation, the creation of our Elevator Pitch Contest for innovative new ideas in food and nutrition, and the launch of our Special Report series. We have covered topics that were simply not on the global nutrition agenda in 2011, including omics innovations and applications, global data visualization tools, and the capacity of social marketing to exert a positive influence on nutrition

behaviors. In presenting this sample of our recent activities, we make no claim to comprehensiveness. Just as we have had to omit the work of many contributors, we have also had to leave out numerous topics that still have an urgent claim on our attention. My hope, however, is that this issue of the magazine will inform, encourage and inspire, and that those who read these pages may make a further contribution of their own to some of the excellent work portrayed here.

.....
**“My hope is that this issue
of the magazine will inform,
encourage and inspire”**
.....


Thanks

I am delighted that this issue also carries an interview with our current and former Chairs of the Board of Trustees of *Sight and Life*, Chris Goppelsroeder and Eileen Kennedy. I am, as ever, grateful for their expertise, insights and support, and would like to thank both them and the entire Board of Trustees for their untiring efforts to guide *Sight and Life's* continuing evolution. I am likewise grateful to the donors who have shown their faith in us over the years and have made it possible for us to exist and grow as an organization. A very special word of thanks

is due to our many colleagues around the world who have been so kind as to provide their very generous testimonials on the occasion of our 35th anniversary. We publish them here with warm appreciation. Last but not least, I would like to add a word of thanks to our global *Sight and Life* team itself, and to everyone who has helped the editorial and production process that has made all the publications of the past decade possible.

I hope you will enjoy this anniversary issue. Just as I wrote in the introduction to the first issue of 2011, your feedback on the magazine, and on our work as a whole, is always extremely welcome.

Best wishes,



Klaus Kraemer

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Check out our NEW website and podcast

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We are celebrating an exciting development in your online experience! In 2021, we launched a state-of-the-art website with fresh and thought-provoking content and an improved user experience. We added features such as digital object identifiers (DOI) and Altmetric to discover and monitor our publications better.

Now you can easily find valuable new resources such as our BrainFood podcast and more than 60 magazines and special reports published by *Sight and Life* on diverse and important topics from women's nutrition to data and food systems.

Visit sightandlife.org for the latest news and learn more about the innovative work happening at *Sight and Life*.

“Backed by science and strong alliances, *Sight and Life* has spurred important innovations in nutrition programmes over the last decade. UNICEF thanks *Sight and Life* for a history of fruitful collaboration and looks forward to joint endeavours so that all children, adolescents and women realize their right to nutrition.”

Victor Aguayo | Director, Nutrition and Child Development, UNICEF | New York, NY, USA

“The critical importance of nutrition as a central part of the global development agenda has been recognised, particularly over the past 15 years. *Sight and Life* has played a critical role in this change, linking up-to-date and top-quality science with effective advocacy, to bring about improved nutrition for millions of people.”

Tom Arnold | Special Envoy for Food Systems, Irish Government; Formerly Coordinator, Scaling Up Nutrition (SUN) Movement; Chief Executive, Concern Worldwide | Republic of Ireland

“Like many others, I rely on *Sight and Life*’s eponymous magazine to keep me abreast of practical, evidence-based trends in public nutrition. Moreover, *Sight and Life*’s programs at the intersection of evidence, nutritional impact, and economic sustainability are pioneering compelling models of harnessing capitalism to benefit human nutrition.”

Reed Atkin | Senior Strategic Advisor, Micronutrient Forum | Washington, DC, USA

“*Sight and Life* sits at the cutting edge of international nutrition: quick to identify the ‘next big thing’, securing top contributors on each topic, and satisfying the needs of eclectic audiences, the terrific team and its magazine are technical enough to keep researchers engaged while at the same time being accessible to NGOs, media and health workers. Overall, a superb resource.”

Gilles Bergeron | Senior Vice President, Nutrition (retired), New York Academy of Sciences | New York, NY, USA

A FURTHER DECADE OF HELPING TO

2011



Intrauterine Programming of Non-Communicable Disease: Role of Maternal Micronutrients

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The Challenges of Scaling Up Multiple Micronutrient Interventions



2015

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Iodine Nutrition in Africa: an Update for 2014



2012



Ritual Fluids in Relation to Early Child Nutrition in Quetzaltenango, Guatemala

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2014



Newborn Vitamin A Dosing is Feasible in Bangladesh

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Key themes in a decade of nutrition thought leadership

- Nutrition interventions
- Food fortification
- Scaling up nutrition
- Nutrition science
- Implementation science
- Social marketing

2011

Building bridges for better nutrition.

MILESTONES AT

Sight and Life celebrates 25 years of service to science and humanity

Sight and Life celebrates the centenary of the discovery of vitamins

Dr Robert Black, Chair of the *Lancet* Maternal and Child Nutrition Study Group, receives the 2nd *Sight and Life* Nutrition leadership award

Inauguration of the *Sight and Life* Global Nutrition Research Institute at Johns Hopkins University

Sight and Life re-establishes itself as a Swiss foundation

2011



Foundation of the Scaling Up Nutrition (SUN) Movement

2012



World Health Assembly (WHA) comprehensive implementation plan on maternal, infant and young child nutrition

2013



Lancet Series on maternal and child nutrition

2014

Publication of inaugural Global Nutrition Report

2015



Conclusion of Millennium Development Goals (MDGs) and launch of Sustainable Development Goals (SDGs)

KEY MOMENTS IN THE

DRIVE THE GLOBAL NUTRITION AGENDA

2017

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Omics Innovations and Applications for Public Health Nutrition: An integrated view



2019

Global Data Visualization Tools to Empower Decision-Making in Nutrition

PAGE 114



2018

PAGE 103

An Innovation Evolution: Why one of the world's most cost-effective tools in the fight against malnutrition still needs innovation



2016

Cracking the Egg Potential During Pregnancy and Lactation

PAGE 75



2020

Social Marketing to Sustainably Influence Nutrition Behaviors: Nutri'zaza's strategy for triggering adequate consumption of complementary foods to prevent malnutrition in Madagascar

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SIGHT AND LIFE

A world free from malnutrition.

Translating Science. Nurturing Lives.

2021

Sight and Life co-edits *Good Nutrition: Perspectives for the 21st century*

Sight and Life co-edits *The Biology of the First 1,000 Days*

Sight and Life stages its second Elevator Pitch Contest

Sight and Life launches egg.hub.org as a one-stop resource on egg consumption and production in LMICs

Sight and Life publishes Special Report on MMS

Sight and Life publishes Special Report on Nutrient Profiling

2016



Proclamation of United Nations Decade of Action on Nutrition, 2016-2025

2017



Global Nutrition Summit, Milan, Italy

2018



EAT Stockholm Food Forum

2019



Launch of 'Accelerators' (new partnerships) at third annual Goalkeepers event in New York City, NY, USA

2020

COVID-19 pandemic undermines nutrition across the world, particularly in low-income and middle-income countries (LMICs)

2021



United Nations Food Systems Summit, New York City, NY, USA

GLOBAL NUTRITION AGENDA

A Unique Position and a Unique Responsibility

Interview with Eileen Kennedy and Chris Goppelsroeder

In 2021, **Eileen Kennedy**, Professor and former Dean of the Friedman School of Nutrition Science and Policy at Tufts University, stepped down from her role as inaugural Chair of the Board of Trustees of *Sight and Life*. She was succeeded by **Chris Goppelsroeder**, who retired from his position as President and CEO of DSM Nutritional Products in the same year. Together, they look back on *Sight and Life's* achievements of the past 35 years – and ahead to the key challenges facing the Foundation today.

Sight and Life (SAL): Eileen, you have been associated with *Sight and Life* for many years, even before you became Chair of the *Sight and Life* Board of Trustees when that body was first created. From your perspective, what is the significance of *Sight and Life* in the global nutrition space?

Eileen Kennedy (EK): I would say that *Sight and Life* occupies a unique position through its focus on linking nutrition science to action. I remember Kofi Annan, the former Secretary-General of the United Nations, once remarking that the world is replete with interventions that stay on the shelf. *Sight and Life* really does deliver impact, however, and the Foundation's work is of an extremely high standard.

SAL: How would you assess the way *Sight and Life* has changed since its creation in 1986?

EK: It's a classic example of an organization that has repeatedly reinvented itself to remain successful. *Sight and Life* was founded 35 years ago on the basis of a deep scientific understanding of the importance of micronutrition, and has always had a clear strategic vision. That vision has of course evolved over the course of the years, and particularly in the past decade, to recognize important developments such as our contemporary understanding of nutrient–genome interactions and global food systems. *Sight and Life* is an extremely responsive and adaptable organization.

“*Sight and Life* is an extremely responsive and adaptable organization”

SAL: *Sight and Life* became a Swiss foundation in 2015, having been originally supported by Roche from 1986 to 2003 and by DSM from 2003 to 2015. In what ways has its status as an independent foundation allowed it to pursue its strategic objectives and deliver on its mission in recent years?

EK: I see this as a very natural evolution. *Sight and Life* was initially created as a ‘Task Force’ to help address the humanitarian crisis of the Ethiopian civil war of the mid-1980s. The Task Force's work was soon seen to have a relevance far beyond that particular conflict, however, and so it continued as an expanded ‘initiative’ under the umbrella first of Roche and then of DSM. DSM was a very generous donor and gave *Sight and Life* new opportunities to grow, but the organization's status today as an independent foundation allows it to interact with a much wider range of potential allies and collaborators. This wider freedom to act will be essential in taking *Sight and Life* to the next level.

SAL: You've stepped down from the role of Chair, Eileen, but you remain a member of the Board of Trustees of *Sight and Life*. What are your hopes for the next decade of the Foundation's evolution?

EK: I have no doubt that *Sight and Life* will continue to champion the fight against global malnutrition, developing innovative responses to the ever-changing nutrition landscape, demonstrating thought leadership in nutrition science and programming, and yet further increasing its power to deliver positive change.

SAL: Chris, after a highly successful career in business, what attracted you to the role of Chair of the Board of Trustees of *Sight and Life* Foundation?



Eileen Kennedy



Chris Goppelsroeder

Chris Goppelsroeder (CG): Before I answer that question, let me say how much I'd like to thank Eileen for her leadership. It was Eileen's profound understanding of governance that created the structures that made it possible for *Sight and Life* to become the viable foundation that it is today. And I'm also very glad that you're remaining on the Board, Eileen!

In terms of my own motivation, I knew a great deal about micronutrients from my role at DSM and prior to that at Roche. However, my work had always focused more on the developed rather than the developing world. I've had a very fortunate existence, and I'm very aware of that fact. Being able to give something back through my new role at *Sight and Life* is a great opportunity and fills me with a lot of happiness. The COVID-19 pandemic has intensified the exposure to malnutrition suffered by a huge proportion of the world's population today, and so the work of the Foundation is more important than ever. I'm very excited at our potential for making an even bigger impact in future.

“The work of the Foundation is more important than ever today”

SAL: *Your last position was as President and CEO of DSM Nutritional Products, one of the world's leading producers of essential nutrients such as vitamins, carotenoids, nutraceuticals and nutritional lipids, as well as solutions for the feed, food, pharmaceutical and personal care industries. How will your experience in that role inform your work at Sight and Life, Chris?*

CG: DSM is the global leader for micronutrients. That leading position entails a profound responsibility. It's not my role to try to replicate the things that I know *Sight and Life* is already doing outstandingly well. I bring different things to the party – the

entrepreneurial expertise of decades in international business and an extensive global network of contacts within the nutrition space. These additional factors can be used to multiply *Sight and Life's* impact. And, when you look around at the problem of malnutrition in the world today, that's what is needed: real impact on the ground.

SAL: *An anniversary is a time to look back but also a time to look forward. Are there ways in which you'd like to see Sight and Life evolving in the coming years?*

CG: At *Sight and Life*, we have an excellent think tank and some piloting capabilities when it comes to understanding problems and mapping out responses to them. What we haven't always been able to do is to implement some of these concepts ourselves. That's been a consequence of our current size and reach. We need to make a step change and try to deliver more impact where it's needed in the world. That means evidence-based programs that can be scaled up to deliver measurable improvements, addressing malnutrition and its consequences and helping people to live healthier and better lives. In other words, we should focus on helping people to help themselves – creating effective business models on the ground to fight malnutrition sustainably. We need now to extend *Sight and Life's* global reach by means of thorough piloting capabilities and then scale-up of innovative new approaches, working together with partners.

SAL: *Can you give us an example, Chris?*

CG: Yes, a good example of this is Eggonomics, a corporate social responsibility project to reduce child malnutrition in which *Sight and Life* and DSM joined forces with two mid-sized egg producers, Nutricorp in Peru and Golden Birds in Brazil. Together with DSM, each of these partners set up and trained a sizeable

number of small local farmers in their remote areas, so that they themselves can produce eggs at dramatically higher productivity levels than normal backyard farms. Simultaneously and with the help of *Sight and Life*, women in those same local communities were educated as to the micronutrient and protein benefits of eggs especially for the development of younger children, thus increasing demand for eggs. I am proud to report that in its first year, 2021, this collaboration produced and sold more than five million eggs – supporting the development of around 25,000 children. It takes innovative ideas, courage and capable partners to find unique new ways of delivering impact where it’s most needed.

.....
“We need to find unique new ways of delivering impact where it’s most needed”
.....

SAL: *A question for you both. How would you assess the achievements of Klaus Kraemer since he first took over at the helm of Sight and Life in 2005?*

EK: Klaus is brilliant, charismatic and extremely tenacious. His leadership of *Sight and Life* has been very effective, especially during difficult times.

CG: I completely agree. On top of that, Klaus has broadened the scope of *Sight and Life*, expanding its product range, innovating its business model, and building an influential network of peers and non-governmental organizations. Klaus is extremely modest, but there’s far more to him – and to *Sight and Life* itself – than meets the eye.

EK: That’s true. Klaus commands enormous respect among the global nutrition community, and people are always surprised when they find out how small the organization actually is.

SAL: *What are your feelings about Sight and Life magazine itself?*

EK: It’s very widely distributed and used, especially in low- and middle-income countries, and I know that it’s always been extremely popular with my graduate students. I believe that it may have become more attractive to contributors over the course of the years. It has a wonderful stable of authors.

CG: Yes, it’s very important for its peer group, no doubt. To achieve what we set out to achieve, however, we must build on the strong science narrative *Sight and Life* has created over the years and communicate beyond its peers to much wider con-

stituencies. It’s important to report not only on what we’ve done but also on how we’ve done it and how this can be scaled up. We need to reach out to new potential donors and also to work with other NGOs around the world to get things done. And their voices need to be reflected in our communications, too.

SAL: *Do you have a final message for our readers?*

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EK: I think the work of *Sight and Life* has become more and more relevant over time, and with relevance comes impact. I’m sure that the organization will continue to build on its strengths and that future generations will build yet further on Klaus’s achievements.

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CG: Absolutely. And I think this is the moment to thank all of our readers, who have given *Sight and Life* so much encouragement over the years. Without their support, the history of *Sight and Life*’s first 35 years would not have been possible.

.....
“This is the moment to thank all of our readers”
.....

SAL: *Thank you, Chris, thank you, Eileen, and the best of luck with what lies ahead for Sight and Life!*

EK: Thank you.

CG: Thank you.

.....
Eileen Kennedy and Chris Goppelsroeder were interviewed by Jonathan Steffen.
.....

New at *Sight and Life*



The *Sight and Life* Podcast: BrainFood

We all have to eat! We've created a place for you to come, kick back and get the latest scoop on nutrition. Join us for an exciting ride as we set you up with the full scope of our *Sight and Life* projects, voices from the field and cutting-edge research. We don't stop there – we take your hard-hitting questions on the latest nutrition trends and hot topics and get the answers straight from the experts.



The *Sight and Life* Eggciting Program

Sight and Life is working to address supply and demand side challenges to egg affordability and accessibility globally. We are devoted to increasing egg production and egg consumption around the world. Our efforts are already helping children and families to access the high-quality protein and nutrition found in eggs.

Through our Eggciting Program we are making shell eggs available and affordable to low-income households through innovative poultry business models in Bangladesh, Ethiopia, India, Indonesia, Kenya and Malawi. We are also piloting new innovations in egg production, egg-based products, models, tools and approaches to address protein and micronutrient malnutrition during pregnancy, infancy, and adolescence. Visit egghub.org for in-depth information.

Resource Hub

Visit our Resource Hub at sightandlife.org for further news, insights, data and communication tools.

FIRST PUBLISHED IN:

Vol. 25 (2) 2011
PP. 16–22



Intrauterine Programming of Non-Communicable Disease:

Role of Maternal Micronutrients

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and Research Centre,
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Introduction

Two thirds of all deaths in the world are due to non-communicable diseases (NCDs), and 80% of NCD deaths occur in low- and middle-income countries.¹ Cardiovascular diseases, obesity and type 2 diabetes (T2D) are the major contributors to the global burden of NCDs. Studies in the life course evolution of these chronic diseases have highlighted an etiological role for factors which govern intrauterine and post-natal growth. Research in this field could offer a novel solution to the “primordial” prevention of conditions which are the most prominent killers in today’s world.

These novel ideas arose from a series of studies by David Barker and his colleagues in the UK. They proposed that intrauterine undernutrition initiated a number of adaptations in the fetus which increased disease susceptibility in later life, especially when post-natal nutrition tended to be “excessive”.² A developing fetus has the ability to grow in different ways depending on the surrounding (intrauterine) environment; this ability is called the “plasticity”.³ An unfavorable environment restricts the ability of the fetus to grow “wildly” and causes a permanent structural or functional change, known as “programming”.⁴ India is the world’s capital of low birth weight (LBW) babies, while at the same time it is evolving into one of the economic powers of the world. It was clear that research in India would shed important light on these new and exciting ideas.

Fetal nutrition, growth, birth size and programming

The original ideas in this field were based on birth weight, for which there is a large database. However, it was clear from the beginning that birth size was only a proxy for factors which affect fetal growth. These include genetic factors, maternal size, and intrauterine environment. Birth weight is not a sensitive indicator of intrauterine nutrition, nor is it specific for nutrition.⁵ Animal experiments show that a brief nutritional disturbance in early pregnancy permanently alters fetal physiology without any effect on birth size.⁶ Thus, birth weight studies helped focus attention on intrauterine life as an important determinant of future health, but the excitement will focus on defining the environmental factors which are the “true exposures” in this association. This is where the current research is being directed.

Possible mechanisms of programming

Fetal growth and development are influenced by an interaction between genetic factors and the intrauterine environment. This was beautifully shown with reference to the interaction between the glucokinase gene and maternal hyperglycemia.⁷ The birth size of the newborn is influenced not only by inheritance of the gene, but also by maternal glycemia.

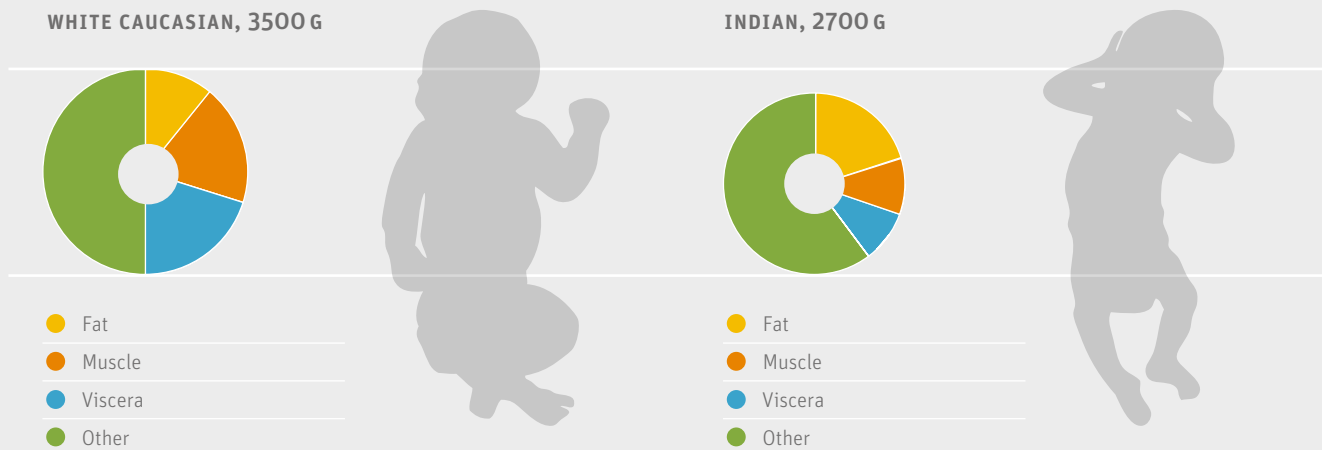
Fetal programming can be manifested in various ways. It might affect size, body composition, systems, organs and cells. It also affects physiology, sometimes without affecting size. Changes include altered setting of different enzyme systems and resetting of the endocrine axes. Endocrine mechanisms are major contributors to programming. Insulin-IGF (insulin-like growth factor) and the hypothalamic-pituitary-adrenal axis have been shown to be prominently affected.⁶

It is increasingly being appreciated that epigenetic changes are at the center of programming. These changes may be mediated by methylation of DNA, acetylation of histones and through the role of micro RNAs, all of which modify gene expression.^{8,9}



“Epigenetic changes are
at the center of programming”

FIGURE 1: Thin-Fat Indian Baby. A schematic diagram to compare the body composition of Indian and white Caucasian babies. Indian babies were ≈ 800 g lighter, muscle thin but more adipose compared to the white babies.^{5,21}



The role of DNA methylation in influencing the phenotype of a growing fetus has been well demonstrated in animal models. Feeding pregnant *Agouti* mice with a methylating cocktail (vitamin B₁₂ + folate + betaine + choline) changes the coat color and reduces obesity, despite inheritance of the mutation.¹⁰ The change in phenotype is linked to methylation in the promoter region of the *Agouti* gene, which silences it.

Evidence from Pune studies

Research at the Diabetes Unit, King Edward Memorial Hospital, Pune has made important contributions to programming research. Our original observation was that diabetes occurred in Indians at a much lower body mass index (BMI), as compared to Europeans, and that this could in part be due to their higher central obesity and higher body fat percent, or adiposity.¹¹ This led to the “thin-fat” Indian concept. Many suggested that this was “genetically” determined, but we have not found any major differences in genetic associations of T2D in Indians compared to Europeans.¹² In 1991, we joined David Barker and Caroline Fall in their “fetal origins” research. The first collaborative research (Pune Children Study) confirmed that low birth weight was associated with insulin resistance as early as four years of age,¹³ and that children who were born small but grew big in childhood had the highest level of risk factors for diabetes and cardiovascular disease.¹⁴ We realized that intrauterine undernutrition could be an important contributor to the risk of adult disease. At the same time, we knew that fetal overnutrition (as in maternal diabetes) also increases the risk of obesity and diabetes in the child.¹⁵ The stage was set to investigate the factors influencing fetal growth and programming. This was the birth of the Pune Maternal Nutrition Study (PMNS).

The PMNS was established between 1993 and 1996 in six villages near Pune, to investigate the influence of maternal body size and nutrition during pregnancy on fetal growth and its future metabolic risks.¹⁶ We also investigated the fathers’ contributions. Over 800 pregnancies were studied. Children were visited every six months for anthropometric measurements, and parents and children were investigated every six years for a detailed assessment of body composition, cardio-metabolic risk factors and neurocognitive development.

Predictors of fetal growth and birth size

Fetal growth and size are influenced by genes, parental body size, maternal nutrition and the mother’s metabolic and vascular competence during pregnancy. Our measurements were guided by McCance’s writings of over 50 years ago: “The size attained *in utero* depends on the services which the mother is able to provide; these are mainly food and accommodation.”¹⁷ We assessed maternal nutrition via anthropometric measurements, nutrient intake and physical activity, and by measurement of circulating nutrient levels.

Maternal body size, body composition and weight gain during pregnancy

The average mother in the PMNS was 21 years old, weighed 42 kg (BMI 18.1 kg/m²), and ate $\approx 1,700$ kcal and 45 g proteins per day during pregnancy. The newborns weighed on average 2,700 g with a ponderal index (PI) of 24.1 kg/cm³; 28% were LBW (<2,500 g).¹⁸

Babies of heavier mothers were larger in all aspects, and babies of taller mothers were longer. Maternal fat measurements influenced the baby’s weight and skin folds. It is interesting that

paternal size predominantly influenced skeletal measurements, while the baby’s adiposity was predominantly determined by maternal factors. Short and fat mothers gave birth to the most adipose babies, suggesting an intergenerational influence of maternal early life “growth retardation” and the mother’s subsequent weight gain on body composition of the growing fetus.¹⁷ One more interesting finding was that babies born to multiparous women had higher skin folds and a higher abdominal circumference than those born to primiparous women.¹⁹

.....
“A gain in maternal tissue during early weeks is an important determinant of fetal growth”

Maternal weight gain during the first 18 weeks influenced all neo-natal measurements, indicating that a gain in maternal tissue during early weeks is an important determinant of fetal growth. Placental volume measurement at 18 weeks’ gestation was also an independent determinant of fetal growth, highlighting the role for this important organ.²⁰

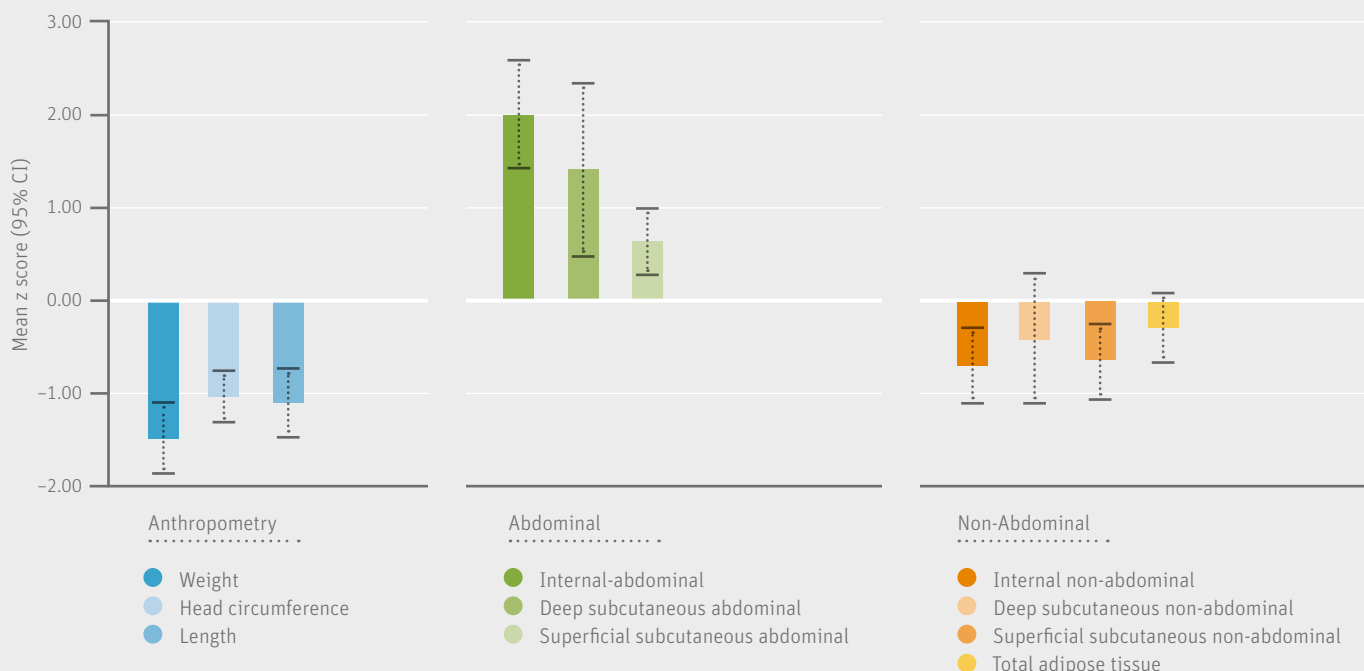
The “thin-fat” Indian baby

We compared the birth measurements of Indian babies with those of white Caucasian babies born in Southampton, UK. Indian babies were lighter (2.7 vs. 3.5 kg, z score -1.74), shorter (47.3 vs. 50.2 cm, z score -1.01) and thinner (PI 24.5 vs. 28.2 kg/cm³, z score -1.62), but their sub-scapular skin fold measurements were relatively well preserved (4.2 vs. 4.6 mm, z score -0.53). At any sub-scapular skin fold thickness, Indian babies had a lower PI than that of the white Caucasian babies.²¹

In a subsequent study, we used whole body MRI to calculate body fat and its regional distribution in neonates. Compared to the larger white Caucasian babies, the Indian babies had similar whole body adipose tissue content (“thin-fat”) and significantly higher absolute adiposity in all three abdominal compartments, viz internal (visceral), deep subcutaneous and superficial subcutaneous. Non-abdominal superficial subcutaneous adipose tissue was, however, lower.²² Thus, Indian babies are more adipose and have a fat distribution that is suggestive of a higher risk of diabetes, as compared to white Caucasian babies.

(Figures 1 and 2)

FIGURE 2: *Thin-Fat Indian Baby.* Anthropometry and MRI comparison of Indian and white Caucasian babies. Despite their anthropometric smallness, Indian babies had a higher amount of fat in subcutaneous and visceral abdominal compartments. White Caucasian babies are used as reference, and z scores for Indian babies are plotted.²² This figure is not to scale. The figure highlights relative adiposity of Indian newborns.



Maternal nutrition during pregnancy

In the PMNS, we measured maternal macronutrient and micronutrient nutrition, with special attention to one-carbon (1-C, methyl) metabolism, which is crucial for cell growth, differentiation and development. Maternal energy and protein intake was not associated with birth size; fat intake was weakly associated. On the other hand, the intake of micronutrient-rich foods (green leafy vegetables, milk and fruits) had a substantial effect on fetal growth. Maternal erythrocyte folate concentrations and vitamin C concentrations predicted larger neonatal size; vitamin B₁₂ was not predictive.¹⁶ Maternal plasma homocysteine concentrations predicted smaller birth weight.²³ Our results suggested an important role for micronutrients, especially for maternal 1-C metabolism in fetal growth and its body composition. (Figure 3)

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“The intake of micronutrient-rich foods had a substantial effect on fetal growth”

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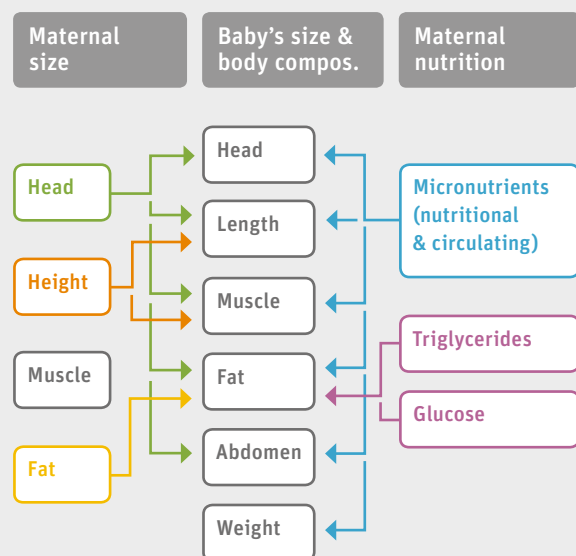
Adipocytes – more than a bag of fat: the role of adipocytokines

It is remarkable that the human newborn has the highest body fat percentage (≈15%) of all mammals, including pigs (≈2%) and sea lions (≈5%).²⁵ The significance of this fact is yet to be established, but it suggests that neonatal adipose tissue must have a significant role in survival. Until recently, adipose tissue was considered only to be a storehouse for triglycerides, to provide energy and mechanical and thermal insulation. We now know that it is the biggest “endocrine organ” in the body. The amount and distribution of adipose tissue influence a wide variety of physiological functions and also predispose to a variety of clinical disorders. Adipocytes secrete a number of molecules called “adipocytokines”. These influence food intake and energy metabolism, the insulin sensitivity of tissues, vascular reactivity, blood clotting mechanisms and, importantly, regulate “innate inflammation”. A growing number of adipocytokines are being discovered and ascribed crucial physiological roles.²⁶ This represents a novel link between diet, physical activity and susceptibility to a number of non-communicable disorders.

We studied one such adipocytokine, leptin, in newborn Indian and white Caucasian babies. Cord leptin concentrations (median: 6.2 ng/mL, Pune; 6.4 ng/mL, London) were comparable in the two groups, but higher in Indian babies when adjusted for the difference in birth weight.²⁷ Thus, the excess adiposity of the Indian babies was reflected in functional disturbances indicative of an increased risk of diabetes and related disorders.

Recently, there has been interest in other adipocytokines which influence insulin resistance and, therefore, the risk of dia-

FIGURE 3: Maternal size and nutrition influence baby’s size and body composition. Maternal head circumference (a surrogate for early life growth and nutrition) is related to neonatal size, her height is related to neonatal length and muscle, and fat to neonatal fat. Maternal dietary and circulating micronutrients (folate and vitamin C) influence neonatal size, circulating glucose and triglycerides are predominantly related to neonatal fat.^{16,24}



betes. These include adiponectin and retinol-binding protein 4 (RBP4). Adiponectin has the highest circulating concentration of all the adipocytokines and influences insulin resistance, inflammation and other cardiovascular risk factors.²⁸ Low adiponectin is an important risk factor for diabetes. RBP4 transports circulating retinol and is synthesized in liver and adipose tissue. It reduces insulin sensitivity and affects glucose metabolism.²⁹ There is scant information on adiponectin and RBP4 concentrations in cord blood.

We measured adiponectin and RBP4 concentrations in stored cord blood samples, and investigated their associations with maternal size, nutrition and metabolic parameters and newborn size. Adiponectin and RBP4 concentrations in cord blood were lower compared to the published data on western newborns. Maternal calorie, fat and protein intake and the mother’s body size were not related to cord adiponectin and RBP4 concentrations. Both adipocytokines were positively associated with the baby’s body composition (adiponectin with neonatal length, and RBP4 with sum of skin folds). Cord RBP4 was positively associated with maternal intake of vitamin A rich foods, suggesting that maternal vitamin A status may influence fetal adipocyte functioning. Longitudinal follow-up of these associations is ex-

pected to reveal the long-term effects of maternal nutrition on adipocyte functioning in offspring.

Follow-up of the PMNS children

The Developmental Origins of Health and Disease (DOHaD) theory suggests that structural and functional changes in the fetus consequent upon maternal nutritional, metabolic and other influences persist in later life. There are not many human studies linking maternal nutrients with offspring body composition and risk factors for NCD. Design of the PMNS allows us to follow up the children and study the effects of fetal programming.

We found that a child's adiposity (DXA) and insulin resistance, the two major risk factors for future diabetes, were significantly related to maternal micronutrient nutrition, especially those nutrients which regulate 1-C metabolism. Maternal folate concentrations were directly related to the adiposity of the child at six years of age, and also to insulin resistance. On the other hand, low maternal vitamin B₁₂ status predicted higher insulin resistance. The most insulin resistant children were born to mothers who had the lowest vitamin B₁₂ but highest folate status.³⁰

In addition, we found that maternal vitamin B₁₂ and folate predicted a child's neurocognitive function, suggesting that the 1-C metabolism of the mother also programs the child's brain development and function.³¹

.....
“Our research suggests that an imbalance in vitamin B₁₂ and folate nutrition and consequent disturbances in maternal 1-C metabolism may contribute to the epidemic of adiposity and T2D in India”

In the PMNS, two-thirds of mothers had low vitamin B₁₂ (<150 pmol/L) status during pregnancy, and a third had raised tHcy concentrations (>10 µmol/L). Folate deficiency was rare.²⁹ This nutrient pattern is at least partly ascribable to vegetarian food habits and partly to the prescription of folic acid by obstetricians. Our research suggests that an imbalance in vitamin B₁₂ and folate nutrition and consequent disturbances in maternal 1-C metabolism may contribute to the epidemic of adiposity and T2D in India.

Folate and vitamin B₁₂ are the major methyl donors in diet, and methylation of DNA is one of the major mechanisms of regulation of gene expression (epigenetics). Methylation silences the genes and affects the phenotype. It will be important to study how an improvement in the maternal nutrition of these nutrients

influences the growth of a fetus and its future health and susceptibility to disease. This will be a step forward in the “primordial prevention” of diabetes and other NCDs.

.....
“Future research should target the option of intervening in the young to influence the intergenerational transmission of health”

Summary

Recent developments in the field of DOHaD have thrown an interesting light on the life-course evolution of many of the chronic NCDs. It is becoming increasingly obvious that a substantial proportion of adult health is programmed *in utero*. The health of young girls in a community is of paramount importance and is a major influence on the health of the next generation. Maternal micronutrient nutrition contributes to the fetal programming of NCDs. Current ideas on preventing NCDs in the middle-aged and the elderly via difficult-to-perform lifestyle adjustments are very ineffective models. Future research should target the more promising option of intervening in the young to influence the intergenerational transmission of health. Balanced micronutrient nutrition of young mothers may be the key.

Acknowledgements

We are funded by the Wellcome Trust (London, UK); the Nestlé Foundation (Lausanne, Switzerland); The International Atomic Energy Agency (Vienna, Austria); the Department of Biotechnology (DBT), Government of India (New Delhi, India); and *Sight and Life*, Basel, Switzerland. Thanks are due to colleagues, collaborators, field workers, and parents and children who participated in the studies mentioned in this article.

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Perspective from 2021

Observations & Interventions in Micronutrient Research in Pune, India

Chittaranjan Yajnik

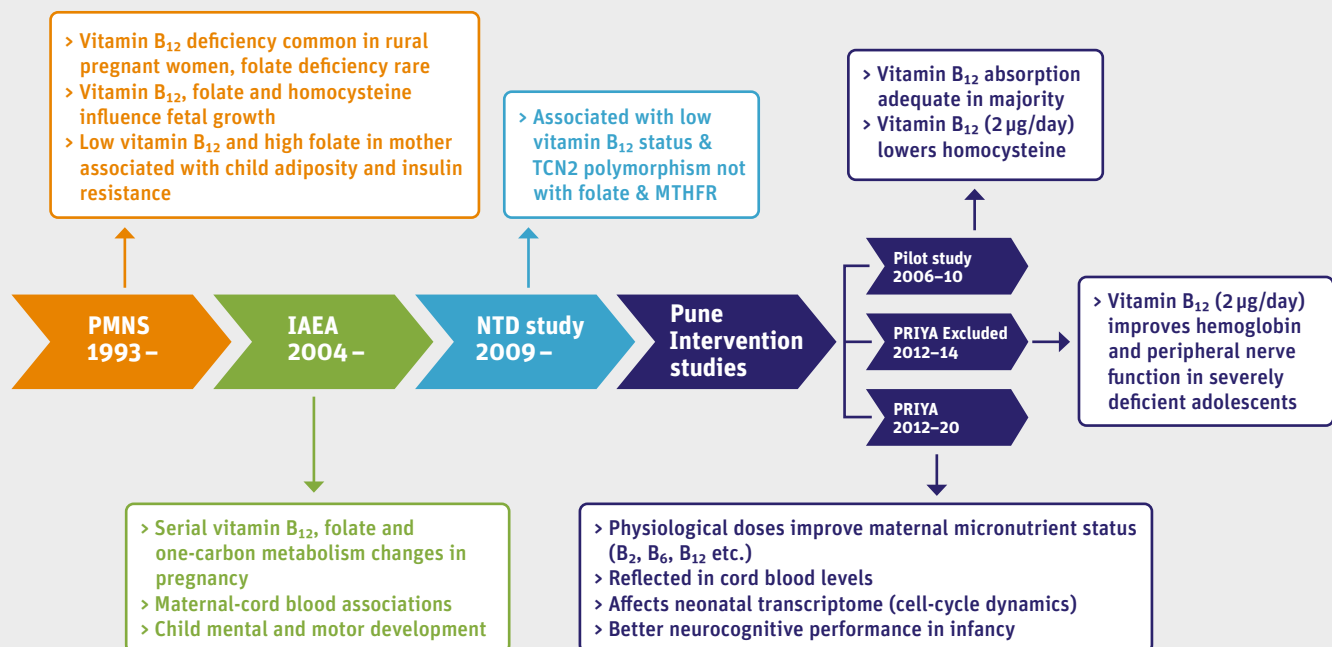
Diabetes Unit, King Edward Memorial Hospital and Research Centre, Pune, India

Exciting research has happened in Pune since the publication in 2011 of our review on the role of maternal micronutrients

in intrauterine programming of non-communicable diseases.¹ This research is summarized in **Figure 1**.

We have completed a preconceptional micronutrient intervention in adolescents with the aim of improving the health of their offspring. This randomized controlled trial was based on our findings in the Pune Maternal Nutrition Study, and is called the Pune Rural Intervention in Young Adolescents (PRIYA)

FIGURE 1: Overview of studies in the Diabetes Unit, King Edward Memorial Hospital, Pune, over the past 10 years



Key

PMNS: Pune Maternal Nutrition Study

IAEA: International Atomic Energy Agency; observational study for vitamin B₁₂ levels in pregnant women

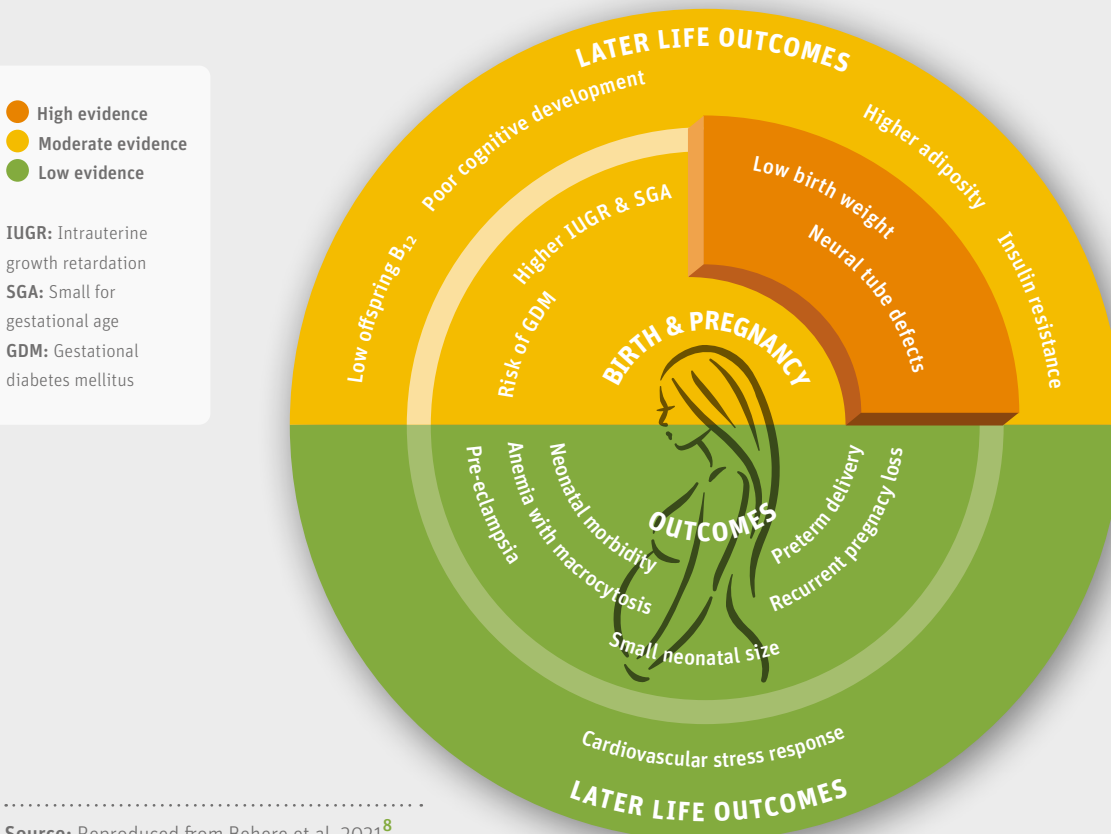
NTD study: Maternal nutritional and genetic determinants of neural tube defects

Pune Intervention studies: Include vitamin B₁₂ absorption study, a pilot trial of vitamin B₁₂ intervention and the PRIYA (Pune Rural Intervention in Young Adolescents) study, a preconceptional randomized controlled trial of vitamin B₁₂ and multi-micronutrients

TCN2: Transcobalamin 2

MTHFR: Methylene tetrahydrofolate reductase

FIGURE 2: Summary of evidence for the association of low maternal vitamin B₁₂ status and different outcomes during pregnancy and later life



study. Interventions included: (1) vitamin B₁₂ alone; (2) vitamin B₁₂ with multi-micronutrients and milk powder; and (3) placebo. The vitamin B₁₂ dose was 2 µg/day, to make it relevant in terms of physiology and public health. All groups received iron and folic acid as per the Indian national policy.² A total of 557 adolescents (17 years of age, 291 boys and 266 girls) were enrolled; those with very low vitamin B₁₂ levels were excluded and treated. Participants were carefully followed up to record marriages and pregnancies, and deliveries were attended to study neonatal outcomes. Very few of the boys married; by contrast, 182 of the girls married and 149 of them delivered a live child during the trial.

Increase in circulating concentrations of vitamin B₁₂

A rewarding increase in circulating concentrations of vitamin B₁₂ and a fall in homocysteine were observed after the intervention. The effects persisted during pregnancy. Cord blood concentrations paralleled maternal vitamin status. Anthropometric measurements were similar in the three groups of babies, but there was an intergenerational increase in birth size (compared with the mother's) except for skinfold thickness – i.e., there was a relative reduction in adiposity. Transcriptomic study of cord blood

revealed alterations in the cell-cycle dynamics in babies born in the vitamin B₁₂ + multi-micronutrient group,³ while babies born in the vitamin B₁₂ alone group showed a better neurocognitive performance.⁴ This is one of the first demonstrations of influencing offspring outcomes by a preconceptional physiological dose supplementation in adolescents and warrants further follow-up of the babies to document later cardio-metabolic outcomes. It also highlights a need for including vitamin B₁₂ in preconceptional nutrition of women in vegetarian populations such as those in India.

“This is one of the first demonstrations of influencing offspring outcomes by a preconceptional physiological dose supplementation in adolescents”

Girls who were excluded from this placebo-controlled trial because of very low vitamin B₁₂ levels (< 100 pmol/L) were sup-

plemented with vitamin B₁₂ (2 µg/day). As a result, their hemoglobin concentration increased, red cell volume reduced and peripheral nerve function improved.⁵ This observation further supports the inclusion of vitamin B₁₂ in public health programs in India.

In a multicenter study, we investigated vitamin B₁₂ and folate levels in mothers of babies with a neural tube defect (NTD). There was an association with vitamin B₁₂ deficiency, not folate deficiency. The association of maternal TCN2 gene polymorphism supported a causal role for vitamin B₁₂ in NTDs.⁶

In the Pune Maternal Nutrition Study, we studied brain structure and function (magnetic resonance imaging) in relation to vitamin B₁₂ and folate exposure *in utero*. Low maternal vitamin B₁₂ levels in pregnancy were associated with altered development of specific areas of the brain and their functional connectivity in the offspring.⁷ These findings raise the possibility of a role for vitamin B₁₂ in influencing brain development. Neurocognitive improvement in the PRIYA trial provides interventional proof.

Vitamin B₁₂ deficiency is common in vegetarian/vegan populations in India. We reviewed studies in pregnant women and found that 30–70 percent of Indian pregnancies have low vitamin B₁₂ status. Vitamin B₁₂ deficiency is associated with increased risk of NTDs, poor intrauterine growth and maternal gestational diabetes mellitus (GDM)⁸ (Figure 2).

There is an intriguing interaction between low maternal vitamin B₁₂ and high folate status in relation to a number of short- and long-term outcomes, suggesting an urgent need to review the policy of supplying only folic acid (IFA tablets) to adolescents and pregnant women in various Indian national programs.⁹ A study in the UK showed that lower vitamin B₁₂ levels and higher folate levels in early pregnancy were associated with a higher risk of detection of GDM in the third trimester,¹⁰ which is similar to the observation in the Parthenon cohort in Mysore.¹¹

Vitamin B₁₂ is made in nature only by microbes and enters the human food chain through animal-origin foods. Some algae obtain vitamin B₁₂ from symbiotic bacteria. These would be an acceptable source of vitamin B₁₂ for vegetarians. We found that consuming *Chlorella* powder daily for 30 days improved vitamin B₁₂ status in our volunteers. We have also used nutrient bars and yogurt fortified with vitamin B₁₂ to improve nutritional status.¹² There is a need to think of novel and sustainable ways of improving micronutrient status by innovative research.

In summary, our studies make a strong case for improving vitamin B₁₂ and other micronutrient status across the life cycle in India, especially in women.

Acknowledgements

I acknowledge Dr Sayali Deshpande-Joshi for her help with preparing this commentary.

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“One of the great strengths of *Sight and Life* has been to provide publications with scientific rigor combined with implementation of effective programs to reduce mineral and vitamin deficiencies. I especially have appreciated their programs directly to improve poor dietary quality, which is the primary underlying cause of Hidden Hunger.”

Howarth Bouis | Emeritus Fellow, International Food Policy Research Institute (IFPRI) | Washington, DC, USA

“I have known *Sight and Life* for 20 years and find its development more than impressive. For a while, I was privileged to support *Sight and Life* myself – for example, in the organization’s first strategic reorientation. For me, working with Klaus has opened many important perspectives on health. As a representative of strategic pragmatism, I appreciate the undogmatic approach of *Sight and Life*.”

Thomas Breisach | Professor of Health and Social Management, FOM University of Applied Sciences, Study Center Munich | Germany

“I have known *Sight and Life* since the mid-1990s, when they had a prominent role in promoting the relevance of vitamin A in child survival. Over the years, *Sight and Life* has been seminal in supporting my micronutrient research through the *Sight and Life* Global Nutrition Research Institute at Johns Hopkins. I greatly value and appreciate the Foundation’s science-based approach to policy and programmatic action and excellence in science communication via sponsored sessions at scientific meetings and through the magazine.”

Parul Christian | Professor, Director, Human Nutrition Program, Johns Hopkins Bloomberg School of Public Health | Baltimore, MD, USA

“*Sight and Life* influenced my own work on assessing nutrient density of foods. Without forgetting about excess fat, sugar, and salt, new nutrient profiling models for global use include priority micronutrients and will address food fortification. Affordable nutrient density for all is the *Sight and Life* approach.”

Adam Drewnowski | Professor, Center for Public Health Nutrition Program in Nutritional Sciences and Department of Epidemiology, University of Washington | Seattle, WA, USA

FIRST PUBLISHED IN:

Vol. 26 (2) | 2012
PP. 40-46



12

H.M.L.
"LEARN"
Health, Education

Ritual Fluids in Relation to Early Child Nutrition in Quetzaltenango, Guatemala

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Noel W Solomons**

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Introduction

Guatemala has the highest prevalence of one of the main forms of childhood malnutrition in Latin America, with 49% of children chronically undernourished, i.e., stunted.¹ Bhutta et al² show that education about complementary feeding can increase height-for-age Z score by 0.25. Nutrition-related interventions can also reduce stunting at 36 months by 36%, and mortality between birth and 36 months by about 25%. Adherence to the World Health Organization (WHO) Complementary Feeding Guidelines³ has also been shown to prevent weanling diarrhea. (The guidelines are related to better micronutrient status and growth.)⁴⁻⁶

In addition to having the highest chronic undernutrition in the Americas, Guatemala also scores most poorly on adherence to complementary feeding guidelines.⁷ Ruel and Menon⁷ attributed the low score for complementary feeding practices to the relative poverty of Guatemala. Together, lack of complementary feeding practices and poverty may explain Guatemala's high rate of stunting as shown in the surveys included (42% and 39% in 1995 and 1999, respectively). On the other hand, recent research (completed and published), supported in part by a *Sight and Life* grant to the Center for Studies of Sensory Impairment, Aging and Metabolism (CESSIAM), shows that in Guatemala, the intakes of most micronutrients were near recommended levels.^{8,9}

It is unclear whether the nutrients contained in complementary foods are lost due to diarrhea. However, complementary feeding is so strongly linked to diarrhea that the syndrome is

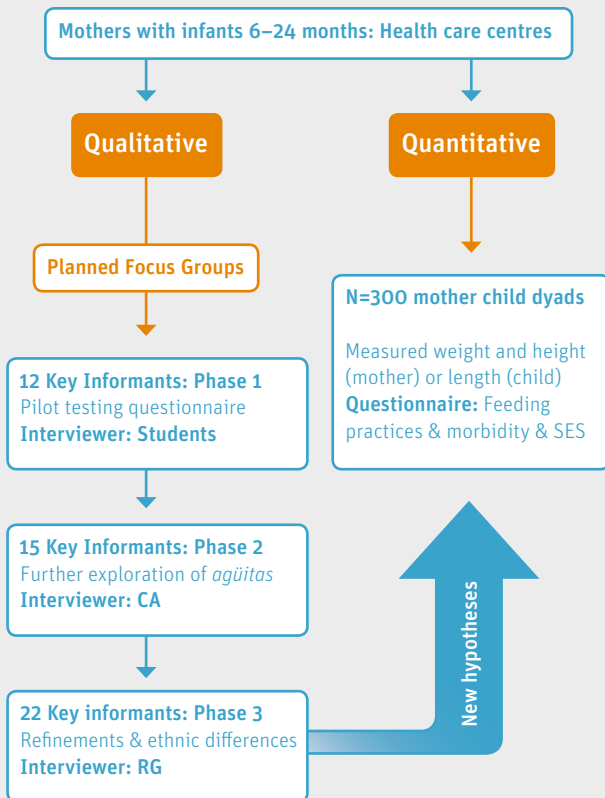
described as “weanling diarrhea.”¹⁰ Weanling diarrhea leads to impaired absorption and/or poor retention of nutrients, particularly vitamins and minerals. There is insufficient information about complementary feeding practices to explain the paradox of consumption of adequate micronutrient levels by Guatemalan infants in the face of widespread undernutrition and deficiency.

Understanding child feeding practices requires a participatory perspective and building local capacity for research. Capacity building is a process in which “the development of knowledge, skills and attitudes in individuals and groups of people relevant in design, development, management and maintenance of institutional and operational infrastructures and processes that are locally meaningful.”¹¹ These processes include different actors and levels of interventions, such as individuals, groups, organizations, institutions and societies, among others. The WHO encourages research organizations to include capacity-building goals in their research proposals in order to strengthen local health research systems.¹² Thus, this research includes additional specific objectives that aim to strengthen local capacity in Guatemala.

“The primary aim of the project is to understand cultural beliefs relating to the complementary feeding practices of 6–24 month-olds in Quetzaltenango, Guatemala”

The primary aim of the project is to understand cultural beliefs relating to the complementary feeding practices of 6–24 month-olds in Quetzaltenango, Guatemala. These beliefs were explored quantitatively to establish whether previously identified cultural practices were associated with chronic undernutrition, i.e., child stunting. We make use of a mixed-methods design, integrating quantitative and qualitative studies, and use both perspectives to generate new knowledge. Formative

FIGURE 1: Key informant interviews contribute new hypotheses for quantitative analysis



CA: Claudia Arriaga

RG: Rosario García

SES: Socioeconomic status

research was carried out to develop culturally appropriate intervention strategies. This was done by utilizing the combined, complementary expertise of the collaborative group, which included local dietetics students and CESSIAM workers. By involving these groups, the capacity-building objectives of this study were also met.

Methods

Study setting: The fieldwork for this study was conducted in the health centers of Quetzaltenango City and La Esperanza, between February and October 2011. Quetzaltenango City and La Esperanza are both urban municipalities, which are situated in the Western Highlands of Guatemala, in the Province of Quetzaltenango, with a mixed population of indigenous and *ladino* inhabitants. In Quetzaltenango, 65% of the inhabitants are indigenous and in La Esperanza 71% are indigenous. Quetzaltenango is the second largest city in Guatemala; by comparison, nearby La Esperanza is more suburban.

Capacity Building: Capacity building was carried out in the form of a short course, training dietetics students in qualitative research. This course included an introduction to theoretical principles, data collection and methods of analysis. In addition to providing training, this project helped generate formative data for an evidence-based intervention plan, which will target the factors most likely to improve weanling diets in Quetzaltenango, Guatemala. A VU University investigator travelled to Guatemala to set up the qualitative research, and to train local staff in qualitative research methods. A group of VU University students also travelled to Guatemala and collected data, together with the local research team. The study was developed collaboratively with CESSIAM co-investigators, drawing on their existing wealth of knowledge, expertise and cultural experience. Qualitative analysis provided formative data, which was then used to identify associations to explore quantitatively, and also to identify possible intervention strategies.

Figure 1 shows the inter-relationship between the qualitative studies and the quantitative data. Mothers of children aged 6–24 months were selected for either the qualitative or the quantitative study. The initial plan was to carry out focus group interviews; however, too few mothers showed up for focus groups for this to be feasible. The strategy was therefore changed to conducting key informant interviews, with the specific aim of identifying reasons why mothers did not attend the initial focus groups. These interviews were conducted in three phases, to identify relevant information both for focus groups and for informing quantitative analysis. Formative research explored mothers' practices and beliefs regarding complementary feeding practices, with particular emphasis on probing questions related to water, sanitation, and hygiene related to fluid intake and complementary feeding in health and in illness. Beliefs and practices identified qualitatively were also used to identify hypotheses to be explored quantitatively. The quantitative results were then used to formulate probing questions, to be utilized in focus group interviews carried out at the end of the study. The following capacity-building objectives were embedded within the qualitative study: training CESSIAM staff and students from Guatemala in qualitative interviewing skills and in developing semi-structured questionnaires; training local experts to develop an appropriate theoretical framework; and training students from Guatemala and the Netherlands to code and analyze qualitative data.

Qualitative research: Guatemalan dietetics students were trained in qualitative interviewing methods during a two-week short course offered at the local university by Colleen M Doak and Gabriela Montenegro. In the first week of the course, dietetics students were taught the principles of qualitative research methods, and worked in teams to develop a theoretical framework us-



Dietetics students creating the theoretical framework.

ing the Theory of Triadic Influence¹³ and the Theory of Planned Behavior. Together, these two models integrate the individual, social and environmental factors influencing health behaviors (triadic influences), together with health behavior theory (the theory of planned behavior). The students developed a framework to help formulate initial questions testing for motivating factors encouraging, as well as barriers to, complementary feeding practices, based on the three streams of influence: individual, social and environmental factors. Questions focused on identifying behaviors that might reduce the risk of weanling diarrhea, improve micronutrient content, and improve child growth.

“Guatemalan dietetics students were trained in qualitative interviewing methods at a two-week course at the local university”

The students were also asked to work in groups, using the theoretical framework to develop questions for focus group interviews as originally planned. The formulated questions were then compiled, discussed in class, and pared down to a final list of questions, which the students, working in pairs, then used to practice qualitative interview techniques in class in preparation for the actual focus group interviews scheduled for the second week. As mentioned above, however, only two participants showed up for the first focus group, so the students carried out key informant interviews instead of the scheduled focus group interviews.

Key informant interviews were carried out in an iterative process in three phases (Figure 1). Mothers of children aged 6–24 months were invited to participate, and the interviews were re-

corded on tape, with the mothers' consent. Phase one of the process consisted of 12 key informant interviews, conducted at the Quetzaltenango health center by eight local dietetic students. The importance of *agüitas* (the local term for liquids – usually herbal infusions or thin cereal gruels – fed to infants in accordance with cultural practices) emerged from answers to questions on early feeding practices, which were collected during the first interviews. The WHO refers to *agüitas* by the more generic term “ritual fluids”,¹⁴ but we use the local Spanish term throughout.

Based on these findings, questions related to *agüitas* were added to the questionnaire in later interviews. In the second phase of the study, Claudia Arriaga conducted 15 interviews in the health centers of Quetzaltenango and La Esperanza. The aim of this second phase of study was to further explore questions about *agüitas*. Claudia Arriaga was brought in to conduct this stage of the interviews, as a member of the CeSSIAM staff and a native-speaking Guatemalan researcher. In the third phase, a local native-speaking interviewer with qualitative research experience was hired to conduct the final sets of interviews (n=22). This final phase aimed to address certain methodological issues which had arisen in previous interviews, specifically to obtain more in-depth answers than before, and to lengthen interview times. Content-wise, the aim of the final phase was to establish the differences between previous answers given by indigenous and non-indigenous mothers. Rosario García began by testing the questionnaires to see which questions proved most problematic. She then adjusted the questions to improve the mothers' comprehension of them, and to allow more in-depth information to be obtained. Reflecting demographic differences in the two study locations, most of the interview subjects in Quetzaltenango were non-indigenous, whereas most of the interview subjects in La Esperanza were indigenous.

Qualitative Analysis: This was carried out as follows: The key informant interviews from the first and second phases were transcribed verbatim by the dieticians and Claudia Arriaga. The interviews carried out by Rosario García were transcribed by non-native speakers (Leonie Peters and Robine van der Starre). Transcriptions were checked by local collaborators afterwards. Analysis of the key informant interviews was carried out in MS Excel by Leonie Peters and Robine van der Starre. This involved copying the original transcripts and organizing their contents into categorized groups, based on themes taken from the conceptual frameworks.

Quantitative analysis: Quantitative analysis identified and recorded relevant details regarding complementary feeding practices, including the exact ages at which complementary foods were introduced, and the average age of introduction. A separate analysis explored which foods or fluids are given or withheld in response to weanling diarrhea. Special attention was given to

TABLE 1: Examples of indications for ritual fluid (*agüitas*) use and the local (Spanish) and botanical (Latin) names of the sources

Type of <i>agüitas</i> Spanish	Botanical name (Genus and Species)
RITUAL FLUID USE FOR INFANTS	
To alleviate stomach pain and colic	
Agua de anís	<i>Pimpinella anisum</i>
Agua de canela	<i>Cinnamomum verum</i>
Agua de hierba buena	<i>Mentha spicata</i>
Agua de naranja	<i>Citrus sinensis</i>
Agua de pericon	<i>Tagetes lucida</i>
To alleviate constipation	
Agua de arroz	<i>Oryza sativa</i>
Agua de ciruelas	<i>Prunus domestica</i>
Agua de hierba buena	<i>Mentha spicata</i>
Agua de manzanilla	<i>Matricaria recutita</i>
Agua de pasas	<i>Vitis vinifera</i>
Multiple health benefits (“heating,” sore throat, lungs, fever, worms)	
Agua de anís	<i>Pimpinella anisum</i>
Agua de manzanilla	<i>Matricaria recutita</i>
Agua de hierba buena	<i>Mentha spicata</i>
RITUAL FLUID USE FOR LACTATING MOTHERS	
To reduce the output of mothers’ milk	
Agua de arroz	<i>Oryza sativa</i>
To increase the output of or improve the quality of mothers’ milk	
Agua de alucema	<i>Lavandula stoechas</i>
Agua de alfalfa	<i>Medicago sativa</i>
Agua de cebada	<i>Hordeum vulgare</i>
Agua de salviasanta	<i>Buddleja americana</i>

agüitas. Based on information from mothers who reported giving *agüitas* to their children in order to prevent gastrointestinal or other illnesses, additional explorations were carried out to analyze the associations between infants introduced to *agüitas* early in life, and their current frequency of reported gastrointestinal or respiratory symptoms. Finally, *agüitas* were explored separately in relation to child stunting, defined as -2 height-for-age Z scores below the reference median.¹⁵

.....
“Most mothers named their mother or mother-in-law as the person influencing their decision to give *agüitas* to their child”

Results from qualitative analysis

General characteristics: In total, 49 mothers visiting the health centers in Quetzaltenango and La Esperanza were interviewed by eight dietetics students (Phase 1), Claudia Ariaga (Phase 2) and Rosario García (Phase 3). The age range of the interviewed mothers was 16–47 years, with a mean age of 25.5 years. During the 12 interviews conducted in Phase 1, the theme of *agüitas* first emerged. In the later phases, additional probing questions were added to further explore the issue of *agüitas*. Most mothers named their mother or mother-in-law as the person influencing their decision to give *agüitas* to their child. Doctors were also mentioned as influencing factors. **Table 1** summarizes the different types of *agüitas* given for health reasons, along with their specific purposes. These findings combine results from all 47 interviews. All of the mothers interviewed reported using *agüitas* mainly as a warming food, to “heat” the body in order to maintain healthy digestion, or to treat gastrointestinal complaints such as constipation, diarrhea and colic. Additionally, mothers also reported using *agüitas* to alter the quantity or quality of their breast milk. Only indigenous mothers mentioned using *agüitas* to treat worms, or for respiratory complaints.

.....
“Infants who were introduced early to *agüitas* were 1.6 times as likely to be stunted at the time of the interview”

Results from quantitative analysis

General characteristics: **Table 2** shows the key demographic characteristics of the quantitative sample. The larger sample size for Quetzaltenango is due to the inclusion of a separate sample of children aged five months, selected entirely from Quetzaltenango. In children over six months old, an equal number of children were interviewed in the Quetzaltenango (n=150) and La Esperanza (n=150) health centers; exactly half the children selected were boys. This sample (5–23 months) was used to explore hypotheses generated from the qualitative results, in which mothers reported that some *agüitas* were given to maintain health and were also used in response to disease. In particular, mothers reported the belief that *agüitas* would help to maintain the healthy functioning of certain organs, particularly the gastrointestinal tract and lungs. Given the associations between feeding practices and child nutrition, we tested the early introduction of *agüitas* in relation to current health-related outcomes. Early introduction of *agüitas*, namely within the first 2.9 weeks of life, was not associated with current morbidity, such as diarrheal or respiratory outcomes. However, infants who had *agüitas* introduced early were

TABLE 2: Socio-demographic characteristics of the sample by introduction of early *agüitas*

	All (n=454)		Early introduction of <i>agüitas</i> (n=88)		Later or no <i>agüitas</i> (n=366)	
	Number	Proportion #	Number	Proportion #	Number	Proportion #
Gender						
Boys	227	50%	42	48%	185	51%
Girls	227	50%	46	52%	181	50%
Age categories						
5 months old	156	34%	33	38%	123	34%
6–11 months old	132	29%	24	27%	108	30%
12–17 months old	78	17%	18	21%	60	16%
18–23 months old	88	19%	13	15%	75	21%
Location						
Quetzaltenango	306	67%	62	71%	244	67%
Esperanza	148	33%	26	30%	122	33%
Teenage mother						
No	383	85%	80	91%	303	84%
Yes	67	15%	8	9%	59	16%
Marital status mother						
Single	64	14%	20	23%	44	12%
United	126	28%	22	25%	104	28%
Married	255	56%	45	51%	210	57%
Divorced/widowed	9	2%	1	1%	8	2%
Level of education mother						
Primary school or less	265	58%	46	52%	219	52%
Secondary school or more	189	42%	42	48%	147	48%
Ethnicity						
Not wearing indigenous dress	304	67%	58	66%	248	68%
Wearing indigenous dress	148	32%	30	34%	118	32%

Proportions do not add up to 100% due to rounding

1.6 times as likely to be stunted at the time of the interview (CI = 1.0, 2.5). However this association was strongest in the youngest age group and attenuates with age, dropping below unity in the oldest age group.

Capacity Building

As part of the activities related to capacity building, the project established a collaboration between the Quetzaltenango branch of the Universidad Rafael Landívar (a local university), and CESSIAM in Guatemala. The qualitative training course held at the university taught new skills in qualitative research to 18 nutrition dietetics undergraduates. These skills were then put into practice during the students' own university research projects, which included qualitative methods such as unstructured interviews and focus groups, and the use of triangulation methodology for analysis. The local university has maintained

its collaboration with CESSIAM, and the training sessions are continuing to be held for new batches of students. Annual qualitative research training is planned. Students who are interested in research subjects relating to ongoing CESSIAM projects will have the opportunity of collaborating with CESSIAM on these as part of their graded theses.

.....
“Training local students in qualitative research and involving them in the data collection process helped to draw out valuable new information”

Discussion

In addition to the analysis shown here, Rosario García carried out a post-training dialogue with the students, to discuss issues related to the training process. Students who participated in the qualitative research methods sessions provided some useful insights for the further development and continuation of the training. It became evident that the students considered the methods learned to be valuable, and wanted to take their training further. More specifically, a majority of the participants expressed an interest in, and need for, more “hands on” training, which would allow them to put the skills they had learned into practice. Students also recommended the introduction of formal diplomas that recognized their training in the subject. These discussions show a clear need for, and interest in, more qualitative research training. In the instance of this study, training local students in qualitative research and involving them in the data collection process helped to draw out valuable new information, namely the findings about *agüitas* presented here.

More information is needed about the possible role *agüitas* may play in displacing breast milk, thereby contributing to micronutrient deficiency. In particular, the early introduction of *agüitas* may contribute to micronutrient deficiency in infants before they have reached sixth month of age. The frequency and quantity of *agüitas* given also has implications for the micronutrient status of infants who are six months and older. It is important to note that, during or after illness, mothers are indeed following the recommendation of giving liquids to replace fluid losses. During or after illness, the use of *agüitas* could be beneficial in that mothers report boiling the leaves they use, thus making *agüitas* administered in this instance more hygienic than other liquids. However, *agüitas* do not contribute micronutrients and, when given in microbiologically contaminated cups or bottles, may result in micronutrient losses caused by diarrheal infection. From a micronutrients perspective, the practice of giving breast milk (reported to be given as an extra fluid during illness by only 7% of mothers) should be encouraged further, as a means of improving micronutrient intake, and as the most hygienic, essential source of liquid during recovery from illness. The fact that most mothers of children aged 6–24 months report continued partial breastfeeding means that this is a feasible recommendation. Analysis carried out at this point also tested for the possibility that the use of *agüitas* may be beneficial to child growth, or may lessen a later risk of infectious disease. Based on cross-sectional analysis, however, we were unable to find evidence to support mothers’ beliefs that the use of *agüitas* was beneficial to their child’s overall health and preventive of later infectious disease risk. Thus, we were unable to confirm a health benefit for *agüitas*.

The qualitative and quantitative results show *agüitas* to be a deeply culturally embedded practice, however. Interventions

could stimulate mothers to take *agüitas* themselves, rather than give them directly to infants. Many mothers have reported doing so already, based on an existing belief that the “heating” qualities of *agüitas* will carry over into the breast milk. Thus, instead of exposing infants to potentially contaminated *agüitas*, mothers could take the *agüitas* themselves and instead provide nutrient-dense breast milk to infants.

These results show the importance of *agüitas* as a concern, which needs further exploration in relation to child nutritional status, micronutrient intake, energy intake and overall health. In particular, these findings raise questions about the programmatic approach to be taken with respect to counseling for infant feeding. As ritual fluids, *agüitas* fit within the WHO definition of full breastfeeding. In our initial analysis on older children, *agüitas* in older children appeared to be protective against child stunting. However, after further analysis including younger children, the associations turned in the opposite direction, showing an increased risk. Upon closer analysis, these findings appeared to be consistent with recall bias, and firm conclusions require further longitudinal analysis. Given the fact that *agüitas* are firmly embedded in local beliefs and practices, we would tend to ignore, or even encourage, this deeply rooted cultural practice. However, if there is the possibility of microbiological risk or adverse medium-term consequences, we might seek to dissuade their use altogether, despite their acknowledged cultural roots.

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“The inclusion of a capacity-building approach led to new and otherwise unattainable knowledge”

Conclusions

This study provides an example of a capacity-building model, in which developing local research capacity is embedded in all stages of the research process. The inclusion of a capacity-building approach ultimately led to new and otherwise unattainable knowledge – insights into the cultural practices and beliefs involving *agüitas* which directly affect child feeding habits would not otherwise have emerged. Likewise, these results show the added value of qualitative research in understanding early child feeding practices in a low-income setting. In particular, the training of dieticians in Guatemala and the inclusion

of a qualitative perspective in the study resulted in identifying the importance of *agüitas* in early child feeding practices. Using the qualitative results, *agüitas* were then explored quantitatively from the perspective of the WHO guidelines, from a biological perspective, and also explored based on the mothers' stated beliefs linking *agüitas* and child health. Understanding *agüitas* from all of these perspectives may well be the key to understanding and improving the child feeding practices most relevant to improving child nutrition in Guatemala.

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Acknowledgements

We thank *Sight and Life* for funding this study. Additionally, we acknowledge collateral support from the Hildegard Grunow Foundation of Munich, Germany, and from Nestlé Foundation of Lausanne, Switzerland. We thank the nutritionists who interviewed the mothers (Elena María Díaz Ruiz, Claudia Alejandra Maldonado and Deborah Fuentes), the students who helped recruit participants and enter data (Jeniece Alvey, Ilse van Beusekom, Linda Oyesiku, Lydia Kim, Marieke Reurings, Natasha Irving, Oscar Padilla, and Robine van der Starre) and the staff of the Quetzaltenango health clinic. Above all, we thank the participants of the study for their collaboration.

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Perspective from 2021

Ritual Fluids in Relation to Early Child Nutrition in Quetzaltenango, Guatemala

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Prologue

We celebrate and commemorate the 35 years of *Sight and Life* magazine, as *Sight and Life* has too been generous with the anniversaries of the Center for Studies of Sensory Impairment, Aging and Metabolism (CeSSIAM). Moreover, they made the investment of financing, which funded the research in the protocol: Developing Evidence-Based Strategies to Improve Early Child Nutrition in Quetzaltenango, Guatemala, colloquially known as *XELA Babies*. Its goal was to assess the adherence of mothers to the distinct practices advocated for infant and toddler feeding by the World Health Organization (WHO) in 2003.¹ In revisiting our goals and words of 2012, we can clearly identify lasting benefits for the participants and institutions, whereas the combination of advances in science and our own reflections has modulated our views on the value of universal, rigid adherence to these 2003 guidelines.

The capacity built

The investigators at Vrije Universiteit Amsterdam had an overt animus that the *XELA Babies* experience would contribute to building research capacity as reflected in the schematic organization of the *Sight and Life* article (see **Figure 1** of the original article). Since the article's publication, the Guatemalan participants mentioned in it have indeed adhered to research path-

ways. Gabriela Montenegro went on to Germany and secured a PhD from the University of Bonn; she currently leads a research project in Guatemala. Rosario García continues her role as Coordinator of research in Quetzaltenango with local and international staff and students. Claudia Arriaga is currently pursuing doctoral studies at Iowa State University. After graduation, both of the Dutch exchange students cited in the text, Leonie Peters and Robine van der Starre, passed through a brief phase of research endeavor. Today, they are both management professionals within health service companies in the Netherlands.

Qualitative research basis

The *XELA Babies* protocol called for qualitative research strategies, which were not prominent during the first two decades of CeSSIAM. We were impressed with how intact and intricate a system of exploiting the beneficial properties of different herbal infusions had emerged in La Esperanza (see **Table 1** of the original article). This exemplifies the deep-rooted nature of the *agüitas* traditions in the community. On the one hand, humanitarian concern would seek to protect infants from the adverse effects of these potentially harmful exogenous beverages. On the other hand, *agüitas* are clearly medicinal for this Mayan highland community, and the direct uprooting would disrespect that culture. With our current perspective, trade-off solutions are more justified than bulldozing the practice into oblivion. Moreover, since publication of the article, CeSSIAM has expanded qualitative research efforts in issues such as the autonomy of female heads of households, the care of new mothers in the 40 days postpartum, and eating practices during lactation.

“With our current perspective, trade-off solutions are more justified than bulldozing the practice into oblivion”

From firm absolutism to tactical trade-offs

WHO recommends exclusive breastfeeding during the first 6 months, but includes an exemption for medications, including nutrient supplements.¹ Chastened by recent publications about breast milk quality in Guatemala^{2,3} and consoled by meta-analysis resolving a more benign consequence for short stature,⁴ we believe that we must not remain such sticklers for the prescriptions of the WHO guidelines¹ on the rigid exclusivity of breastfeeding, and must instead consider trade-offs as well. CeSSIAM research shows broad deficiencies of B vitamins² and minerals³ in maternal milk.

Despite 60 percent greater stunting in infant recipients of *agüitas* in La Esperanza, linear growth failure in the absence of infections or dietary deficits is a more benign condition than previously considered.⁴ So our inflexible stance has evolved, and today we feel less constrained from looking at alternative approaches, such as direct nutrient supplementation, to compensate for nutrient deficiencies in Guatemalan mothers' breast milk. This nutrient delivery, of course, would be in a *medication* context, insisting that microbiological safety is strictly assured, with the exclusivity of human milk as the infant's diet during the first semester of life.

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“Klaus Kraemer has developed *Sight and Life* from a small organization to a world-class think tank dedicated to healthy nutrition with a prime but not exclusive focus on developing countries. Under his leadership, *Sight and Life* has become a recognized partner in many projects to improve nutrition jointly with civil society organizations, universities, donors and authorities. His approaches to improve nutrition and nutritional status are unique, simple and effective in translation.”

Manfred Eggersdorfer | Professor for Healthy Ageing, University Medical Center Groningen | The Netherlands

“*Sight and Life* is seen by many as **the innovator** in the micronutrient space of malnutrition. Their passion and contribution to solve real-life malnutrition issues is contagious! I felt it personally when supporting the pilot/launch of one of their ideas, the Egg Hub in Latin America. Now I’m proud at becoming one of them.”

Chris Goppelsroeder | Chairman of *Sight and Life* Board of Trustees and former President & CEO, DSM Nutritional Products Ltd | Kaiseraugst, Switzerland

“It is a pleasure to endorse the ground-breaking work that *Sight and Life* has undertaken under the gifted leadership of Dr Klaus Kraemer. It has consistently focused on critical issues, drawing on a wide range of expertise from around the globe, embracing perspectives, knowledge and values from multiple sectors to address nutrition challenges.”

Jean-Pierre Habicht and Gretel Pelto | Emeritus Professors, Division of Nutritional Sciences, Cornell University | Ithaca, NY, USA

“*Sight and Life* looks at nutrition-related issues holistically and follows a data-driven approach to the challenge of tackling malnutrition. The organization translates science into easily understandable information for diverse audiences and helps to bridge gaps among different stakeholders. I enjoy the timely articles in *Sight and Life* magazine, which provide interesting perspectives that are valuable for my work.”

Laura Hackl | Postdoctoral Associate, Division of Nutritional Sciences, Cornell University | Ithaca, NY, USA

FIRST PUBLISHED IN:

Vol. 27 (3) | 2013
PP. 50-55



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Iodine Nutrition in Africa: an Update for 2014

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Included as an insert to this issue of *Sight and Life* is the current issue of the Iodine Deficiency Disorders (IDD) Newsletter. The IDD Newsletter has been published for over 25 years and it is the central “meeting place” of the global iodine community. The focus of the latest issue is on iodine nutrition in Africa and highlights the successes and challenges to salt iodization programs on the continent. To subscribe to the quarterly electronic IDD Newsletter visit www.iccidd.org.

Introduction

The elimination of iodine deficiency and its serious consequences, called the iodine deficiency disorders (IDD), are among the health priorities of most countries in the world. These IDDs include impaired mental development, adverse effects on growth, infant mortality, hypothyroidism, reproductive failure, and endemic goitre,¹ which may lead to decreased educability, apa-

thy, and reduced work capacity and may ultimately result in impaired social and economic development.²

Salt iodization programs in approximately 150 countries have markedly improved the global iodine nutritional status over the past decade. This is reflected in the decrease in the number of iodine-deficient countries worldwide from 54 in 2003 to 47 in 2007 and then to 32 in 2011.³ Despite remarkable progress, the successes have been regionally variable, with some regions showing little progress. Against the background of a general global improvement in iodine status and a marked improvement in four of the six WHO regions since 2003, the trend in Africa indicated a small decrease in the proportion of school-age children (SAC) with insufficient iodine intake as judged by urinary iodine concentration (UIC) below 100 µg/L, while the number of African SAC with insufficient iodine intake remained the same between 2007 and 2011.

The regional burden of iodine deficiency in Africa compared to other regions is further emphasized by the finding that seven of the top 10 iodine-deficient countries with the greatest numbers of SAC with insufficient iodine intake in 2011 are from Africa.³ These countries, ranked by the number of deficient SAC, were: Ethiopia, Sudan, Algeria, Angola, Mozambique, Ghana, and Morocco. In terms of proportion of the population with insufficient iodine intake, Africa is ranked second with 40%, behind Europe with 44%. When the proportions are calculated in terms of numbers of the total population with a UIC of less than 100 µg/L, 321.1 million African people had an insufficient iodine intake, compared to the 393.3 million in Europe and the 541.3 million in Southeast Asia.

Because of the large number of countries included in each of the six WHO regions, the regional statistics in a global review do not uncover the variation in iodine status and trend over time within the various countries of the regions. This review aims to unpack the available data of 54 countries on the African continent to achieve a more in-depth view of the iodine nutrition status in African countries. The countries counted to the African continent include all countries of the WHO African Region, plus eight countries of the WHO Eastern Mediterranean Region.

Data sources

Currently the most up-to-date global dataset summarizing survey data related to the assessment of the iodine nutrition status



“Seven of the top 10 iodine-deficient countries in 2011 were in Africa”

A knapsack sprayer in use in Ethiopia.



Dr Vincent Assey training small-scale salt producers to use knapsack sprayers to iodize salt. This technology has helped ensure that almost all salt from salt-producing areas in Ethiopia is iodized. It has been used in Tanzania for the past ten years, maintaining coverage of iodized salt at over 80 percent.

in countries is managed and frequently updated by the Human Nutrition Laboratory of the ETH in Zurich, Switzerland. The updated version as of September 2013 was used for this review. The original dataset was developed using country data on UIC compiled in the WHO Vitamin and Mineral Nutrition Information System Micronutrient Database as well as an extensive search strategy in PubMed, Current Contents Connect, and ISI Web of Science. Additional information was generated by contacting iodine scientists around the world through the ICCIDD Global Network and through agencies such as WHO and UNICEF and their regional offices. Specific criteria were applied for inclusion of data in the dataset for the time period 1993–2013. Preference was given to data from national surveys and in the absence of national data, sub-national data was used.³

The median UIC was used for the classification of iodine status of populations as follows: moderate iodine deficiency (20–49 µg/L), mild iodine deficiency (50–99 µg/L), optimal iodine nutrition (100–299 µg/L), and risk of adverse health consequences (IIH, autoimmune thyroid disease) (≥ 300 µg/L).^{1,4} The available UIC data of African populations in 2007⁵ and in 2013 was used to assess the iodine status and to track changes in iodine status over time.

The countries' household coverage of iodized salt was obtained from UNICEF's Child Info Database.^{6,7} Data on popu-

lation sizes of African countries was obtained from the UN Population Division.⁸ Nigeria has the biggest population in Africa (158 million), followed by Ethiopia (83 million), Egypt (81 million), Democratic Republic of the Congo (66 million), South Africa (50 million), Tanzania (45 million), Kenya (41 million), North Sudan (36 million), Algeria (36 million), Uganda (33 million), and Morocco (32 million). The other 43 countries have populations smaller than 30 million. Salt iodization programs in these 11 countries therefore have the biggest impact on the overall iodine status of the continent and should thus be well managed.

Coverage of iodized household salt

According to UNICEF, the household coverage of iodized salt by country varies from one extreme to the other on the African continent.^{6,7} Countries with successful iodized salt programs achieving a household coverage of more than 90% are: Burundi, Kenya, Nigeria, Uganda, Tunisia, Namibia, Zimbabwe, and Libya. The challenge, of course, is for countries to sustain this excellent level of household coverage and not to allow their programs to weaken over time. Countries with promising household coverage rates of between 80 and 90% are: Rwanda, Sao Tome & Principe, Cote d'Ivoire, Lesotho, Comoros, the Congo Brazaville, and Tanzania.

TABLE 1: Iodine status of African countries in 2007 and 2013

Iodine status	Median urinary iodine concentration ($\mu\text{g/L}$)	Countries, <i>n</i> (%) ¹	
		2007	2013
Moderate ID	20–49	4 (10%)	6 (14%)
Mild ID	50–99	11 (28%)	5 (11%)
Adequate iodine nutrition	100–299	22 (55%)	30 (68%)
Excessive	> 300	3 (8%)	3 (7%)
Countries with data		40 (100%)	44 (100%)
No data		13	10
Countries in region		53	54 ²

¹Percentages (%) refers to number of countries in each category out of the total number of countries with data.

²Sudan has been divided into North and South Sudan since 2007.

At the other end of the scale, 20 African countries (40%), with household coverage rates reported, had household coverage rates of less than 50%. These 20 countries represent 325.6 million people, or 31.9% of the population on the African continent. Low coverage rates of less than 50% are an indication of weak salt iodization programs seriously in need of corrective action.

The household coverage rates in the UNICEF Child Info Database are mostly based on iodine measurements using rapid test kits. Therefore these results are indicative of household salt containing any amount of iodine, not necessarily of salt containing more than 15 ppm of iodine. The advantages of this method are its low cost and the fact that the result is immediately available. However, recent national surveys tend to use quantitative measurements for the iodine content of salt, such as the titration or an equivalent method, allowing more accurate planning and decision-making in the design and implementation of salt iodization programs.

Iodine status

Of the 40 African countries that had UIC data available in 2007, 15 countries (38%) were iodine deficient, while 22 countries (55%) had adequate iodine nutrition, and three countries (8%) had excessive iodine intakes. No UIC data was available for 13 African countries in 2007.

In Africa, the largest burden of iodine deficiency in 2007, because of large population sizes, was in Ethiopia, Sudan, Algeria, Morocco, Ghana, and Mozambique. Countries with fairly large population sizes ranging between 5 and 20 million people that had no UIC data available in 2007 included Madagascar, Angola, Malawi, Somalia, and Sierra Leone.

Iodine status in 2013

Overall, considerable improvements in available data and iodine status of African countries had been achieved in the 2007–2013

period. During this period, iodine data was reported for four countries that previously had no UIC data available (Angola, Malawi, Somalia, and Sierra Leone). All surveys were national, except for Angola. Therefore, iodine data was available for 44 out of the 54 African countries in 2013, covering 96% of the African population. Recent surveys, carried out from 2003 to 2013, are available in 27 countries; 25 of them were nationally representative. In 17 countries the data is more than 10 years old (1993–2002). Accelerated effort to obtain updated information on iodine nutrition is urgently needed in these countries. Data is entirely lacking for 10 countries, although the majority of them are small countries (< 1 million inhabitants). Madagascar and Libya are two populated countries without data, but national UIC surveys are planned, and new data should be available in the next year or two. New national surveys are underway in Tunisia and Djibouti as well as data from a recently conducted national survey in Ghana.

Notable shifts occurred in the iodine status of many countries on the African continent. **Table 1** shows that the number of iodine deficient countries decreased from 15 in 2007 to 11 in 2013, with an improvement in Senegal, Cape Verde, Cameroon, Mauritania, and Zambia. A regional survey carried out in the central Bie province of Angola in 2006 indicated very low iodine status (median UIC 29 $\mu\text{g/L}$) and Angola has therefore been added to the list of iodine-deficient countries. At the same time, the number of countries with documented iodine sufficiency (median UIC between 100–299 $\mu\text{g/L}$) increased from 22 to 30 since 2007.

Three African countries have excessive iodine intakes (UIC > 300 $\mu\text{g/L}$), exposing the populations to risk of adverse health events. In 2007 the Democratic Republic of the Congo, Liberia and Uganda had median UICs exceeding 300 $\mu\text{g/L}$, indicating excessive iodine intakes. Since then, new surveys showed that the former two countries had solved their problem by 2013, while



Even in small communities, salt iodization can be easily carried out with a knapsack sprayer. This image is from Pemba island in Zanzibar. This approach has increased the availability of iodized salt from 1 percent in 2001 to 73 percent in 2010 and raised the median UIC from 53 $\mu\text{g/L}$ to 134 $\mu\text{g/L}$.

no new data is available for Uganda and therefore the country is still considered to have an excessive iodine status. However, in Benin the median UIC increased to 318 $\mu\text{g/L}$, and UIC data reported for the first time for Somalia also indicated excessive iodine intake (median UIC = 417 $\mu\text{g/L}$). There is reason to believe that, because the household coverage of iodized salt in Somalia is very low, another factor, such as a high concentration of iodine in the drinking water, is responsible for the high UIC in Somalia. Despite the improvements in iodine status between 2007 and 2013, a significant burden of iodine deficiency still remains in Africa. It should be noted that 11 countries are still iodine-deficient in 2013, six countries are moderately iodine-deficient with median UIC < 50 $\mu\text{g/L}$, and five countries have mild iodine deficiency with median UIC of 59–99 $\mu\text{g/L}$. The proportion of individuals with UIC values below 100 $\mu\text{g/L}$ exceeded 80% in five of the six moderately iodine-deficient countries, indicating widespread iodine deficiency. In Ghana, the sixth country, which was also moderately deficient, 71% of people had UIC values below 100 $\mu\text{g/L}$.

As in 2007, the largest burden of iodine deficiency in 2013 (because of large populations) is still in Ethiopia, Algeria, Sudan, Morocco, Angola, Ghana, and Mozambique. CIDA has identified five countries (Ethiopia, Ghana, Sudan, Tanzania, and Bangladesh), four of which are situated in Africa, for extensive

activities to improve iodized salt coverage and strengthen the iodine programs.

.....
“Several studies have demonstrated that pregnant women are another vulnerable group exposed to iodine deficiency”

School-aged children have traditionally been used as a proxy of the iodine status in the general population. In recent years, however, several studies have demonstrated that pregnant women in most populations are another extremely vulnerable group exposed to iodine deficiency and that the iodine status of children does not necessarily reflect the iodine status of pregnant women.⁹ A typical example is Tanzania’s 2010 Demographic Survey report on women of reproductive age, where the overall median UIC was 160 $\mu\text{g/L}$.¹⁰ In-depth data analysis segregating pregnant, lactating and non-pregnant women indicated median of UIC 136, 113 and 194 $\mu\text{g/L}$, respectively.¹⁰ The iodine status of non-pregnant women in 2010 was not very different compared

with 204 µg/L in schoolchildren in 2004,¹¹ but was very different from that of pregnant and lactating women. It therefore appears critically important that the iodine status of pregnant women should be assessed, in addition to that of children. Currently data on the iodine status of pregnant women is limited, and organizers of new surveys should consider also collecting data on the iodine status of this vulnerable group.

Conclusions

The main finding of this review is a steady improvement of the iodine status on the African continent, as a result of successful national salt iodization programs. Adequate iodine status has been documented in 30 of the 54 African countries; a notable increase from 22 countries in 2007. However, iodine deficiency is still present in 11 countries. Concerted actions are needed to speed up the implementation and improve the coverage of iodized salt on the African continent.

For actions in countries to succeed sustainably in the delivery of adequately iodized salt to consumers and the food industry, certain universal measures need to be taken. These include careful day-to-day monitoring of the quality of iodized salt at the point of production complemented by external quality assurance. Invariably, small producers pose challenges to complying with the legal requirements regarding the iodine content of salt, but this needs to be addressed within countries in a tailor-made fashion. In most countries, the low socio-economic sector of the population and those living in rural or remote areas are usually vulnerable to exposure to under- or non-iodized salt. To solve these kinds of challenges, specific strategies need to be formulated for the distinctive circumstances of individual countries.

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“It always seems impossible until it is done”
(Nelson Mandela)

“*Sight and Life* supports many policy and research agendas to improve micronutrient status among the most vulnerable people of our planet. Their work is fundamental to address the broad issues in many areas of the world where a healthful diet remains a major challenge, especially for women and children.”

Daniel Hoffman | Associate Professor, Department of Nutritional Sciences, School of Environmental and Biological Sciences, Rutgers Global Health Institute | New Brunswick, NJ, USA

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Richard Hurrell | Professor Emeritus, ETH Zürich | Switzerland

“*Sight and Life* has made an invaluable contribution to the generation of research linked importantly to the practical implications for national-level policies and programs. My research over the past 30 years has been based in low- and middle-income countries and focused on multi-sector approaches to eliminating malnutrition. A key component of my arsenal of tools has been the evidence-based work of *Sight and Life*. Equally important has been *Sight and Life* magazine, which I have used in my graduate-level teaching. *Sight and Life* is truly a jewel in the crown of impactful organizations.”

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Spencer Kirk | Managing Director, Kirk Humanitarian | Salt Lake City, UT, USA

Perspective from 2021

Iodine Nutrition in Africa in 2021

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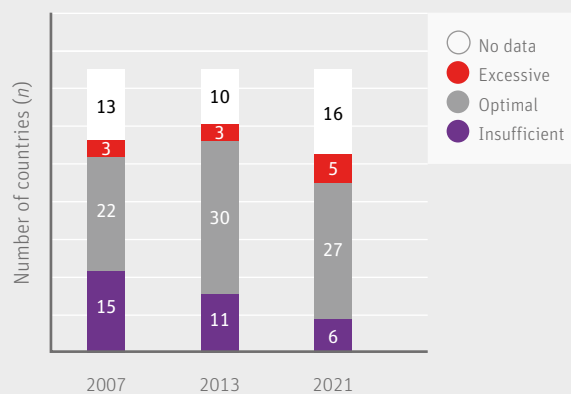
Diets in many countries cannot provide adequate iodine without iodine fortification of salt.¹ Over the past 20 years, the global proportion of households using iodized salt has increased from 70 percent to 89 percent.² The number of countries with adequate iodine intake has nearly doubled, from 67 in 2003 to 118 in 2021, reflecting the effectiveness of national salt iodization programs.³ However, nine countries in Africa still have no or unknown legislation mandating salt iodization.⁴ Here we provide an update of iodine nutrition since 2013 (the date of our previous *Sight and Life* article) in the 54 countries on the African continent.⁵

Improved iodine status of many countries in Africa

Over the past decade, notable shifts occurred in the iodine status of many countries in Africa^{3,6} (Figure 1). The number of countries with insufficient iodine intake decreased from 11 in 2013 to six in 2021. The iodine intake improved in Angola, Ethiopia, and The Gambia, thanks to increased access to iodized salt, as well as in Algeria, Ghana, and Morocco, probably due to increased consumption of imported processed foods made with iodized salt.^{7,8} The iodine intake is overall inadequate in Burundi, Mali, and South Sudan, probably due to poor border control of iodized salt, and in Mozambique and Madagascar because of inadequate iodization by large- and small-scale salt producers. In Burkina Faso, the donor funds supporting iodized salt shrank and the iodine intake deteriorated from adequate to inadequate.

The number of countries with excessive iodine intake increased from three to five between 2013 and 2021. New data

FIGURE 1: Iodine status of countries on the African continent (2007–2021)



Source: Adapted with permission from the Iodine Global Network⁶

documented excessive iodine intakes in Djibouti, Equatorial Guinea, and Cameroon, in addition to Benin and Uganda. The iodine intake shifted from excessive to adequate in Somalia, although remaining high. The excessive iodine intakes are primarily due to high iodine levels in groundwater, as in Djibouti and Somalia, or high iodine levels in salt, as is the case for Cameroon.

In 2021, one-third of countries on the African continent had no data or data older than 15 years. Furthermore, it is possible that the 27 countries with optimal iodine status may be hiding disparities and inequities within the countries at a subnational level, by geographic location, socioeconomic status or by physiological status, leaving the vulnerable strata of society unprotected. For example, in Morocco, the iodine status of school-age children is overall adequate nationally, but the population of the high-mountainous regions remains iodine-deficient.⁹ Further, while the iodine intake may be adequate for nonpregnant women, it may be insufficient for pregnant women. There is an urgent need to evaluate less costly, more equitable and sustainable means of monitoring iodine status.

Requirements for effective salt iodization

To date, global guidance around salt iodization has mainly focused on adequate iodization of household salt. However, there is now strong evidence that dietary patterns are shifting towards increased consumption of industrially processed foods, including in African countries. If this salt is iodized, it could significantly contribute to the iodine intake, as is the case in Ghana where, despite a low household iodized salt coverage, the iodine status of the population is optimal.^{7,8} However, iodine levels in salt for processed foods is not known or monitored in most countries. Iodized salt may also be consumed by cattle and, along with fortified fodder, this may lead to considerable concentrations of iodine in cow's milk, as recently observed in Tanzania and South Africa.¹⁰ Dairy products may therefore contribute to iodine intake in some parts of Africa.

Overall, iodine intake has steadily improved in Africa as a result of successful national salt iodization programs. However, of the 30 countries with optimal iodine in 2013, only 18 have documented optimal iodine status based on recent data in 2021, and new data is needed. Innovative ways of sustainably supporting salt iodization on the African continent are also needed as well as monitoring of iodine from non-household salt sources.

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FIRST PUBLISHED IN:

Vol. 28 (1) | 2014
PP. 28-33



Newborn Vitamin A Dosing is Feasible in Bangladesh

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Key messages

- > Newborn vitamin A supplementation (NVAS) may be a promising new intervention in contexts with moderate to severe maternal vitamin A deficiency in South Asia.
- > We tested the feasibility of integrating NVAS into two existing health contact points under existing health services in Bangladesh.
- > After five months of implementation, NVAS was delivered to 54.7% and 44.1% of newborns within 30 days of life.
- > Including NVAS as part of postnatal services appeared to significantly increase postnatal visits twofold in both models.
- > NVAS was well tolerated by infants, achieved reasonably high coverage, was easily integrated into existing health service delivery contacts within a five-month implementation time span, and increased postnatal visit coverage rates.

- > NVAS is a promising new intervention that is feasible in Bangladesh where a high proportion of births take place in the home. Further improvements are needed, however, to reach a higher proportion of newborns within the first two days of life.

The urgent need to address mortality rates

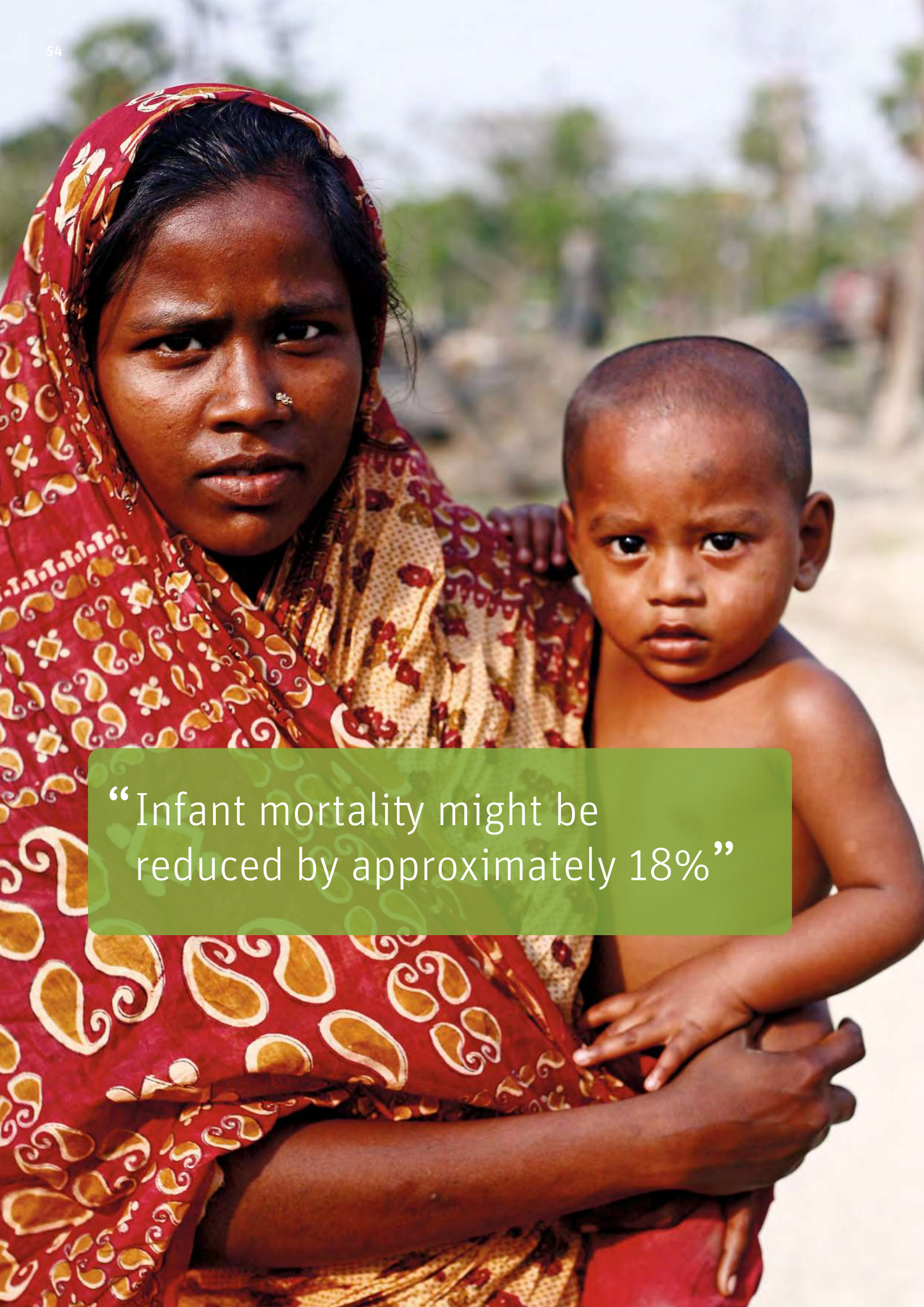
There is an urgent need to address high neonatal and infant mortality rates in many developing countries. In Bangladesh, 104,000 infants die each year before their first birthday,¹ most of whom do not survive past six months.² A major public health challenge has been to reduce early infant mortality through effective and practical interventions. Vitamin A (VA) supplementation has been long known to reduce child mortality over six months of age, but it may similarly reduce early infant mortality if given at birth.

Newborn vitamin A supplementation (NVAS) is a promising new intervention in South Asia that involves supplementing infants shortly after birth with a single, large oral dose of vitamin A (50,000 IU). Evidence for intervention efficacy is available from three field trials in southern Asia (Indonesia, India, and Bangladesh), which show significant reductions of $\geq 15\%$ in infant mortality in the first six months of life.^{3,4,5} When combined, the results suggest that infant mortality can be reduced by approximately 18% in southern Asia by giving newborns a single, oral dose of vitamin A.^{6,7} Results from two other studies in the region, in Pakistan and India, have not yet been published.

In an effort to explore the feasibility of NVAS as a life-saving intervention, the Government of Bangladesh approved pilot testing in three districts: Tangail, Pirojpur and Nilphamari.^{8,9} Micronutrient Initiative and USAID's A2Z project, in collaboration with Johns Hopkins Bloomberg School of Public Health and other country partners, set out to test feasible delivery models to reach newborn infants with vitamin A in the context of a high proportion (71%) of births occurring in the home and low (30%) postnatal care for mothers and newborns.¹⁰

Developing a feasible delivery model

The overall objective of the pilot was to identify, develop and evaluate a feasible delivery model for delivering newborn VA



“Infant mortality might be reduced by approximately 18%”

FIGURE 1: Counseling card given to pregnant women.



that could be efficiently integrated into existing community-based maternal and neonatal health services. Secondary objectives were to explore the acceptability of NVAS among intended recipients; the manner and practicality in which NVAS dosing could be implemented within existing health service contact points considering resource, time and other constraints; and the extent to which integrating this new intervention into existing health service contact points might change those services.

A Technical Advisory committee was formed consisting of the Canadian International Development Agency, UNICEF, Government of Bangladesh partners (Institute of Public Health Nutrition, Directorate General of Health Services, Directorate of Family Planning, the Revitalization of Community Health Care Initiative, and the Bangladesh Medical Research Council), the Micronutrient Initiative, Johns Hopkins University and the A2Z Micronutrient Project. Formative research was undertaken to explore feasible delivery platforms or health service contact points to reach newborns with a dose of vitamin A within the existing community-based maternal and newborn services and to understand the needs and types of communication required and materials to be developed.¹¹ Two health service contact points

were identified as potential platforms for NVAS integration: antenatal care (ANC) and postnatal care (PNC) visits. The ANC contact point had the potential advantage of providing the vitamin A dose to the mother during an ANC visit so that it would be available for her or a family member to squeeze into the mouth of the newborn at the time of birth. The PNC contact point had the advantage of a trained health worker visiting the newborn shortly after birth and delivering the NVAS dose directly to the newborn. To determine the feasibility and coverage of each delivery model, the models were pilot-tested in paired *upazilas* (sub-districts) from three districts.

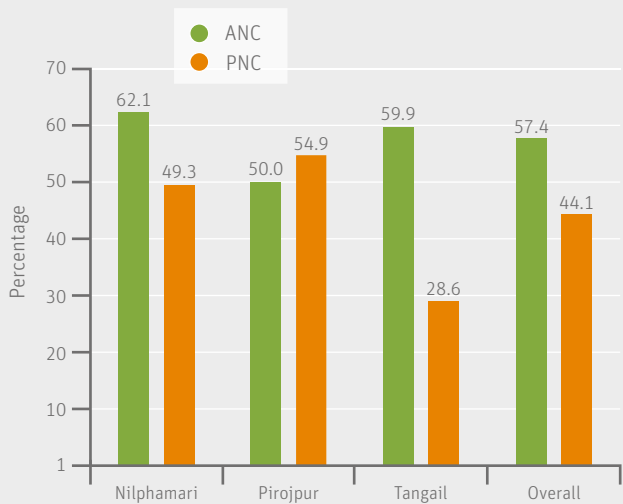
The *Antenatal Care (ANC) Model* consisted of usual ANC care to pregnant women, but health workers also gave expectant mothers an individually packaged dose of vitamin A (50,000 IU), instructions and counseling on why, when and how to administer the dose to their newborn, a counseling card (Figure 1), and a health worker contact card that included the worker's name, mobile phone number and address so that the mother or family member could notify the health worker about the birth. The *Postnatal Care (PNC) Model* required the mother or family member to inform the health worker about a birth so that the health worker could directly administer the vitamin A dose to the newborn. To facilitate birth notification, health workers informed pregnant mothers, during clinic or home visits, about the importance of early birth notification and provided women with a card containing the health worker's name, mobile phone number and address.

Methods

Two *upazilas* from three districts – Nilphamari, Tangail and Pirojpur – were selected and randomly assigned to either the ANC or PNC delivery model based on both *upazilas* having a reasonably comparable geographical setting, population size, and health worker-to-population ratio. A baseline survey in each *upazila* ($n \sim 900$ per *upazila*) was conducted in December 2010, after which a six-month implementation phase commenced from January to June 2011, followed by an endline survey ($n \sim 566$ per *upazila*) in August to September 2011. The baseline and endline surveys used a two-stage sampling procedure, with the first phase consisting of a random sample of 30 *mauzas* (i.e. clusters) based on population proportional to size, and the second phase consisting of a random selection of ~ 30 women in each cluster who had delivered a live-born infant in the previous six months. Both the baseline and endline surveys collected data on household socioeconomic status; previous pregnancy history; services and care received during the last pregnancy; use, timing and content of ante- and postnatal care received; and receipt, timing, acceptability, and perceived positive and negative effects of the newborn vitamin A dose.

In addition, 30 health assistants (HAs) and 30 family wel-

FIGURE 2: Percentage of newborns dosed with vitamin A within the first 30 days of life by district and delivery model.



ANC = Antenatal Care Model; PNC = Postnatal Care Model

fare assistants (FWAs) from each *upazila* were randomly sampled from a list of all HAs and FWAs and interviewed about the implementation procedures related to the NVAS delivery models and problems faced during implementation.

Ethical approval for the study was obtained from the Bangladesh Medical Research Council (BMRC) and the Academy of Educational Development Institutional Review Board (AED, IRB).

“NVAS coverage was significantly higher in the ANC model than the PNC model”

Results

After six months of pilot implementation, overall NVAS coverage across both delivery models within 30 days of birth was 50.8%, but it was significantly higher in the ANC model (57.4%) compared with the PNC model (44.1%) ($P < 0.001$) (Figure 2). The mean (SD) time of dosing was 2.4 (6.5) and 1.7 (3.7) days for the ANC and PNC models respectively ($P < 0.01$), with 88.5% and 85.6% of dosed newborns receiving vitamin A within the first two days of life, resulting in a 'first-two-day coverage rate of 50.2% and 37.3%, respectively. Although the ANC delivery model intended mothers or family members to administer the vitamin A dose, in actuality – and surprisingly – health workers dosed newborns at approximately similar rates in both delivery models: 65.1% in ANC and 72.7% in PNC model

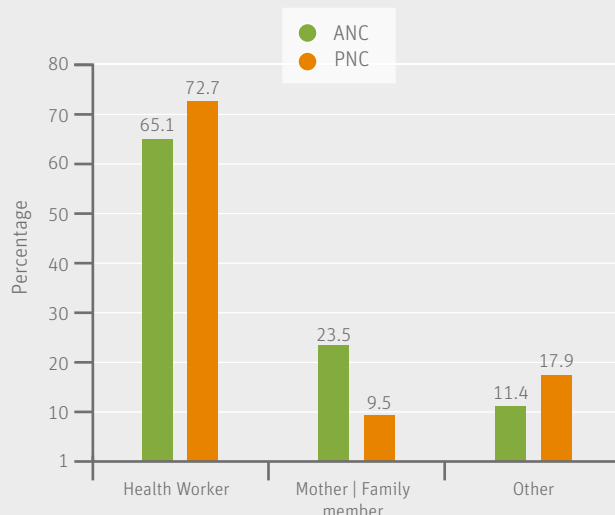
(Figure 3). Very few mothers reported side effects, and these were self-limiting.

As expected, integrating NVAS into ANC visits did not significantly or consistently affect antenatal care provision under either model, or change ANC coverage from baseline and endline (data not shown). On the other hand, we hypothesized that NVAS integration into postnatal care visits would improve both visit coverage and timing because the training, counseling cards and instructions to mothers emphasized the importance of reaching newborns within two days of birth. In addition, mothers were provided health worker contact cards which included the health workers' mobile phone number and address. Interestingly, PNC coverage increased across all six *upazilas* relative to baseline coverage (Figure 4). Overall, postnatal coverage increased more than twofold (28.4% at baseline to 60.5% at endline) in the PNC model and slightly less than twofold (38.4% at baseline to 65.9% at endline) in the ANC model.

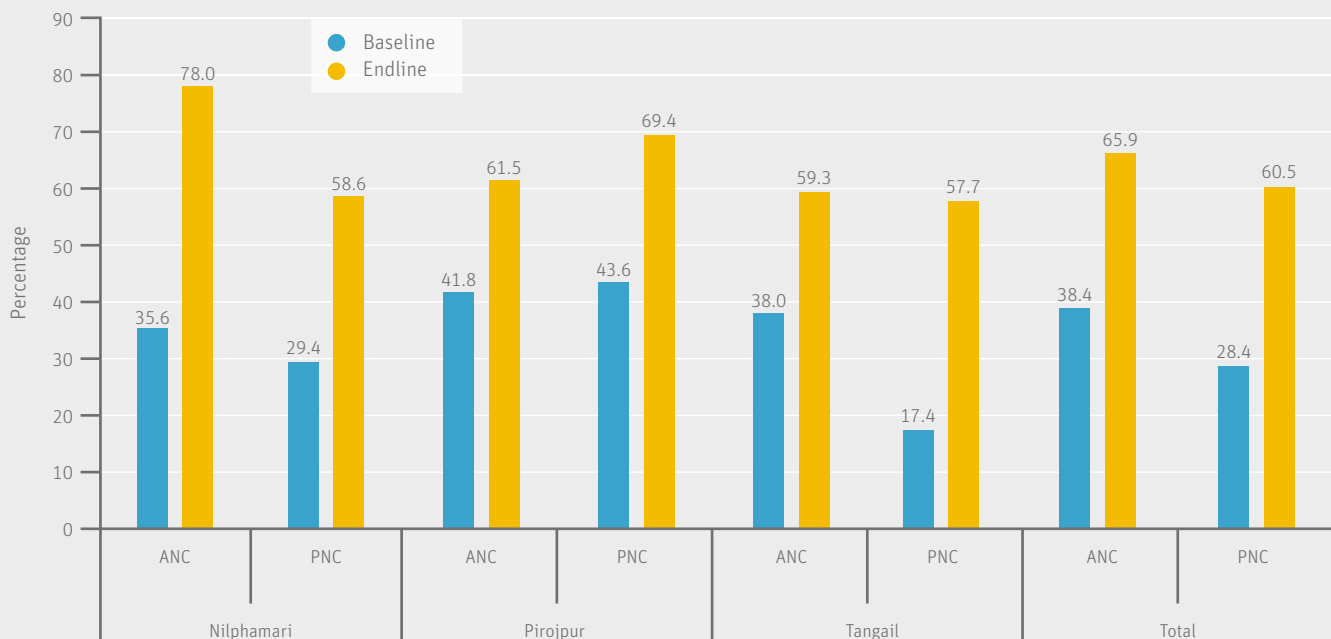
Health workers were notified about births via mobile phone (22.0%), by a family member visiting the health worker's house (18.9%), by the health worker making a routine visit to the house (16.6%), by giving birth in a hospital (16.1%), by the health worker being present at the time of delivery (11.4%), or by other means (15%).

“Health workers played an integral part in both delivery models”

FIGURE 3: Person who dosed the newborn by delivery model.



ANC = Antenatal Care Model; PNC = Postnatal Care Model

FIGURE 4: Baseline and endline postnatal care visits by district and NVAS delivery model.

ANC = Antenatal Care Model; PNC = Postnatal Care Model

As reported above, health workers played an integral part in both delivery models. Workers in the ANC model reported that 91.6% of women felt very confident in their ability to dose the infant, yet nearly 60% of workers said that “many” or “very many” mothers requested assistance in dosing (data not shown). Health workers in the ANC model most frequently felt that the program could be improved by making people more aware (53.1%) and increasing staff (15.4%) (data not shown). Less than 2% of health workers in the PNC model reported problems in dosing the newborns. Health workers’ confidence in reaching mothers within 48 hours of birth was variable in the PNC model, ranging between 18% and 86% (data not shown). Obstacles to reaching infants included working on a holiday, communication issues, or women going to their husband’s family home to deliver their baby.

Conclusions

In both models, health workers were a crucial component in NVAS dosing. The ANC model achieved a significantly higher coverage than the PNC delivery model, though mothers and family members waited for a health worker to assist with dosing. This finding may indicate that while women lack the confidence to dose their newborns themselves, they take on the responsibility for ensuring supplementation when the vitamin A capsule is given at the ANC visit and is in the home. Integrating NVAS into the ANC and PNC services increased PNC. This is likely due

to the perceived importance of reaching the child within two days of birth to complete a tangible task. During the six-month implementation period, the NVAS intervention was well integrated, implemented, and monitored within the government’s health services, and was well accepted by mothers and health workers. Mobile phones were the predominant means of birth notification, and mobile phone usage for this purpose increased significantly from baseline to endline, attesting to the value of providing expectant mothers with the mobile phone number of the catchment-area health worker. In light of these findings, the integration of NVAS into ANC and PNC services in Bangladesh seems reasonable and feasible. While reasonably high NVAS coverage levels were obtained in a short six-month pilot phase, further improvements are needed to ensure that a higher proportion of newborns are dosed within two days of life.

Acknowledgements

We gratefully acknowledge the collaboration, support and cooperation provided by the National Nutrition Services (NNS), Directorate General of Health Services (DGHS), Directorate General of Family Planning (DGFP), Revitalizing of Community Health Care Initiative, Bangladesh (RCHCI,B) and Bangladesh Medical Research Council (BMRC), Ministry of Health & Family Welfare (MoHFW), the Government of Canada, USAID, and UNICEF. We also thank Silvana Faillace (formerly AED), Robert Stanley (formerly Johns Hopkins), Shamim Ahmed (formerly MI), Alison

Greig (MI), Melanie Galvin (MI), Dr. Sakil (MI), Sk. Ali Ahmed (MI), and Mahbubur Rashid (formerly JiVitA). Finally, we gratefully acknowledge funding from the USAID A2Z Micronutrient and Child Blindness Project, and the Micronutrient Initiative.

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Perspective from 2021

The Need for More Nuanced Policy Guidance

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Since publishing the findings of our feasibility study on neonatal vitamin A supplementation (NVAS) in Bangladesh in 2014, new evidence confirms NVAS reduces infant mortality in South Asia in contexts where prevalence of maternal vitamin A (VA) deficiency and rates of early infant mortality are high, but not in contexts characterized by low prevalence of vitamin A deficiency and lower rates of infant mortality.¹ Unfortunately, this new evidence has not led to policy recommendations from the World Health Organization (WHO), nor to the implementation of NVAS in appropriate country contexts. Even in Bangladesh, where both NVAS efficacy and feasibility evidence is strong, NVAS has not been scaled up. Why?

Why hasn't NVAS been scaled up? I believe we can rule out the following:

1. Lack of VA deficiency among infants. All newborns are born with low liver stores and depend on the VA from breast milk and/or from other dietary sources. There is ample evidence of low VA breast milk content in populations with maternal VA deficiency.
2. Lack of maternal VA deficiency. Given the estimated 11 million VA-deficient pregnant women in 2009,² it is unlikely that maternal deficiency has disappeared, although updated estimates are critically needed.
3. High levels of neonatal mortality are no longer a problem. Of the estimated 5.2 million children under 5 who died in 2019, 75% (3.9 million) were under the age of one.³

Key barriers to NVAS policy and programming

So, what has impeded an NVAS policy and programming in appropriate contexts? In my view, the following are key barriers:

1. The lack of WHO context- or region-specific recommendations on NVAS. WHO tends to issue global recommendations. Without a WHO policy on NVAS, most countries – even those with high infant mortality and vitamin A deficiency – will not issue a national NVAS policy or introduce a new potentially life-saving intervention. As previously mentioned, the significant heterogeneity across studies suggests that the effects of NVAS on survival are influenced by level of infant mortality and the severity of vitamin A deficiency. Given the life-saving potential of NVAS in appropriate contexts, more nuanced and context-specific recommendations should be considered by WHO.
2. Inability for high-quality local evidence to drive local policy and programs. Despite the strong evidence for the survival benefit of NVAS in Bangladesh, the engagement of the local scientific associations in policy discussions, and the demonstrated feasibility of NVAS, the intervention was not scaled up in Bangladesh. More could have been done to engage local scientific bodies and the Bangladesh Ministry of Health in the NVAS research – both the efficacy and feasibility studies, and to build local capacity to evaluate and act on evidence-based findings even without WHO's 'blessings'.

“Thousands of newborn lives might have been saved over the past decade by scaling up NVAS”

The significance of differing underlying risks and contextual factors

On a more personal note, I am sometimes haunted by the thought that thousands of newborn lives might have been saved over the past decade in Bangladesh (and in other contexts with high VA deficiency and infant mortality) by scaling up NVAS. We

need to find better ways to provide more nuanced policy guidance, strengthen the role that locally generated evidence plays in shaping local policies and programs, and form alliances with global and local advocates to strengthen evidence-based policy-making. One policy and one intervention rarely fits or benefits all situations and contexts. While global recommendations are incredibly useful, there is a need to consider differing underlying risks and contextual factors so as not to ‘throw the baby out with the bathwater’.

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FIRST PUBLISHED IN:

Vol. 29 (2) | 2015
PP. 32-38



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The Challenges of Scaling Up Multiple Micronutrient Interventions

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With eight hundred million still living in extreme poverty and hunger, the Millennium Development Goals (MDGs) were created with a vision of a world with less poverty, hunger and disease; improved survival prospects for mothers and children; greater primary education; equal opportunities and empowerment for women; and a healthier environment.¹ While several countries have progressed towards achieving the MDGs, many interventions have nonetheless failed to improve the quality of life in a large number of the world's countries (Figure 1).² To be sure, despite enormous in-country and international efforts to achieve the first MDG of ending extreme poverty and hunger, an estimated 800 million people still face these challenges daily.³ One in seven children under the age of five years is still underweight (i.e., they weigh less than 2 standard deviations of the population average for their age and sex), and one in four children worldwide, or approximately 161 million children, are still stunted (i.e., they are below 2 standard deviations in height for age and sex).³

The crucial importance of evidence-based interventions

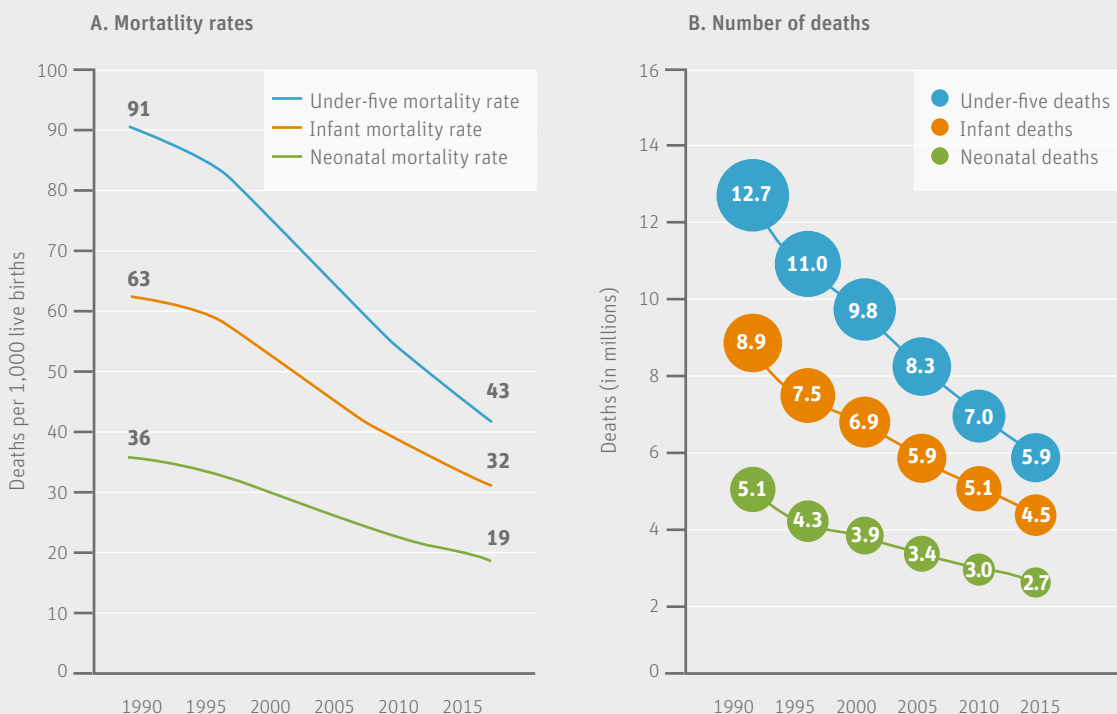
The implementation of evidence-based interventions is recognized by the international global public health and nutrition community as being essential to meet and surpass the MDGs. Of the 17 new Sustainable Development Goals (SDGs),⁴ two goals specifically address nutrition and implementation:

Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

Of the 169 targets outlined within the 17 SDGs, Goals 2 and 17 include the following targets specifically associated with nutrition and implementation (*italics inserted*):

- 2.1:** By 2030, *end hunger* and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.
- 2.2:** By 2030, *end all forms of malnutrition*, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons.
- 17.9:** Enhance international support for *implementing* effective and targeted capacity-building in developing countries to support national plans to implement all the Sustainable Development Goals, including through North-South, South-South and triangular cooperation.
- 17.16:** Enhance the Global Partnership for Sustainable Development, complemented by *multi-stakeholder partnerships* that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the Sustainable Development Goals in all countries, in particular developing countries.

FIGURE 1: Global under-five, infant and neonatal mortality rates and number of deaths, 1990–2015.

Source: United National Children's Fund (UNICEF), 2015² (with permission)

17.17: Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships.

“We define scaling up as the intentional process of taking an intervention that has been successful in one context, and expanding or replicating the relevant policies, programs, or projects to other locations so that the intervention can benefit more people in an equitable and sustainable way”

Scaling up MNP interventions

The focus of the international global public health nutrition community to mitigate the burden of micronutrient deficiencies or “hidden hunger” among children under the age of 5 years is in

line with the SDG targets to end hunger and malnutrition. The process of scaling up (for MNPs or other interventions), however, is the final component of a four-stage process that includes research and discovery; setting up a supply (value) chain; developing business models for implementation; and, finally scaling up (Figure 2). We focus here on conceptualizing and framing processes for scaling up health interventions, and specifically on scaling up MNPs.

We define scaling up as the intentional process of taking an intervention that has been successful in one context, and expanding or replicating the relevant policies, programs, or projects to other locations so that the intervention can benefit more people in an equitable and sustainable way. Our focus on *equitable* scaling up draws attention to the needs of vulnerable and underserved populations, which tend to be the hardest to reach.⁵ While the notion of bringing-to-scale implies a reasonably straightforward process of expanding the reach of a local intervention, successfully scaling is in fact a complex social, political, and institutional process.⁶ Few pilot projects include the necessary components to maximize their prospects for scaling up, and among those that do seek to scale up, there is a poor record of local pilot projects extending their reach in any significant way.⁷ As a result, many successful interventions in health, employment, empowerment and socioeconomic development

remain confined to their original target areas; they are meeting local needs, but with little impact beyond.

Despite the rapid expansion of academic and practitioner literature on the subject and the obvious importance of scaling up in development work, the consensus on how best to transform local interventions into global solutions is just beginning to build. At least two reviews published recently summarize evidence from theoretical frameworks of scaling up health interventions.^{8,9} There is clearly a continued need for improved knowledge about best practices regarding the varied processes of how decision-makers prioritize, design and ultimately implement scaling-up strategies.

We have previously published an article on this topic in the Stanford Social Innovation Review.¹⁰ This article offers a summary of a practical framework to guide the processes of expanding relevant policies, programs and projects in order that successful local development interventions can benefit more people and have a larger impact.

Two approaches to scaling up

There are, we believe, two ways to think about sustainable national and multi-country scaling: **1)** scaling by replication; and **2)** scaling by custom design. Scaling by replication involves a process by which local solutions (products, programs, or poli-

cies) are exported and implemented elsewhere, with little or no concern about variations in local contexts and the specific end-users. This kind of “one-size-fits-all” approach presumes a universal logic in implementation: what works in one place should work in another. It assumes that good ideas, from a supply-side and functional point of view, should obliterate contextual variation. Unfortunately, with a few exceptions, scaling by replication alone does not work.

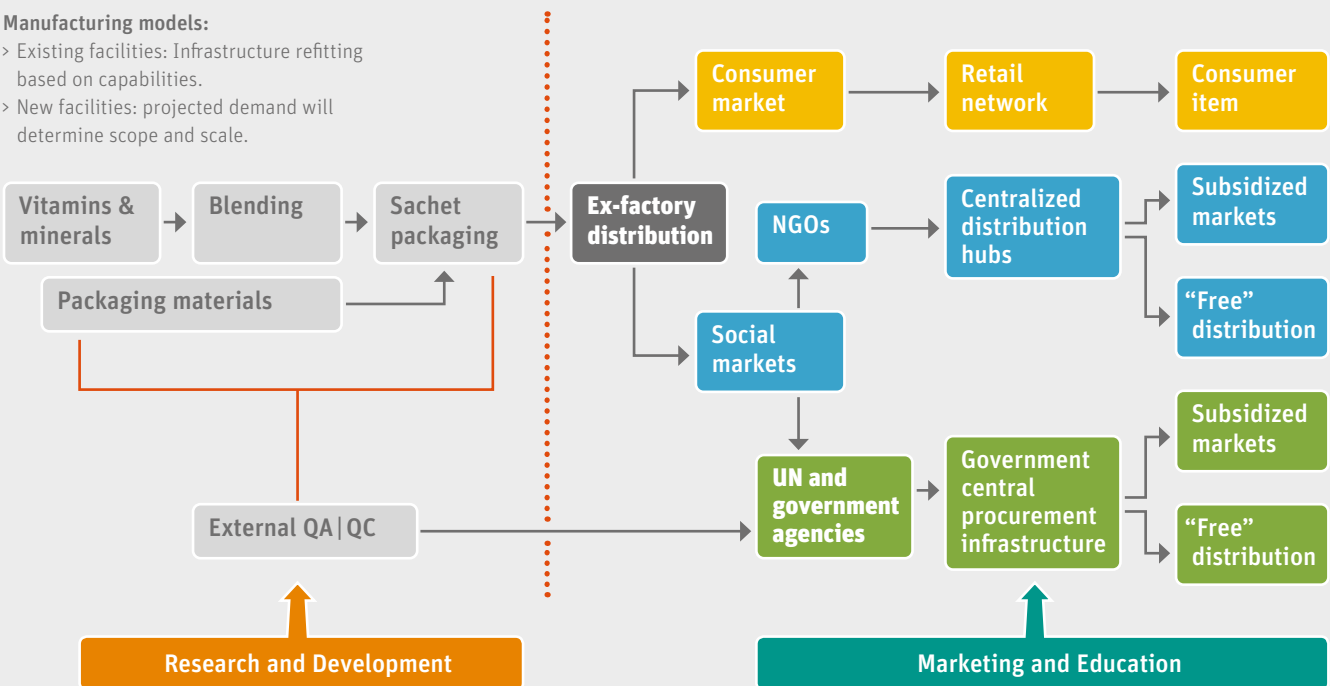
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“We propose a compromise between replication and custom design”

In scaling by custom design, local variables and local context are paramount. Solutions are custom designed to fit specific local contexts, shaped by costs, cultures, norms and existing practices. This approach is intuitively appealing, but rarely generates the efficiencies and economies of scale critical in the broader scaling-up process. We propose a middle-ground approach: one that describes a compromise between replication and custom design. At the center of our approach to scaling up is the assertion that one must come up with this compromise

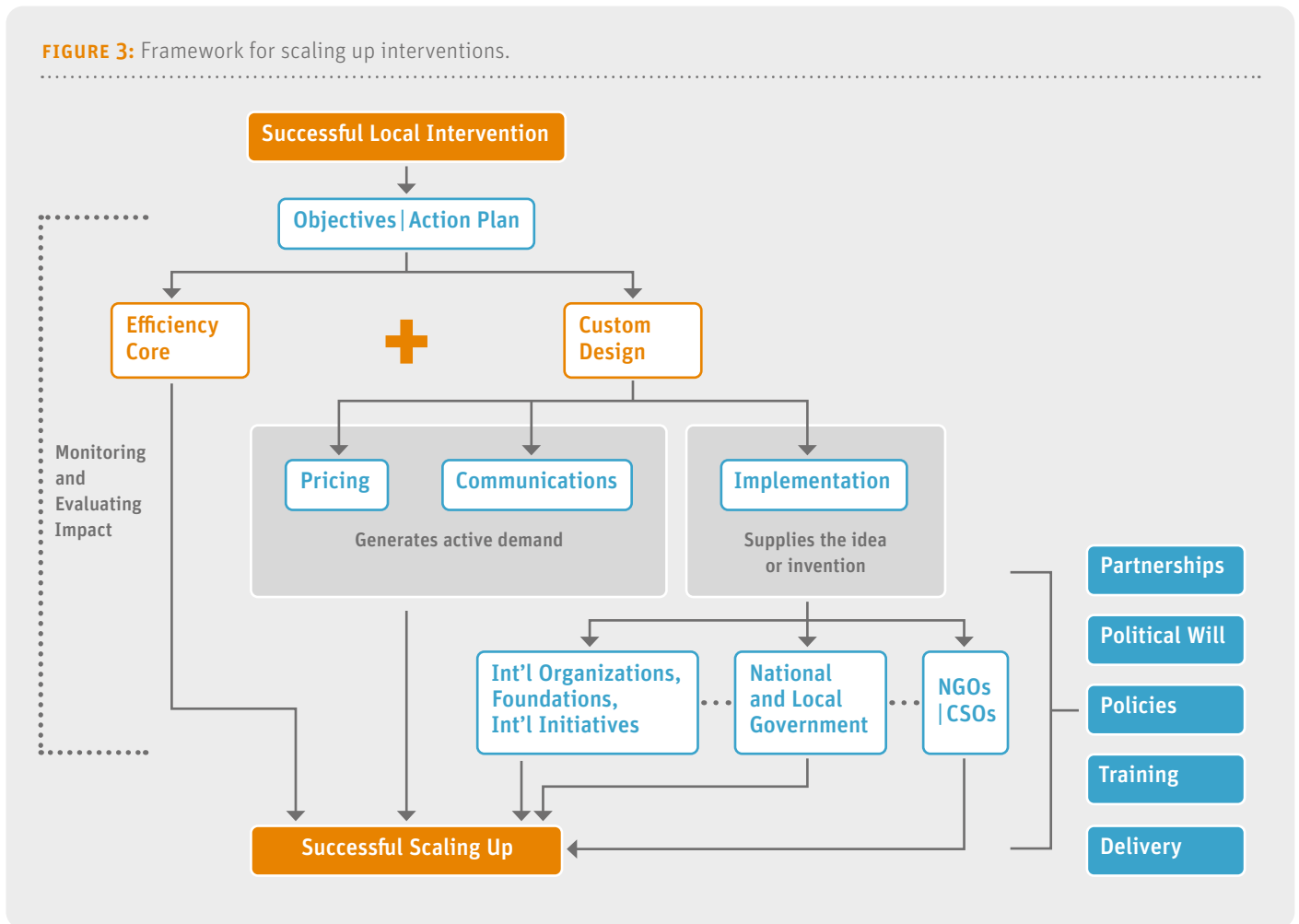
FIGURE 2: Research and design stages for Sprinkles multiple micronutrient powders (MNPs).

Manufacturing models:

- > Existing facilities: Infrastructure refitting based on capabilities.
- > New facilities: projected demand will determine scope and scale.



Source: Sprinkles Global Health Initiative

FIGURE 3: Framework for scaling up interventions.

between custom design and pure replication by identifying and adapting what we are calling the *replicable efficiency core* of a proven solution (Figure 3). The *efficiency core* is a specific part, rather than the entire solution, which can be replicated with minimal modification to fit many varied local contexts.

The efficiency core of MNPs

The efficiency core of micronutrient powders, independent of the local context, is defined by the mixture of vitamins and minerals in a tasteless powder form available in a single-serve package format that, when added to any complementary foods, does not appreciably change the taste or color of the food. In addition to their ease of use, factors that contribute to the efficiency core of MNPs include: that they are food-based rather than a medicinal product; that they can be used in populations with low literacy; that they do not conflict with breastfeeding practices; and that they can be used to promote the timely introduction of complementary foods at 6 months of age, along with appropriate complementary feeding practices. Furthermore, MNPs are lightweight, inexpensive, easy to transport and store, and require limited technology to manufacture. These factors do not change, irrespective of where the product

is used, and thus they are defined as the replicable efficiency core. As suggested by Yamey et al,¹¹ MNPs meet the criteria of an intervention that is simple and has scientifically robust technical policies, necessary for scale.

We cannot presume, however, that a strong efficiency core for MNPs or any social solutions – be they in health, productivity, employment generation, empowerment and so on – will necessarily lead to adoption of those solutions by all end-users in all jurisdictions. Thus, where necessary, this efficiency core may be expanded or modified with an effective *custom design* to expressly fit specific local contexts to generate active adoption of the intervention (Figure 3). In the case of MNPs, examples of custom design include: using local language and appropriate artwork on the package; adapting the specific ingredients to meet local needs (e.g., vitamin D included in Mongolian MNPs because of high prevalence of vitamin D deficiency rickets);¹² and social marketing strategies appropriate for the local context.

In other words, scaling up requires, on the one hand, the replication of the intervention's efficiency core (Figure 4), and on the other, the adaptation of that efficiency core (i.e., customization of local implementation strategies) to ensure the replicable

FIGURE 4: What is the Efficiency Core for MNPs?

- > Easy to use and high acceptability among families and children; focus on ages 6–24 months
- > A food-based rather than a medical approach
- > Does not require literacy
- > Does not conflict with breastfeeding practices
- > Used to promote the timely introduction of complementary foods at 6 months of age and proper weaning practices
- > Can be used for other ages throughout the life cycle
- > Light weight, easy to store and transport
- > Inexpensive and low tech to manufacture



efficiency core is adopted and that active demand is generated. Active demand can be generated by identifying and executing **1)** an appropriate communications plan, and **2)** a pricing strategy – a communication strategy that clearly conveys the value and credibility of an intervention or program, its observable benefits, relevance, relative advantage, and viability, in conjunction with an appropriate price that is low enough to be affordable to the targeted group, but high enough to signal intrinsic value to the user, thus generating active demand. For example, recent studies have shown that charging a nominal fee (versus charging no fee) resulted in an increased use of bed-nets.¹³ In Mongolia, locally adapted social marketing strategies were used to promote the use of MNPs.¹²

“Scaling up requires the replication of the intervention’s efficiency core plus the adaptation of that efficiency core”

An effective implementation strategy

Generation of active demand for an intervention or program, however, must be supported by an implementation strategy that takes into consideration potential partnerships, the strength of political will, supportive public policies, training opportunities, and delivery options that are specific to a given context. Effective implementation strategy requires systematic planning from the outset (i.e., at the time of pilot intervention) so that “local”

implementation is in line with the objectives of scaling up and conducive to a sustainable strategy. Special attention has to be paid to ensure interventions and programs reach the most vulnerable and underserved populations.¹⁴

Partnerships are essential to implementing any intervention or program at scale. Sharing common interests, clearly defined organizational roles, and open communication can accelerate collaborations between international, national, and local actors. For example, the United Nations agencies, in collaboration with national and/or local governments, or with international non-governmental organizations (iNGOs) and civil society organizations (CSOs), have implemented MNPs at scale in many contexts and contributed to the successful national distribution of MNPs in a number of jurisdictions. The political will of an organization or a person (“champion”) – which we define as the desire to scale up the intervention – is critical to ensure that an intervention or program is scaled up. Scaling also requires national public policies that are conducive to scaling up,¹¹ or at least, policies and programs that do not constrain or inhibit the process of expanding reach. Adequate resources for training must be available to ensure that local personnel have the skills needed to carry out the implementation program and to invest in sustainable human resources.¹⁵ Furthermore, efforts at scaling up must be supported by appropriate delivery mechanisms, including the logistics surrounding the delivery or distribution of the intervention as well as financial resources needed to scale up. Robust systems for monitoring and evaluation designed to ensure pragmatic, timely data collection, and which can be used to improve and redesign the implementation strategy, should be in place from the very start (Table 1).

TABLE 1: Summary of illustrative cases of the scaling-up framework and principles.

Cases	Objective	Efficiency Core	Custom Design
West Africa Onchocerciasis Control Program (OCP) [1974 – 1990] ¹⁶	To reduce the prevalence of “River Blindness” by eradicating infected blackflies.	Aerial spraying of insecticides in rivers where blackflies bred. Also sprayed villages closer to the breeding sites.	None highlighted – this example highlights the era when implementation science was heavily biased towards the replication model for scale.
Indonesia’s Kecamatan Development Program (KDP) [1998–current] ^{17,18}	To alleviate poverty in rural communities, strengthen local government and promote local governance.	KDP’s fiduciary structure of providing block grants to sub-districts and villages for small-scale infrastructure, social and economic activities.	Government acceptance and ownership of KDP; political will and national commitment; also KDP’s scale at the national level occurred in the context of institutional collapse and major economic crisis. In 2013, KDP was incorporated as a new national law.
Oportunidades, Mexico [1997 (Progresa) – current] ¹⁹	To alleviate poverty and build capacity through provision of services to the underprivileged and poor populations in Mexico.	Conditional cash transfers for seeking health, nutrition and education services.	Political, fiscal, and socio-cultural space was created for the program; fiscal and social policies to facilitate demand and supply; robust monitoring and evaluation frameworks are in place.
Roll Back Malaria (RBM) Partnerships across Africa [2005 – current] ²⁰	Package of proven malaria interventions used simultaneously to increase coverage and quickly achieve the optimal health.	Proven malaria interventions: Insecticide treated nets (ITNs), indoor residual spraying, prevention in pregnancy with intermittent treatment.	Distribution system in each country; varying costs of delivery and achieving high coverage.

The new Sustainable Development Goals identify development challenges that can be mitigated by implementing effective solutions at scale, so that the benefits can be extended to a greater proportion and to the most vulnerable populations. Scaling up, by definition, broadens impact. It is more than just sharing knowledge and best practices, however. It requires upfront planning and it has to be intentional, equitable and sustainable. It is, at its core, about implementation, that “last-mile” challenge to ensure health innovations are adopted by the end-users. The challenge of scaling up resides not in the ability of implementers to replicate entire system-solutions, but rather to identify the “efficiency core” of the solution which can be most efficiently adapted and modified to fit varied local contexts.

It is important to realize, however, that scalability is not synonymous with sustainability. The initially successful MNP program in Mongolia has recently run into trouble because of financing and the withdrawal of the World Vision partnership. A sustainable strategy for scaling up requires long-term commitments as well as sufficient time for the process to occur (e.g., 10–15 years in some cases).

As of last year, according to UNICEF, the scaling-up of MNP programs has tripled from four in 2011 (Bangladesh, Bolivia, Do-

minican Republic and Mongolia) to 13 in 2013. In this article, we have identified some of the principles that might have enhanced the scaling-up of MNP programs.

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Perspective from 2021

The Challenges of Sustaining Multiple Micronutrient Interventions

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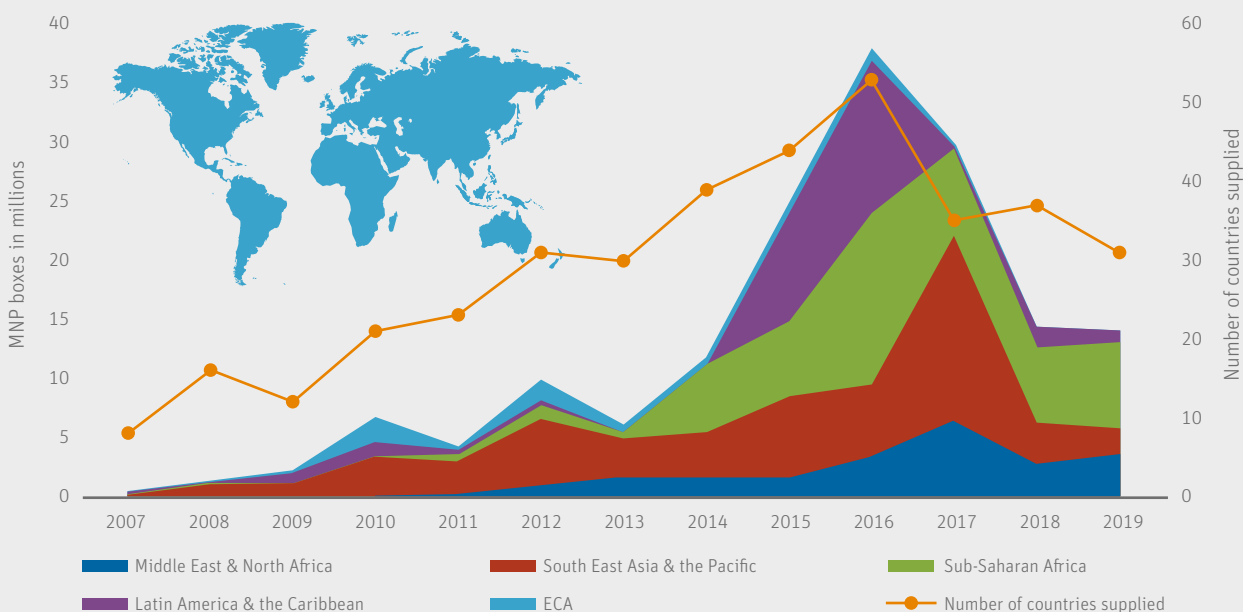
In our original article in 2015, we focused on the process of scaling up micronutrient powders (MNPs). We defined scaling as a four-stage process that included: research and discovery; setting up a supply (value) chain; developing business models for implementation; and finally scaling up (original **Figure 3**). We defined scaling as the intentional process of taking an intervention that has been successful in one context, and expanding or

replicating the relevant policies, programs, or projects to other locations so that the intervention can benefit more people in an equitable and sustainable way.

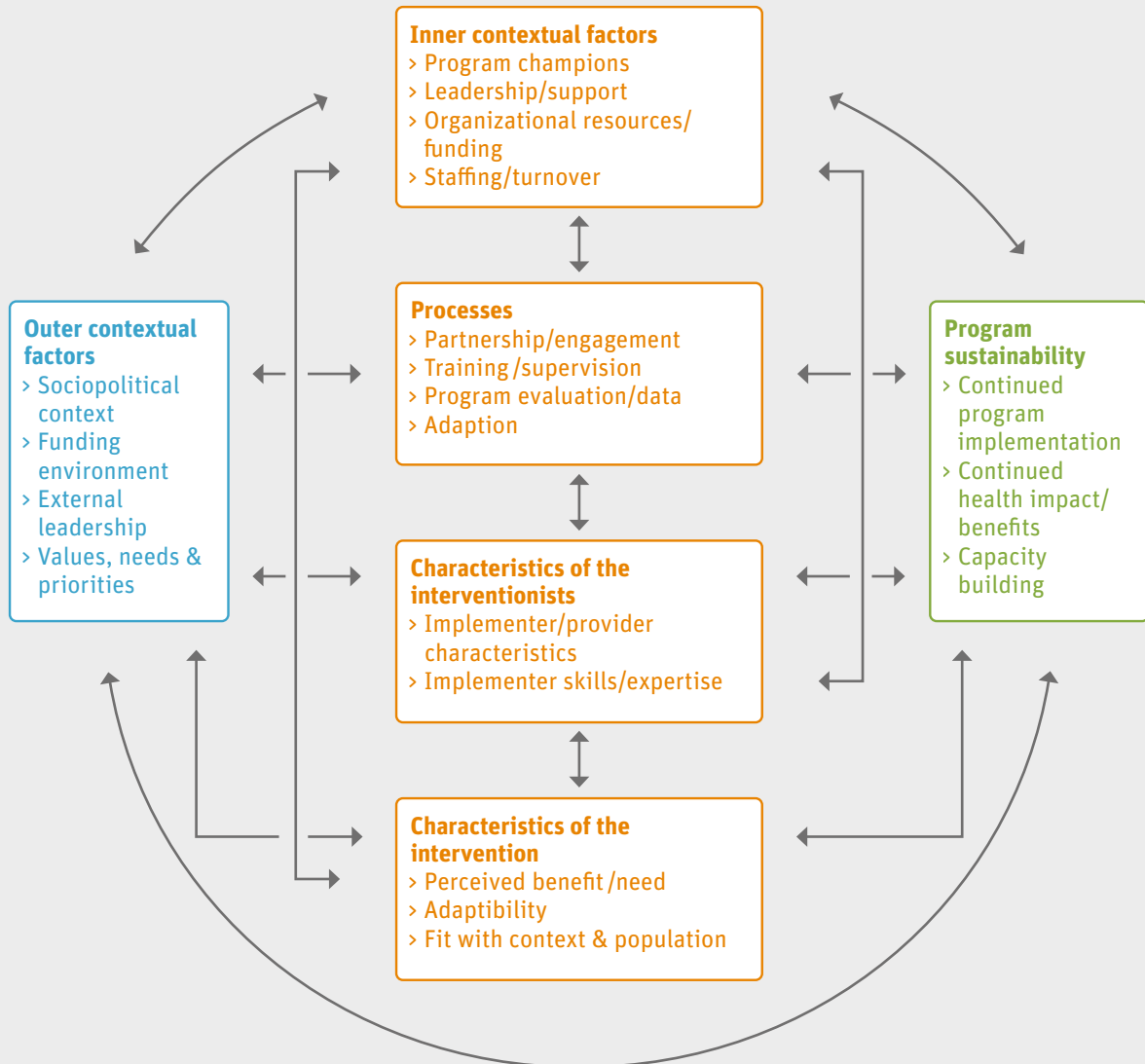
Significant rise in demand for MNPs

Since 2015, MNPs have been scaled to many countries. UNICEF has to a large degree been responsible for the storage and distribution of MNPs. UNICEF procures MNPs from the private sector for storage at its warehouse in Copenhagen and directly delivers them to countries. The demand for MNPs increased from approximately 27 million sachets in 2007 to 1.2 billion sachets in 2017.¹ UNICEF has procured MNPs on behalf of 80 different

FIGURE 1: UNICEF micronutrient powder (MNP) deliveries by region, 2007–2019



Source: UNICEF Supply Division

FIGURE 2: An integrated sustainability framework

Source: Shelton et al. 2018³; reproduced with permission

countries since 2007, about one-third of which are low- and middle-income countries (LMICs). The remainder are sent to middle-income countries (MICs), accounting for 47 percent of the value of MNPs. Most of the countries have been in Asia, Europe, and Central Asia (ECA), as well as in Latin America and the Caribbean (Figure 1). Demand in sub-Saharan Africa has also been increasing significantly since 2013, accounting for 30 countries. In 2019, 58 countries were implementing home fortification programs with UNICEF support. The number of children benefiting from home fortification programs quadrupled from 2014 to 2019, increasing from 4 to 16 million, and has surpassed UNICEF's 2021 target of reaching 12 million.

The key to long-term viability and success

In 2015, our focus was on implementing MNP programs in new countries with high rates of anemia and on scaling up country programs. There was little emphasis on the sustainability of programs and probably not a clear distinction between scalability and sustainability. We now realize that scalability is not synonymous with sustainability, yet sustainability is the key to long-term viability and success. Sustainability is important to public health programs for a number of fairly obvious reasons. First, there is often a delay between the beginning of program-related activities and their observed effects on population health, so the program must be sustained long enough for it to realize its effects. Second, and perhaps most important, sustained programs can

maintain their effects over a long period, resulting in a greater and longer impact. Additionally, if a program were perceived to be beneficial yet unsustainable, the absence of sustainability would lead to an investment loss for the funders and bring disappointment to participants, therefore posing obstacles to subsequent community implementation.

“There is now more focus on the sustainability of MNP programs than on scaling them up”

There is now more focus on the sustainability of MNP programs than on scaling them up – indeed, there is a new ‘science of sustainability.’ Schell et al. identified a nine-domain conceptual framework for program sustainability that included: political support, funding stability, partnerships, organizational capacity, program evaluation, program adaptation, communication, public health impacts, and strategic planning.² The goal of the framework was to help create an understanding of sustainability across public health decision-makers including practitioners, funders, and researchers. Schell et al. suggest that the sustainability of programs is determined by the interrelationship among the nine domains over time; the same goes for their benefits. Others have suggested an ‘integrated sustainability framework’³ (Figure 2).

According to Proctor et al., sustainability is defined as: “the extent to which a newly implemented intervention is maintained or institutionalized within a service setting’s ongoing stable operations,” with institutionalization defined as a transition from temporary to permanent funding and inclusion of the intervention (program) in local or national policy.⁴ Despite the increasing recognition of the importance of the sustainability of public health interventions, there has been very little empirical research.⁵ That is certainly the case for MNPs. The increased interest among researchers, funders, and community partners to improve their understanding of sustainability calls for resources and research in this area.

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FIRST PUBLISHED IN:

Vol. 30 (2) | 2016
PP. 74-80



Cracking the Egg Potential During Pregnancy and Lactation

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- > Chicken production and egg consumption may be a locally available and feasible option to improve maternal diets during pregnancy and lactation.

Key messages

- > This paper sets forth a nutritional rationale why eggs, and interventions to provide more eggs to at-risk pregnant and lactating women, in addition to iron and folic acid supplements, may be a sensible strategy to reduce neonatal deaths and stunting.
- > Eggs provide a balanced source of energy and protein as well as essential fatty acids and a large range of vitamins, minerals, and other bioactive compounds that could likely improve nutrition during pregnancy and birth outcomes.
- > Eggs have great potential to improve nutrition among vulnerable populations living in resource-poor settings. Eggs are also likely to be especially important in vegetarian populations.
- > Maternal consumption of eggs during lactation can also enhance the breast milk content of certain nutrients and thus potentially contribute to child nutrition and development when children are breastfed. Nevertheless, egg consumption is relatively low among women of reproductive age.

The value of a simple egg

It should not be surprising that a simple egg, which provides a chicken embryo nutritive support from conception to the time it hatches, might also be an important food to support fetal growth and development during pregnancy. Eggs have great potential to improve nutrition among vulnerable populations living in resource-poor settings.¹ They provide a nearly complete source of protein and are also an important source of essential fatty acids, choline, vitamins A and B₁₂, selenium, and other critical nutrients. At the same time, compared to other animal-source foods, they cost less and are available and valued as a food in virtually all parts of the world.

A woman's nutrition before and during pregnancy is essential to ensure optimal fetal growth and development as well as for her own health and wellbeing. The 2013 Lancet Series on Maternal and Child Nutrition provided evidence that poor maternal nutrition is the cause of more than 200,000 neonatal deaths and 20% of stunting in children less than five years of age.² It also identified balanced energy protein supplements and supplements of calcium and multiple micronutrients as promising interventions to reduce intrauterine growth restriction and small-for-gestational-age births.³ In this paper, we set forth a nutritional rationale why eggs, and interventions to provide more eggs to at-risk pregnant and lactating women, in addition to iron and folic acid supplements, may be a sensible strategy to reduce neonatal deaths and stunting.

The contribution of eggs to nutrient requirements during pregnancy and lactation

Eggs provide a balanced source of energy and protein as well as essential fatty acids and a large range of vitamins, minerals, and other bioactive compounds that could likely improve nutrition



Chickens in the Cotopaxi Province, Ecuador

during pregnancy and birth outcomes. The recommended levels of nutrient intake for pregnant and lactating women, the nutrient content of a 50 g egg, and the proportion of the required intake met by consuming two 50 g eggs are presented in **Table 1**. The proportion of dietary requirements for pregnant and lactating women provided by eggs is summarized by categories in **Table 2**. During pregnancy and lactation, two 50 g eggs provide more than 25% of the nutrient requirement of riboflavin (vitamin B₂), cobalamin (vitamin B₁₂), phosphorus, selenium and choline.

Yet, egg consumption is relatively low among women of reproductive age. Round V of the Demographic and Health Surveys conducted between 2005 and 2010 collected dietary information from women of reproductive age (**Table 3**). Egg consumption the day prior to the survey ranged from 2.9% in India to 62.5% in Honduras and was lower in African countries compared to those in Latin America and the Caribbean with the exception of Haiti, where consumption was also very low.⁴

Fetal cells grow in size and number at a rapid rate, requiring a steady and increasing pool of nutrients, such as protein. Pregnant women also have their own protein needs.⁵ An ideal food during pregnancy is one with a high digestible indispensable amino acid score (DIAAS).⁶ Eggs, similar to other animal-source foods, are classified as one of the highest quality proteins, using the new DIAAS indicator.

While protein deposition in maternal and fetal tissues increases throughout pregnancy, most occurs during the third trimester. The current Estimated Average Requirement (EAR) and Recommended Daily Allowance (RDA) recommendation is for all stages of pregnancy and does not take into account the changing needs during its different trimesters. A recent study suggested that protein requirements are substantially higher than current recommendations at about 14%–18% of total energy.⁵ When the protein intake is balanced at < 25% of energy, a reduced risk of low birth weight has been observed. However, excess protein may also be harmful. One study found that high protein diets in low-income New York City women were associated with greater risk of small-for-gestational-age infants when the protein intake was > 34% of calories.⁷ Two eggs per day would provide ~70 kcal from protein, which would not put a woman in excess of 34% of her caloric intake from protein.

The nutritional value of an egg, however, goes beyond high-quality protein. It is also an important source of fatty acids, which vary in accordance with hen species and the diet they receive. Moreover, chicken feed can be enhanced with docosahexaenoic acid (DHA), which in turn enhances the content in eggs.⁸ Essential fatty acids and DHA in particular are critical for early brain development.⁹ Studies have shown that cholesterol, relatively high in eggs, does not increase the risk of heart dis-

TABLE 1: Recommended levels of nutrient intake (RDA or AI) for pregnant and lactating women, nutrient content of eggs, and the proportion of dietary intake provided by eggs^{38,39}

Nutrients	Unit	AI/RDA Pregnancy (19–50 y)	AI/RDA Lactation (19–50 y)	Large Egg (50g)	Egg per 100g	% of pregnancy AI/RDA provided by 2 large eggs	% of lactation AI/RDA provided by 2 large eggs
Energy	kcal	–	–	72	144	–	–
Protein	g	71	71	6.28	12.56	17.7	17.7
Lipids (total)	g	ND	ND	4.76	9.51	–	–
Linoleic Acid (18:2n-6)*	g	13.0	13	0.77	1.54	11.8	11.8
α -Linolenic Acid (18:3n-3)	g	1.3	1.3	0.02	0.04	2.9	3.1
DHA (22:6n-3)	g	–	–	0.03	0.06	–	–
Vitamins							
Vitamin A, RAE	μ g	770	1300	80	160	20.8	12.3
Thiamin (B ₁)	mg	1.4	1.4	0.02	0.04	2.8	2.8
Riboflavin (B ₂)	mg	1.4	1.6	0.23	0.46	32.6	28.5
Niacin (B ₃)	mg	18	17	0.04	0.08	0.4	0.24
Pantothenic acid (B ₅)*	mg	6	7	0.77	1.53	25.7	22.0
Pyrrodoxin (Vitamin B ₆)	mg	1.9	2.0	0.09	0.17	8.9	8.5
Cobalamin (Vitamin B ₁₂)	μ g	2.6	2.8	0.44	0.89	33.8	31.4
Folate, DFE	μ g	600	500	24	47	8.0	9.6
Choline*	mg	450	550	146.9	293.8	65.3	53.4
Vitamin C (ascorbic acid)	mg	85	120	0	0	0	0
Vitamin D (D ₂ +D ₃)	μ g	15	15	1	2	13.3	13.3
Vitamin E (α -tocopherol)	mg	15	19	0.52	1.05	6.9	5.5
Vitamin K	μ g	90	90	0.2	0.3	0	0
Minerals							
Calcium*	mg	1000	1000	28	56	5.6	5.6
Copper	mg	1.0	1.3	0.04	0.07	8.0	6.2
Iodine	μ g	220	290	0	0	0	0
Iron	mg	27	9	0.88	1.75	6.5	19.6
Magnesium	mg	350	310	6	12	3.4	3.9
Manganese*	mg	2.0	2.6	0.01	0.03	1.4	1.1
Phosphorus	mg	700	700	99	198	28.3	28.3
Potassium*	mg	4700	5100	69	138	2.9	2.7
Selenium	μ g	60	70	15.4	30.7	51.3	44.0
Sodium	mg	–	–	71	142	–	–
Zinc	mg	11	12	0.64	1.29	11.6	10.7

Adequate Intakes (AIs) are denoted with an *; otherwise values are Recommended Dietary Allowances (RDAs).

ease and stroke.¹⁰ In fact, one study suggested that low serum cholesterol during pregnancy is associated with adverse birth outcomes.¹¹ Eggs are also relatively low in saturated fat, with only about 1.5 g per egg.

Eggs are an important source of choline, an important precursor of phospholipids, which are needed for cell division, growth and membrane signaling.^{12,13} Inadequate intake during pregnancy has been associated with neural tube defects,¹⁴

changes in brain structure and function in the offspring,¹⁵ and adverse pregnancy outcomes.¹⁶ Through its role as a methyl donor, choline may also have epigenetic effects during pregnancy.¹⁷ Although choline is found in a number of plant-based and animal-source foods, none surpasses eggs with respect to choline per kilocalorie. More than 50% of the nutrient requirement for pregnant and lactating women is provided by two 50 g eggs (Table 1).

Eggs are also a good source of bioavailable vitamin A and carotenoids, vitamins E, D, and B₁₂ and folate. The relative contribution of vitamin B₁₂ may be particularly relevant in Latin America and the Caribbean, as deficiency continues to be a problem in most locations and population groups of those regions.¹⁸ This may be the case among the poor in other parts of the world as well. Observational studies have shown an association between eggs and reduced risk of night blindness,^{19,20} as well as xerophthalmia.^{21,22} Data collected between 1995 and 2005 show that 14.3% and 18.4% of pregnant women have serum retinol <0.70 µmol/L in Africa and Asia, respectively.² Night blindness was reported by 9.4% of pregnant women in Africa and 7.8% of women in Asia. Vitamin A supplementation in pregnancy reduces night blindness, which is also associated with increased low birth weight and infant morbidity.²³ As shown in **Table 1**, two 50 g eggs provide 21% and 12% of the vitamin A requirement for pregnant and lactating women, respectively.

Although eggs are generally low in minerals, selenium is an important exception, with two 50g eggs providing 51% of the dietary requirement for pregnant women and 44% of the daily requirement for lactating women (**Table 1**). Selenium plays important epigenetic and antioxidant roles that may be especially important during pregnancy.²⁴

The potential role of eggs to enhance concentration of key nutrients in breast milk

Maternal consumption of eggs during lactation can also enhance the breast milk content of certain nutrients and thus contribute to child nutrition and potentially development when children are breastfed. The concentration of nutrients in breast milk is most affected by a mother's intake of water-soluble vitamins. It is also influenced by her intake and stores of fat-soluble vitamins, though to a lesser extent. Micronutrients have been classified into two groups, according to the effect of maternal intake and the status of the micronutrient content of breast milk.²⁵ In Group 1 are those affected by maternal status including thiamin, riboflavin, vitamin B₆, vitamin B₁₂, vitamin A, iodine, and selenium. More recently, choline and vitamin D have been added to this list (Lindsay Allen, personal communication). Vitamin C also is transferred through breast milk. In Group 2 are those not affected by maternal status, including folate, vitamin D, calcium, iron, copper and zinc. During lactation, low maternal intake or stores of micronutrients in Group 1 reduces the amount in breast milk, which may negatively affect a child's development.²⁶ Therefore, adequate intake of Group 1 micronutrients is necessary to ensure breast-milk adequacy.

In addition to water-soluble vitamins and selenium, fatty acids in breast milk are extremely sensitive to maternal consumption and body composition, with implications for infants' neurological development.²⁷ The transfer of n-6 (omega-6) and

n-3 (omega-3) fatty acids from the maternal diet into breast milk occurs with little interconversion of 18:2n-6 to 20:4n-6 or 18:3n-3 to DHA. There is also little evidence of regulation by the mammary gland to maintain individual fatty acids constant with varying maternal fatty acid nutrition. DHA has gained attention because of its high concentrations and roles in the brain and retina. A recent study among Chinese women showed that supplementation of DHA during pregnancy increases the concentration of polyunsaturated fatty acids in breast milk.²⁸

However, a recent systematic review concluded that there have not been rigorous studies between the dietary intake of

TABLE 2: Proportion of daily nutrient requirement (RDA or AI) provided by two 50 g eggs during pregnancy and lactation

Pregnancy	Lactation
0 – < 5%	0 – < 5%
Niacin	Niacin
Vitamin C	Vitamin C
Vitamin K	Vitamin K
Iodine	Iodine
α-Linolenic acid	α-Linolenic acid
Vitamin B ₁	Vitamin B ₁
Manganese	Manganese
Magnesium	Magnesium
Potassium	Potassium
≥ 5 – < 15%	≥ 5 – < 15%
Vitamin B ₆	Vitamin B ₆
Vitamin E	Vitamin E
Folate	Folate
Linoleic acid	Calcium
Vitamin D	Copper
Zinc	Linoleic acid
Calcium	Vitamin A
Copper	Vitamin D
Iron	Zinc
≥ 15 – < 25%	≥ 15 – < 25%
Protein	Protein
Vitamin A	Pantothenic acid
Iron	
≥ 25%	≥ 25%
Riboflavin	
Pantothenic Acid	Riboflavin
Vitamin B ₁₂	Vitamin B ₁₂
Phosphorus	Phosphorus
Selenium	Selenium
Choline	Choline

TABLE 3: Percentage of women aged 15–49 who gave birth in the last 3 years who consumed eggs in the preceding 24 hours, DHS Surveys 2007–2010⁴⁰

World region	Year	Eggs (%)
sub-Saharan Africa		
Ethiopia	2005	3.8
Ghana	2008	21.6
Liberia	2007	19.6
Namibia	2006–07	20.5
Nigeria	2008	17.7
Sierra Leone	2008	12.1
Uganda	2006	3.6
Zambia	2007	14.0
Zimbabwe	2006–07	11.1
South/Southeast Asia		
Cambodia	2005	19.9
India	2005–06	2.9
Indonesia	2007	n.a.
Nepal	2006	6.1
Philippines	2008	39.4
Latin America and the Caribbean		
Dominican Republic	2007	47.0
Haiti	2005–06	6.9
Honduras	2006–07	62.5

single nutrients and their presence in human milk.²⁹ Reasons cited by the authors include the difficulties in the collection of dietary data as well as the availability of appropriate breast-milk samples. In most studies, sample size was limited, the period of dietary recall relative to the timing of the sample obtained inconsistent, and there was a lack of control of potential confounding factors. Therefore, to understand the effect of egg consumption on the composition of breast milk, studies should have clear protocols for milk storage and analysis, definition of the time lag between the diet and milk analysis, and adjustment for other factors such as energy intakes and anthropometric characteristics.

Role of eggs in vegetarian populations

Eggs are likely to be especially important in vegetarian populations. In India, with a population of approximately 1.25 billion, nearly one-third are vegetarian. The 2005–2006 India National Family Health Survey showed that low birth weight affects nearly 20% of births and is associated with low socioeconomic status.³⁰ As noted in **Table 3**, egg consumption among Indian women of reproductive age is extremely low.

Cultural and economic aspects of egg consumption

In some cultures, egg consumption during pregnancy may be taboo. For example, Nepali women have cited religion as a reason for not consuming eggs.³¹ In contrast, in rural Zambia, only about 5% of households believed that eggs were taboo for pregnant women, while 83% said that eggs were nutritious for pregnant women and 90% held this view for lactating women.³² Generally, these kinds of barriers may be overcome with well-informed and carefully conducted social marketing and behavior change communication strategies.³³ For example, in a recent large-scale intervention in Bangladesh, egg consumption among children 6 to 24 months of age in the intensive intervention group increased from 18% to 48% compared to 19% to 31% among children in the non-intensive group.³⁴

Economic barriers appear more important than cultural ones. Data from Demographic and Health Surveys show a high correlation between egg consumption and socioeconomic status, with consumption increasing in a dose-response manner with wealth quintile (**Table 4**).³⁵ In rural Zambia, 43% of households reported that cost was the primary limitation to routine egg consumption.³² Although rural households often raise chickens, they frequently sell the eggs to purchase other essential items. For example, in Zambia, before chicken survival and productivity were improved, households would sell the eggs or chickens rather than consume them.³⁶ However, as a result of a technical assistance project to develop community-operated, semi-intensive egg production facilities, which resulted in higher egg yields, both producer income and community consumption of eggs improved. Homestead and/or small community chicken-and-egg production in the context of inputs to increase yield and protect children from chicken feces may simultaneously address nutrition and poverty.¹

Eggs provide convenient solutions to problems of food preparation, storage, and transport. Eggs can be purchased in a single unit or units. Furthermore they are easy to prepare, require little fuel because of quick cooking, and can be eaten alone or mixed into a variety of dishes. Hard-boiled eggs can also be easily transported for consumption elsewhere, which is particularly important for women who farm, take care of animals, go to the market or work in other activities outside the home.

Environmental concerns

Raising chickens at home may increase exposure to chicken feces and pose risks of diarrheal infections, environmental enteric disorder and respiratory infections.³⁷ Particularly among young children, these illnesses are risk factors for mortality and linear growth retardation. At the same time, studies show that ownership of small animals is associated with improved nutrition. Keeping young children away from chicken feces through better poultry practices can mitigate the negative effects of chicken

TABLE 4: Percentage of women aged 15–49 who gave birth in the last 3 years who consumed eggs in the preceding 24 hours by household wealth quintile, DHS Surveys 2007–2010⁴¹

Country	Year	Wealth quintile	Eggs (%)
Ghana	2008	Lowest	13.8
		Second	16.4
		Middle	24.5
		Fourth	26.7
		Highest	31.8
Liberia	2007	Lowest	17.7
		Second	13.1
		Middle	14.6
		Fourth	24.1
		Highest	35.4
Madagascar	2008–09	Lowest	2.6
		Second	3.7
		Middle	4.9
		Fourth	4.8
		Highest	18.1
Nigeria	2008	Lowest	11.0
		Second	12.0
		Middle	14.3
		Fourth	23.4
		Highest	31.9
Tanzania	2010	Lowest	3.1
		Second	4.4
		Middle	5.5
		Fourth	6.8
		Highest	9.4
Zambia	2007	Lowest	9.3
		Second	10.0
		Middle	10.5
		Fourth	21.6
		Highest	23.5

feces. Interventions to improve poultry production and egg consumption among pregnant and lactating women would need to put in place reasonable control measures to reduce household exposure to chicken feces.

Summary

Chickens and eggs are ubiquitous globally and well known to be highly nutritious. While there are no rigorous studies identifying health benefits to mothers and newborns or benefits to child cognition of interventions to improve consumption during pregnancy and lactation, such interventions would appear to be

attractive. Chicken production and egg consumption may be a locally available and feasible option to improve maternal diets during pregnancy and lactation.

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PERSPECTIVE
FROM 2021



A word cloud showing the words most frequently used in the original contribution.

Perspective from 2021

Eggs during Pregnancy and Lactation and Beyond: What have we learned in the past 5 years?

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In the 5 years since our article ‘Cracking the egg potential during pregnancy and lactation’ was published,¹ the recognition that eggs likely provide critical nutrients during pregnancy and lactation for newborn and child health and neurodevelopment, and also that they can contribute to reducing poverty and supporting sustainable food systems has continued to grow. Eggs are rich in choline and docosahexaenoic acid (DHA), two nutrients hypothesized to have favorable effects on birth outcomes as well as on child growth, morbidity, inflammation, and neurodevelopment.² They contain high levels of several other nutrients and vitamins, including lutein and other carotenoids, and vitamins E, D, and B₁₂, and folate;³ they are also rich in selenium and iodine. Inasmuch as pregnant and lactating women have higher protein and other nutrient requirements compared with non-pregnant women,⁴ eggs are an ideal food to consume during this time. Nonetheless, because they are expensive relative to other sources of energy,⁵ consumption is low among women.¹

A likely pathway to improve birth outcomes

Despite the increasing recognition of egg consumption during pregnancy and lactation as a likely pathway to improve birth out-

comes and other outcomes related to child health and neurodevelopment, such intervention research is yet to be conducted; however, several studies have looked at the acceptability of eggs to women and barriers to their consumption, demonstrating the feasibility of such interventions.⁶ And while several studies have resulted in mixed results regarding the benefits of 6-month supplementation with eggs early in the complementary feeding period,^{7,8} research is warranted to identify the settings where egg interventions are most likely to have positive effects, and the length of time supplementation is needed. For example, in Bangladesh, a 12-month egg and milk intervention among children aged 6–12 months resulted in improved linear growth, cognitive, language, and motor scores.⁹ Beyond their benefits to pregnant and lactating women and young children, eggs may have benefits for preschool and school-age children; however, no studies have evaluated the impact of eggs on child development, school performance, or growth. Incorporating eggs into midday meal programs could also spur local egg production, thus supporting the growth of local economies.

“Gender-sensitive, small-scale poultry production has the potential to lift poor households out of poverty”

Evidence is building that gender-sensitive, small-scale poultry production has the potential to lift poor households out of poverty. In Ethiopia, women tend to control cash from the sale of eggs, and an intervention to improve household egg production resulted in substantial increases in child egg consumption as well as in household income.¹⁰ Increases in income, particu-

larly if managed by women, have the potential to improve other aspects of the lives of pregnant and lactating women, including the purchase of other nutritious foods and access to healthcare for mother and child. Further unpacking of the multiple pathways through which small-scale poultry production can benefit maternal and child nutrition is needed. These pathways include, but are not necessarily limited to, increased egg consumption, income generation, and women's empowerment. From an environmental perspective, there is a need for interdisciplinary research to work with communities to foster long-term environmental and economic sustainability.¹¹

Lower environmental impact than red meat

The recent United Nations Food Systems Summit highlighted the importance of climate-smart food systems (UN Food Systems Summit 2021: SDG2 Advocacy Hub).¹² In the context of the environmental consequences of the industrial production of beef, and the need for sustainable sources of nutrient-dense animal foods in some populations, the role of poultry and egg production merits attention. The food system constitutes the single biggest impact humans have on nature and is responsible for a third of global anthropogenic greenhouse gas emissions.¹³ A recent analysis (using data from life-cycle assessments in high-income countries) concluded that the relative environmental impact of eggs was similar to that of fish and dairy, and lower than that of red meat.¹⁴

In sum, despite the potential promise to deliver important nutrition, health, developmental, and economic benefits and to contribute to sustainable food systems, the role of small- and medium-scale poultry production and egg consumption from pregnancy through the school-age period is greatly under-researched. Perhaps this is the moment to call for substantial investment in egg research so that in another 5 years we will have more answers than questions about the potential of eggs to enhance the lives of millions of women and children.

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FIRST PUBLISHED IN:

Vol. 31 (2) | 2017
PP. 42-52



Omics Innovations and Applications for Public Health Nutrition

An integrated view

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Key messages

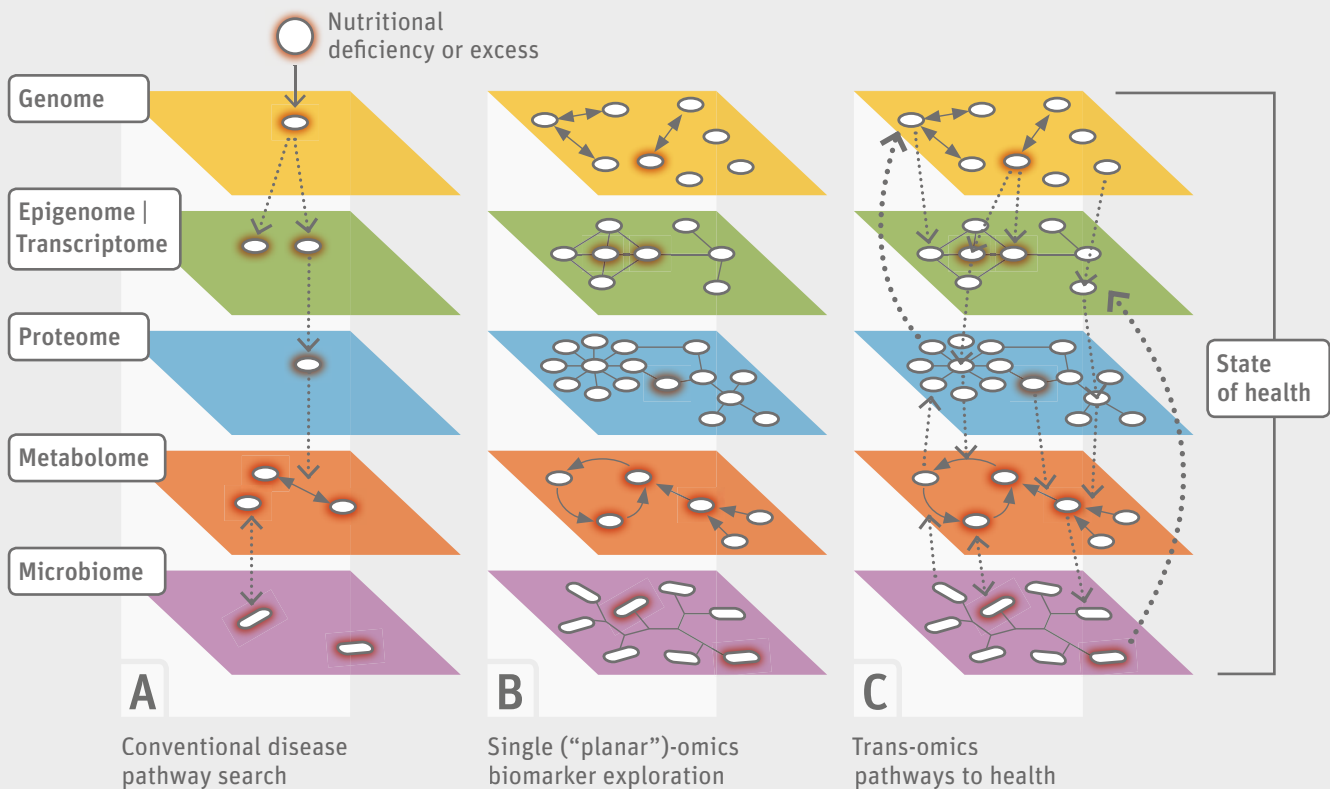
- > Omics technologies comprise sets of molecular mapping tools that can help us understand and navigate to or from states of health, including nutrition.
- > Single omics studies explore sets of genes, epigenetic marks, transcripts, proteins, or metabolites, as well as microbial communities, in an unbiased manner.
- > Trans-omics studies offer opportunities to connect, integrate, and map a group of molecules across multiple omics layers to identify pathways, interactions and feedback loops that may more fully reveal the biology and, likely, suites of diagnostic markers, therapeutic targets and pathways to and from disease states.
- > Omics approaches are transitioning from the theoretical level to the level of practical application to benefit vulnerable populations.
- > Human studies need to be greatly expanded in number and breadth and rigorously designed to overcome methodological, analytical and biological complexities in omics data.

Introduction

Let's assume that you have been taken to a place you have never been before, and are not sure how you got there. The first thing you might do is look at a Google map, which may reveal several roads leading to the place, each with outlying intersections and roads from other towns. Different overlays may reveal varying terrain, weather or road conditions throughout the region leading to your destination. Now, imagine a health problem affecting a population at your destination, and the plexus of pathways (routes), biochemical networks (towns), function (traffic flow) and other influential conditions (terrain, road upkeep, weather, etc.) that may lead to the health problem, overlaid on the map. Omics technologies comprise sets of molecular mapping tools for each overlay that can help us understand and navigate to or from states of health, including nutrition. This breakthrough approach has become possible due to advances in the development and application of high-throughput technologies, which allow us to analyze large-scale biological data to form new molecular maps to health and disease.

“Omics technologies can help us understand and navigate to or from states of health”

Conventional hypothesis-driven studies typically focus on a few specific molecules of interest based on prior knowledge: a nutritional deficiency or excess may set into motion a genomic aberration or epigenetic change that affects RNA expression, protein synthesis, metabolite production, or certain bacterial growth (Figure 1A). Single omics studies explore sets (individual *overlays*) of genes, epigenetic marks, transcripts, proteins, or metabolites, or microbial communities, in an unbiased manner. They are data-driven and provide opportunities to discov-

FIGURE 1: Simplified frameworks in molecular nutrition studies

Each layer represents the genome, epigenome, transcriptome, proteome, metabolome, or microbiome, and circles or rounded rectangles indicate genes, epigenetic marks, transcripts, proteins, metabolites, or microorganisms, depending on the layer. Solid and dashed arrows represent associations within and across layers, respectively. Please note that the epigenome and transcriptome, which are separate omics-layers, are combined for the sake of simplicity.

Modified figure from Yugi et al.¹ Reproduced with permission obtained from the publisher.

er unknown factors and biological networks at each molecular level associated with a phenotype (Figure 1B).

A limited but increasing number of trans-omics studies offer opportunities to connect, integrate and map a group of molecules across multiple omics layers to identify pathways, interactions and feedback loops that may more fully reveal the biology and, likely, suites of diagnostic markers, therapeutic targets and pathways to and from disease states (Figure 1C).¹ Omics technologies are now poised to fill gaps in biological knowledge and provide roadmaps to prevention strategies in public health nutrition.

In the "Frontiers in Nutrition" edition of *Sight and Life* (1/2015), the principles of each omics technology and emerging opportunity were discussed. The aim of this article is to highlight some of the recent progress and innovations in omics, mainly focusing on infant and child nutrition and health (Table 1). In addition, this review will project the translation of omics-based discovery into potential public health applications, drawing on *plasma proteomics* as an example.

Genome

There has been a growing interest in understanding effects of genetic variation on child health, enabled by genotyping single nucleotide polymorphisms that may predispose biological pathways to misfire. For example, a genome-wide association meta-analysis study reported that the secretor genotype of the *FUT2* gene, which encodes an enzyme for histo-blood group antigen production (a host defense mechanism), portends a higher risk of diarrheal disease in children.² The finding illustrates the potential importance of genetic variants in the *FUT2* gene that may identify children susceptible to enteropathogenic organisms.

In contrast to inherited genetic predispositions, studies of DNA damage biomarkers have revealed genome integrity can be modified by nutritional status and diet early in life. Micro-nucleated cells, which indicate missing genetic information and chromosomal damage, have been observed more frequently in malnourished than well-nourished Egyptian children.³ Large birth size has also been associated with increased cytogenetic

DNA damage biomarkers in the cord blood lymphocytes of otherwise well-nourished Australian infants.⁴ Telomere length attrition is considered a genomic marker of chromosomal instability and future disease risk. In Latino preschool children, exclusive breastfeeding and infant obesity were respectively negatively and positively associated with telomere shortening.⁵ In the same study, soda consumption was associated with shortened telomere length. Thus, nutritional imbalance – leading to deficiency or excess – may be deleterious to genome health early in life. Among future challenges are the need to establish causal relationships between nutritional exposures and DNA damage, efficacies of dietary interventions to attenuate or reverse DNA damage, short- and long-term health effects of early-life genome damage, and wider use of genome health assays in nutritional epidemiology and population science.

.....

“Nutritional imbalance may be deleterious to genome health early in life”

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Epigenome and Transcriptome

Gene expression is regulated by chemical modifications of histones and DNA without changing the underlying DNA sequence. Maternal nutritional or other exposures during embryo-fetal development can lead to epigenetic changes in fetal DNA that may influence disease risk later in life. The hypothesis of diet-epigenome interaction was tested in a rural Gambian population, examining seasonal variations in maternal levels of nutrients involved in methyl-donor pathways. The study revealed that DNA methylation of infants differed by season of conception at specific metastable epialleles, which reflect systemic (tissue-wide) epigenetic development in early life.⁶ In the same cohort, gestational aflatoxin exposure was associated with differential DNA methylation in a set of genes, including growth-promoting and immune-modulating genes, suggesting potential biological mechanisms of compromised host defense and growth impairment by aflatoxin exposure in utero.⁷ Another epigenome-wide association study conducted in the United Kingdom showed that both maternal pre-pregnancy obesity and underweight were associated with differential DNA methylation in the fetus, shown to mediate intergenerational adiposity transmission.⁸

Among transcriptomics studies, which explore the complete set of RNA molecules, Yu et al examined the pathogenesis of environmental enteric dysfunction (EED), an asymptomatic condition of intestinal inflammation, malabsorption and barrier dysfunction, by profiling the human intestinal transcriptome isolated from fecal samples of Malawian children.⁹ Transcripts associated with EED suggest that EED can be characterized by

numerous immunologic responses and impaired mucosal repair. This study provides potential biomarker candidates of gut function and a noninvasive approach that can be used in the future to elucidate host-microbiota dynamics in the gastrointestinal environment.

Proteome

A plasma proteomics project using tandem mass spectrometry was initiated, motivated by the need for a strategy to assess multiple nutritional deficiencies in populations on a single analytic platform.¹⁰ Assuming that nutrient metabolism is coordinately associated with a network of measurable proteins, and that such proteins possess sufficient variability to predict nutrient status, plasma nutriproteomes have been reported to date for vitamins A, D, E and K and selenium, comprising plasma transporters, immune and tissue repair proteins, and numerous metabolic homeostatic factors in a population of school-aged Nepalese children.^{11–15}

The utility of plasma proteomics has been further extended to quantify clusters of proteins associated with attained stature and arm muscle mass, but not fat mass, reflecting a lean, generally undernourished phenotype.¹⁶ Proteins associated with child height have included insulin-like growth factor (IGF)-1 and its three binding proteins, likely reflecting the major role of IGF regulation in linear growth. Nearly 100 plasma proteins originating in the liver and peripheral tissues involved in host defense, nutrient metabolism, and tissue repair have been linked to α_1 -acid glycoprotein, a generalized inflammatory biomarker, revealing a dynamic and informative proteome of subclinical inflammation.¹⁷ Six stable and constitutive protein biomarkers of inflammation have been associated with intelligence test scores measured a year after blood collection, possibly reflecting both chronicity and consequence of low-grade inflammation.¹⁸

.....

“Plasma proteins have a capacity to reflect short- and long-term biological linkages to nutritional and health status”

.....

The findings collectively suggest that plasma proteins have a capacity to reflect short- and long-term biological linkages to nutritional and health status. With biological validity of identified biomarkers, widespread population use of proteomics methods will depend on targeted, portable, low-volume, and inexpensive analytic methods (**see box, A Proteomics Technological Transition: Biomarker discovery to public health application**).



A and B: Children in Sarlahi, Nepal were visited in their homes for assessment of nutritional and health status including anthropometric measurements and blood sample collection.



C: Blood samples were processed by trained technicians at a local laboratory in Sarlahi.

D: Our initial proteomics work was based on two-dimensional difference in-gel electrophoresis analysis of serum samples from pregnant Nepalese women.

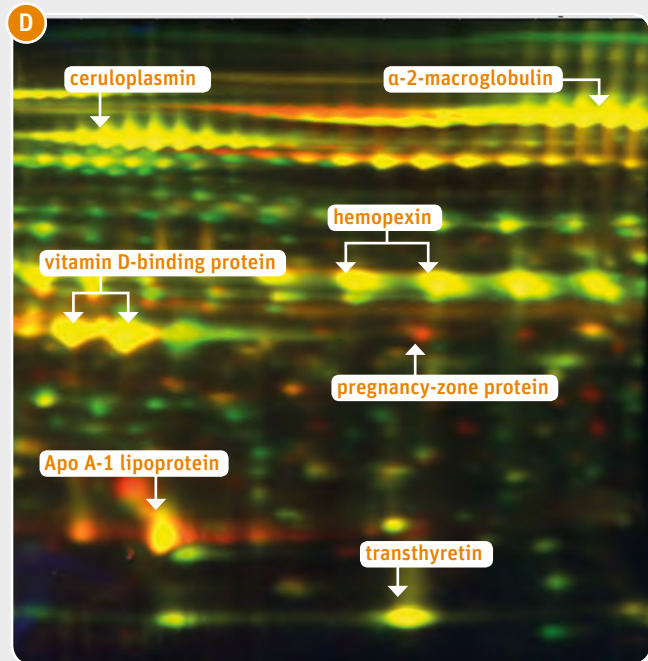


Photo credits: Keith P West Jr. (A, B, and C) and Robert N Cole (D)

Metabolome

Metabolomics is now being applied to elucidate the pathogenesis of childhood undernutrition and identify associated metabolic signatures using mass spectrometry or nuclear magnetic resonance spectroscopy. Bartz et al revealed remarkable changes in concentrations of amino acids, fatty acids, acylcarnitines, hormones, growth factors and cytokines in response to dietary regimens among severely malnourished Ugandan children.¹⁹ In this study, fatty acids played a central role in metabolic response to acute malnutrition and case fatality was predicted by a low concentration of leptin, reflecting the importance of fat storage and metabolism for energy supply and survival.

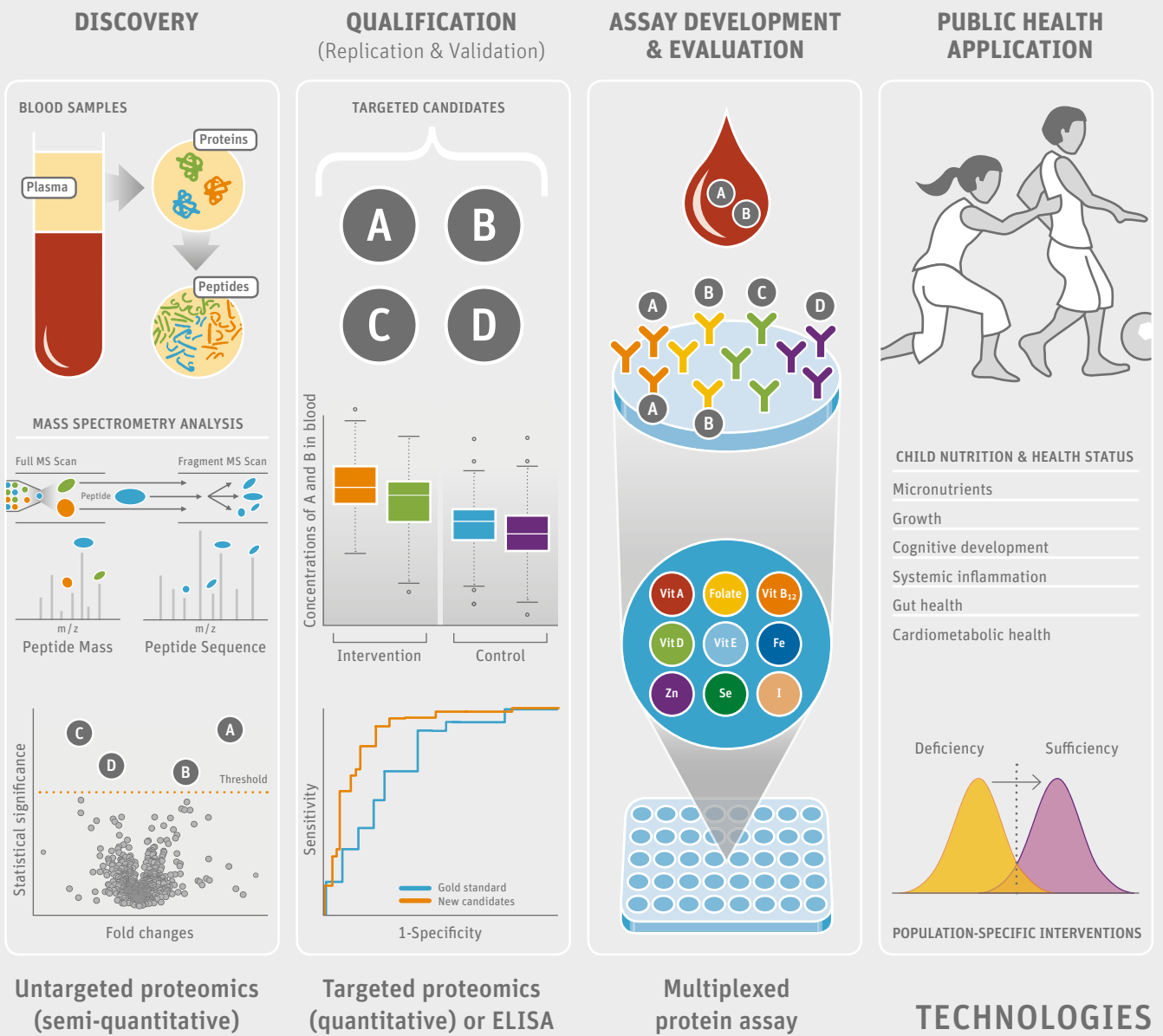
In Malawi, alterations in the serum metabolome were found to be more prominent in children with kwashiorkor than marasmus.²⁰ Nutritional rehabilitation stimulated the recovery of most amino acid profiles but sphingomyelins and phosphatidylcholines were incompletely restored, suggesting metabolic deficits remained after clinical stabilization. Alterations in amino acids and choline have also been observed in stunted children,^{21,22} possibly reflecting common metabolic and nutritional disturbances in wasting and stunting syndromes. Among amino acids, tryptophan metabolism has been consistently perturbed in studies of malnutrition and EED.^{20,22,23}

As nutritional metabolomics studies expand, it is likely that common metabolites will be identified as specific biomarkers for diagnostics, and used for monitoring specific pathway effects of therapeutic and public health interventions.

“As nutritional metabolomics studies expand, it is likely that common metabolites will be identified as specific biomarkers for diagnostics”

Microbiome

Microbiome studies are steadily revealing the importance of gut microbiota for child growth and health, achieved by combining high-throughput gene sequencing technologies with innovative experimental designs, including use of germ-free animals. Subramanian et al have, for example, created relative microbiota maturation indices from “age-discriminatory” microbial signatures from fecal samples of healthy Bangladesh children.²⁴ The indices have shown that severe acute malnutrition was associated with relative microbiota immaturity, which was only incompletely and transiently restored by conventional nutritional therapies. Blanton et al have shown that immature microbiota transplanted from undernourished Malawian children resulted in reduced weight and lean body mass gain and metabolic abnormalities in mice, and this negative effect was ameliorated by an invasion of “age and growth-discriminatory” microbiota from healthy donors.²⁵

FIGURE 2: Conceptual workflow of the proteomics-driven development of nutrition and health assays for populations

Sialylated oligosaccharides, functioning as prebiotics, were depleted in the breast milk of Malawian mothers of severely stunted infants relative to that of mothers of healthy infants.²⁶ Supplementing purified sialylated bovine milk oligosaccharides to a typical local diet improved lean body mass gain, bone morphology and metabolism in tissues of animal models colonized with microbiota from a stunted infant. Collectively, these studies provide preclinical evidence that immature development of gut microbiota is a cause of growth impairment and suggest that probiotic or prebiotic strategies may be needed to promote microbiota maturity and child growth.

Challenges and Opportunities

Omic technologies hold promise to reveal intermediate pathways, mechanisms, and interactions of growth, development, functional health, and disease, and thus to advance knowledge, change thresholds of action, and transform public health practice. Each omics poses technical, logistical, implementation, and cost challenges that impede rapid progress in discoveries and applications. Human studies need to be greatly expanded in number and breadth and rigorously designed to overcome methodological, analytical, and biological complexities in omics data. Interdisciplinary collaborations and training opportunities should be enhanced to promote interactions across fields

of biomedical science, nutrition, bioinformatics, biostatistics, computational biology and epidemiology. Effective communication across diverse stakeholders including academia, funders, biotechnology firms and governments will ensure common understanding in this fast-changing field of science and facilitate dissemination and utilization of omics research findings.

“Embracing the complexity of omics will offer novel strategies to address key challenges in global health”

Conclusions

Studies in the omics field have demonstrated the complexity of biological response to suboptimal nutritional status. These approaches are transitioning from theoretical to practical application to benefit vulnerable populations. Appreciating healthy skepticism around the utility of omics, our vision remains clear that embracing the complexity will offer novel strategies to address key challenges in global health. Because health promotion and disease prevention are a long public health journey, omics approaches have potential to serve as a roadmap that assists travelers in exploring new territories or identifying the most expeditious routes.

A Proteomics Technological Transition: Biomarker discovery to public health application

Vision and goal: Micronutrient deficiencies are a global health problem but remain hidden for lack of assessment tools in low-resource settings. The vision of a plasma proteomics project, supported by the Bill & Melinda Gates Foundation, was that clusters of proteins predictive of micronutrient status, and possibly inflammation and other functions, could be discovered, targeted for quantification, and measured, eventually, within a single, inexpensive assay.

Process: The conceptual workflow (Figure 2) illustrates ongoing efforts to promote discovery^{11-13,15} and transition to quantification, a future inexpensive assay, and public health application.

Discovery: The aim of discovery is to quantify the direction and strength of association between protein biomarkers and conventional nutritional indicators (e.g., micronutrient, anthropometry) and inflammation status. Proteins are digested into peptides for detection and relative quantification.

Statistical analysis is performed to select correlated proteins with low chance of false discovery.

Validation: The goal of this phase is to establish candidate proteins, replicated across populations and measured in assays that determine absolute concentrations in plasma samples (e.g., enzyme-linked immunosorbent assay [ELISA] or targeted proteomics). Randomized trials or longitudinal studies are desirable to establish both correlations and responses to nutritional supplementation.

Assay development and evaluation: This stage sets out to produce a protein assay that simultaneously quantifies multiple protein biomarkers. For example, the technology of antibody-based multiplexed protein measurement can be used to develop an array that has antibodies attached to capture various proteins in each single cell of a plate.²⁷ Multiplex ELISA assays with customized combinations of biomarkers have been already tested for vitamin A, iron, iodine status plus inflammation, and malaria markers.^{28,29} High biological sample and analyte throughput is desirable compared to conventional immunoassays.

Application: The feasibility of using a multiplex protein assay as an advanced tool for nutrition research and public health practice is established. Depending on the purpose of studies, the assay can be utilized to (1) characterize nutritional status of populations (e.g., micronutrients), (2) evaluate effects of nutrition-specific or nutrition-sensitive interventions on nutrition or health status (e.g., growth and gut health), and (3) provide prognostic insights into health and disease burden (e.g., cardiometabolic health). The assay will provide invaluable information about nutritional and health status of target populations that can promote more context-based program development and policy decisions.

Acknowledgements

Bill & Melinda Gates Foundation [OPP5241 (Senior Officer: Yiwu He) and GH614 (Senior Officer: Ellen Piwoz)], the *Sight and Life* Foundation and DSM Ltd and the George G Graham Professorship Endowment Fund. I am most grateful to Keith P West, Jr and Kerry Schulze for reviewing this article and providing their feedback.

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TABLE 1: Summary of selective recent omics studies on infant or child health

Study population	Biospecimen	(Omics) technologies	Study design	Exposure outcome
Genome				
Children in 8 developed countries (0–18 mo and 12–30 mo)	Blood samples	High-density single nucleotide polymorphism (SNP) arrays	Genome-wide association meta-analysis	Reported or diagnosed diarrhea
Egyptian children (2–60 mo)	Peripheral red blood cells	Flow cytometric micronuclei assessment	Case-control	Malnutrition (kwashiorkor vs. marasmus) and bacterial pneumonia
Australian infants (at birth, 3 and 6 mo)	Peripheral blood (cord blood) lymphocytes	Cytokinesis-block micronucleus cytome assay	Prospective cohort	Birth anthropometry (weight, length, and head circumference)
Urban Latino children in the US (from birth to 5 yr)	Dried blood spots	Quantitative polymerase chain reaction	Prospective cohort	Obesity, abdominal obesity, breastfeeding, and dietary intake
Epigenome				
Gambian mother-infant (2–8 mo) dyads	Peripheral blood leukocytes and hair follicles	Quantitative bisulfite pyrosequencing	Prospective cohort	Dry (“harvest”) or rainy (“hungry”) season of conception
Gambian mother-infant (2–8 mo) dyads	White blood cells	Bisulfite pyrosequencing and Infinium HumanMethylation450 BeadChip	Prospective cohort	Aflatoxin exposure during early pregnancy
British mother-offspring (at birth, 7.5 yr, and 17.1 yr) pairs	Cord blood and childhood and adolescent peripheral blood	Infinium HumanMethylation450 BeadChip	Prospective cohort	Pre-pregnancy obesity or underweight
Transcriptome				
Malawian children (12–61 mo)	Feces	High-density microarray (GeneChip Human Transcriptome Array)	Prospective cohort	Environmental enteric dysfunction (EED)
Proteomics				
Nepalese children (6–8 yr)	Plasma	Isobaric tag for relative and absolute quantitation (iTRAQ) mass spectrometry	Cross-sectional	Vitamins A (retinol), D (25-hydroxyvitamin D), and E (α-tocopherol), copper, and selenium
Same as above	Plasma	iTRAQ mass spectrometry	Cross-sectional	Anthropometric measurements including (1) height-for-age z-score, (2) arm muscle area, and (3) arm fat area and triceps and subscapular skinfolds
Same as above	Plasma	iTRAQ mass spectrometry	Cross-sectional	Inflammation (α ₁ -acid glycoprotein)
Same as above	Plasma	iTRAQ mass spectrometry	Prospective cohort	General intelligence test scores (7–9 yr)

Biomarkers | main findings

Reference

The SNP rs8111874 at chromosome 19q13.33 reached a genome-wide significant association with diarrheal disease around 1 year of age. Children with the A allele of the causal variant rs601338 in the FUT2 gene (non-secretor phenotype) had lower risk of diarrhea.

Bustamante et al²

Micronucleated-reticulocytes and erythrocytes were more frequently observed in malnourished children with pneumonia than well-nourished children with/without pneumonia. The frequencies of micronucleated cells were higher in children with kwashiorkor than children with marasmus.

Elsayh et al³

Birth weight and length, and maternal weight and BMI during pregnancy were positively associated with the frequency of one or more of DNA damage biomarkers including micronuclei, nucleoplasmic bridges and nuclear buds. Head circumference at birth was negatively associated with the frequency of apoptotic cells.

Dass Singh et al⁴

Exclusive breastfeeding at 4–6 wk of age was associated with longer telomere length, while early exposure to foods other than breast milk before 4–6 wk of age and infant obesity at 6 mo of age were associated with shorter telomere length at 4 and 5 yr of age. High soda consumption at 3 yr of age was associated with shorter telomere length.

Wojcicki et al⁵

CpG methylation rates at six metastable epialleles in peripheral blood leukocytes and hair follicles were consistently higher in infants conceived in the rainy season compared to those conceived in the dry season.

Dominguez-Salas et al⁶

Differential DNA methylation was observed in 71 CpG sites including growth factor genes such as FGF12 and IGF1, and immune-related genes such as CCL28, TLR2, and TGB1. One aflatoxin-associated methylation region (miR-4520b) was identified.

Hernandez-Vargas et al⁷

Twenty-eight and 1621 CpG sites were differentially methylated in fetuses of pre-pregnancy obese and underweight mothers, respectively, compared with fetuses of normal weight mothers; differentially methylated sites associated with maternal over- or undernutrition tended to be associated with offspring adiposity.

Sharp et al⁸

Fifty-one transcripts encoding a broad range of immune response, epithelial cell adhesion, and mucin production were associated with and differentially expressed by EED. Among these, 17 transcripts (AQP9, CLEC7A, FCGR2A, FCGR3B, IFTM1, IFITM2, IFITM3, LYN, LYZ, MND4, MSN, NCF2, PLEK, PROK2, S100A8, SAMS1, and SELL) were associated with change in height-for-age z-scores over the 3 months after stool collection.

Yu et al⁹

Retinol-binding protein 4, vitamin D binding protein, apolipoprotein C-III, ceruloplasmin, and selenoprotein P were correlated with plasma retinol, 25-hydroxyvitamin D, α -tocopherol, copper, and selenium, respectively ($r=0.58-0.88$). Adding newly identified second-tier proteins explained additional variation in nutrient concentrations.

Cole et al¹¹

(1) (+) IGF-1, IGFALS, IGFBP3, afamin, tetranectin, apolipoprotein L1, carnosinase1, and vasorin; (-) S100A12 and IGFBP2; (2) 17 proteins including extracellular matrix proteins were associated with arm muscle area; (3) no proteins were associated with fat mass measurements.

Lee et al¹⁶

(+) 41 proteins including positive acute phase proteins, complement factors, protease inhibitors, and intracellular signaling molecules; (-) 58 proteins involved in transporting or binding to micronutrients, lipids, growth factors, and sex hormones, and homeostasis of extracellular matrix.

Lee et al¹⁷

(+) APOA1, APOA2, APOC1, APOC3, APOM, APOD, IGFALS, IGFBP3, and transthyretin; (-) AGP1, C2, C5, C9, CFI, ACT, LRG1, RCN1, TIMELESS, LBP, PKM, DNAAF1, and EVI5; Six proteins (AGP1, C9, CFI, CFHR5, ACT, and RCN1) involved in inflammatory response remained negatively associated with general intelligence test scores in fully adjusted models.

Lee et al¹⁸

Study population	Biospecimen	(Omics) technologies	Study design	Exposure outcome
Metabolome				
Severely malnourished children admitted to hospital in Uganda (6 mo–5 yr)	Serum	Tandem mass spectrometry (targeted), gas chromatography/mass spectrometry (non-targeted), and conventional chemistry assay	Clinical nutritional rehabilitation	Inpatient and/or outpatient nutritional treatment (milk-based formulas and/or ready-to-use foods)
Severely malnourished children admitted to hospital and community controls in Malawi (9–59 mo)	Serum	Liquid chromatography-tandem mass spectrometry (targeted)	Clinical nutritional stabilization; case-control	(1) Kwashiorkor vs. marasmus (2) Nutritional stabilization (3) Severe acute malnutrition vs. community control
Malawian children (12–59 mo)	Serum	Liquid chromatography-tandem mass spectrometry (targeted)	Cross-sectional	Stunting
Brazilian children (6–26 mo)	Urine	¹ H-nuclear magnetic resonance spectroscopy	Case-control	(1) Undernutrition (stunting, wasting, and underweight). (2) Changes in HAZ (2–5 mo)
Malawian children (12–59 mo)	Serum	Liquid chromatography-tandem mass spectrometry (targeted)	Cross-sectional	Environmental enteric dysfunction
Microbiome				
Bangladesh children with severe or moderate acute malnutrition (6–20 mo)	Feces	16S ribosomal RNA gene sequencing	Randomized intervention trial and post-intervention follow-up	Food interventions (ready-to-use therapeutic food or a locally produced food combination)
Healthy or undernourished Malawian children (fecal donors) (6 and 18 mo)	Feces	16S ribosomal RNA gene sequencing, Targeted mass spectrometry	Animal experiment (5-week-old germ-free mice)	Fecal microbiota from healthy or undernourished children
6-month postpartum Malawian mothers from two birth cohorts	Human milk (from mothers); Feces (from a 6 mo-old stunted Malawian infant)	Liquid chromatography time-of-flight mass spectrometry, 16S ribosomal RNA gene sequencing, Microbial RNA-Seq, Targeted MS/MS, and GC/MS	Animal experiment (germ-free mice and piglets)	Purified bovine milk oligosaccharides supplementation

(+) and (-) indicate positive and negative associations with exposures/outcomes, respectively

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Biomarkers | main findings

Reference

(+) Albumin, amino acids, propionyl carnitine, leptin, IGF-I, insulin, and phosphorous;	Bartz et al ¹⁹
(-) Fatty acids, ketones, even-chain acylcarnitines, growth hormone, ghrelin, cortisol, IL-6, glucagon-like peptide-1, and peptide YY; A low concentration of baseline leptin was most strongly associated with child mortality.	
(1) Albumin, lysine, methionine, threonine, aspartate, tryptophan, kynurenine, acylcarnitines, and phosphatidylcholines were more depleted in children with kwashiorkor than in those with marasmus.	Di Giovanni et al ²⁰
(2) Albumin, amino acids, biogenic amines, phosphate, potassium, and some lysophosphatidylcholines increased, while most sphingomyelins and phosphatidylcholines were not improved.	
(3) Metabolic profiles of severe acute malnutrition remained different from those of community controls, even after nutritional treatment.	
(-) All essential amino acids (tryptophan, isoleucine, leucine, valine, methionine, threonine, histidine, phenylalanine, lysine), conditionally essential amino acids (arginine, glycine, glutamine), non-essential amino acids (asparagine, glutamate, serine), and biogenic amines and sphingomyelins; alterations in glycerophospholipids	Semba et al ²¹
(1) Alterations in choline and tryptophan metabolisms, reduced energy expenditure, and increased proteolytic activity of the gut microbiome; (2) urinary N-methylnicotinamide and β -aminoisobutyric acid predicted short-term growth among undernourished children.	Mayneris-Perxachs et al ²²
(-) Tryptophan, citrulline, ornithine, phosphatidylcholines, and sphingomyelins;	Semba et al ²³
(+) Glutamate, taurine, and serotonin	
Children with severe and moderate acute malnutrition had microbiota immaturity relative to healthy children of similar chronologic age; food interventions improved microbiota maturity, but the effects were not sustained after cessation of treatment in severely malnourished children.	Subramanian et al ²⁴
Mice colonized with microbiota from undernourished children gained less weight and lean body mass than mice colonized with microbiota from healthy children, and showed alterations in bone morphology and metabolic abnormalities; invasion of age- and growth-discriminatory strains from mice with healthy donor microbiota or specific species (<i>Ruminococcus gnavus</i> and <i>Clostridium symbiosum</i>) into the microbiota of mice with undernourished donors improved growth and metabolic phenotypes in mice.	Blanton et al ²⁵
Sialylated human milk oligosaccharides were more abundant in the breast milk of mothers of healthy infants than that of mothers of stunted infants; adding sialylated bovine milk oligosaccharides to a typical Malawian diet improved lean body mass and nutrient metabolisms in liver, muscle, and brain in mice and piglets colonized with bacterial strains from a stunted Malawian infant.	Charbonneau et al ²⁶

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Perspective from 2021

Translating Omics Discoveries into Public Health Application

Uncovering uncertainties in biomarker discovery and validation

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It is my great pleasure to congratulate *Sight and Life* on its 35th anniversary of globally advocating innovative solutions for healthier diets and good nutrition. The Frontiers in Nutrition (2015) and Technology and Entrepreneurship (2017) issues exemplified *Sight and Life's* continuous emphasis on revealing and addressing malnutrition through rapidly evolving technologies. In my essay in 2017, Omics Innovations and Applications for Public Health Nutrition, I proposed that omics approaches are poised to greatly expand knowledge and reveal road maps of biological pathways affected by nutrition. While this appears more inevitable than ever before, how far have we progressed during the past 5 years, and what more is needed to accelerate the path toward public health application?

Progress and challenges

Among benchmarks of progress are an increased number of omics studies in nutrition, perhaps driven by enhanced analytical techniques coinciding with the evolution of statistical approaches, automation of platform pipelines, and optimization of platforms for unconventional biological matrixes. This expanding capability is evident in recent reviews on the use of omics methods in child malnutrition (genomics,¹ metabolomics,² proteomics,³ and the microbiome⁴).

Despite leaps forward, challenges to application persist in this era of concurrent expansive discovery and rapid technological innovation. So far, most discovered omics signatures have yet to deliver generalizable and targetable markers that improve the detection and targeting of high-risk populations

or guide more effective designs of public health interventions, programs, and products. What are the critical gaps in translating discovery findings into actionable and practical public health practices?

The need for reliable, valid-for-use discoveries

Reliable, valid-for-use discoveries are needed to inspire increased investments in omics research. Such success stories may be best achieved by rigorous and adequately powered studies designed to reveal temporal and causal changes in omics biomarkers. Much of omics research in public health nutrition to date has been opportunistic, nested within existing epidemiological studies. Observational omics data allow associational reasoning but need to be further validated, as they are sensitive to biases and lack of generalizability. In addition, researchers frequently face limitations in accessing existing clinical or omics datasets from other studies that are necessary to assess the validity of discovery findings. Lastly, uncertain and unstandardized biomarker discovery and validation processes hinder the scientific community and key stakeholders from making efficient and effective decisions for further development of biomarkers for public health utility.

“Further efforts are needed to enhance the credibility of discovery findings”

How can we strengthen scientific integrity and facilitate the translation of omics discovery into meaningful public health insights? Investigators need a rigorous study design (e.g., longitudinal sampling, a dose-response study) for discovery and a

well-developed plan to assess the validity of discovery findings (e.g., cross-validation with independent studies) at the outset of an investigation. As not all studies can have experimental/interventional or longitudinal omics data, further efforts are needed to enhance the credibility of discovery findings, such as applying comprehensive data analytics that can integrate multi-omics data or meta-analysis of single-omics studies. Improved data accessibility to omics repositories and expanded collaborative research networks will be critical to catalyzing the effort. Also, to ensure that the biomarker development pipeline is streamlined, an expert consensus guideline should be established to provide standardized best practices that are specifically tailored for omics studies that intend to target population health.

Becoming smart travelers

A major goal of omics research in public health nutrition is to apply its methods, data, and interpretations toward better understanding and advancing the health of populations at risk of being malnourished. From this perspective, we need to be smart travelers who know how to use and read a new road map properly to identify the fastest route that will help us reach our destination.

Disclaimer

This essay has been written by the author in her personal capacity.

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FIRST PUBLISHED IN:

Vol. 32 (1) | 2018
PP. 30-34



VIEWPOINTS

Perspectives in Nutrition Science

An Innovation Evolution

Why one of the world's most cost-effective tools in the fight against malnutrition still needs innovation

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Key messages

- > As the first major fortification initiative in developing countries, Universal Salt Iodization paved the way for the technology, systems, and structural innovations that have enabled us to reach nutritionally vulnerable populations with micronutrients globally.
- > An innovation evolution is needed to maximize the future impact of food fortification. This calls for ingredient innovations that expand beyond micronutrients, systems innovations that leverage the data revolution and artificial intelligence, and structural innovations that widen the remit of responsible parties to consumer-facing food manufacturers, retailers, and the start-up ecosystem for food innovation.
- > Innovations to improve nutrition should be driven by a deep understanding of the unmet nutritional needs, aspirations, behaviors, and preferences of consumers who remain underserved by markets and face limited access to affordable, nutritious foods.
- > We bear a collective responsibility for transforming our food systems to provide more nutritious and affordable foods to consumers in low- and middle-income countries, and we need to move forward with optimism and urgency.

The impact of Universal Salt Iodization

One of the greatest public health success stories is also one of the least known. It started with a beautifully simple innovation: putting iodine into table salt. Salt is regularly consumed around the world by rich and poor alike, and so by fortifying salt with iodine, most people's daily iodine needs could be met at a negligible cost with no change in behavior. In the 1990s, 113 countries were classified as iodine-deficient; that number is now 20. The impact of Universal Salt Iodization (USI) on human capital development is staggering when one considers that iodine deficiency is the most common cause of preventable mental retardation worldwide and that it can reduce IQ scores by an average of 13.5 points. The global scale-up of USI inspired the establishment of new institutions in the early 2000s to extend the success of USI into the fortification of edible oils and cereals such as wheat, maize, and rice to address other micronutrient deficiencies in low- and middle-income countries. With that amplification, the global infrastructure for reaching nutritionally vulnerable groups in developing countries with fortified foods was born.

In the past 15 years, mandatory fortification of various staples and condiments has been scaled across sub-Saharan Africa and many countries in Asia. However, in the context of a dynamic and rapidly evolving food system, fortification cannot realize its full potential for impact as a static public health intervention based upon delivering what is known and accepted today. Even an intervention as successful as salt iodization has had to respond to a changing context, including increased consumption of salt through processed foods, growing rates of diet-related chronic disease in lower- and middle-income countries, and technological advances that enable the addition of multiple micronutrients to salt. These present both challenges and opportunities for innovation.

Breakthroughs in fortification

Historically, there has been a tendency to emphasize innovations in products and technology. However, the types of



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In the past 15 years, mandatory fortification has been scaled across sub-Saharan Africa and many countries in Asia

breakthroughs needed to improve global nutrition will not stem from product or technological innovations alone but will also require innovation in the underlying systems and structures. Viewed through this lens, three types of innovation can be defined:

- > **Technology innovations** enable formulation of the appropriate food vehicles with the appropriate levels of micronutrients to reach consumers with fortified products that can withstand real-world transport, storage, and food preparation conditions.
- > **Systems innovations** are necessary to galvanize and incentivize industry to manufacture, package, and distribute fortified foods within the constraints of their businesses.
- > **Structural innovations** have enabled complex yet accountable public-private partnership structures between ministries of health, regulators, food processors, and international and non-governmental organizations to pursue public health objectives through both commercial food markets and public-sector channels.

Technology innovations

Technology innovations in food fortification have addressed the combinability, stability, bioavailability, and sensory challenges posed by certain micronutrient compounds, with iron being a critical focus given its public health importance and the persistent challenges faced with its delivery. For instance, sodium iron EDTA (NaFeEDTA), which has been on the market for over 20 years, has over time been introduced into a number of fortification programs to enhance iron bioavailability in foods with strong absorption inhibitors, such as phytates in high-extraction wheat flour. Newer solutions also exist to address technical challenges associated with specific food vehicles, such as new, encapsulated iron forms that can be blended with salt, and chelating ferric pyrophosphate (FePP) with citric acid and trisodium citrate to improve bioavailability while minimizing sensory challenges in rice. Additionally, a range of encapsulation technologies, from fungi to polymers, are in development to protect iron and other micronutrients from sensory interaction with the food matrix, improve their combinability with other micronutrients, and in some cases, improve the bioavailability of iron. Technologies are also in development that address the safety risks associated with iron intake. These technologies take different approaches to more slowly releasing iron into the bloodstream, better mimicking the



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An innovation evolution is needed to maximize the future impact of food fortification

pathway of iron from natural sources, and avoiding the inadvertent feeding of pathogens in high-infection populations.

“There is a need to widen the range of ingredient solutions to better capture evolving consumer needs”

Looking ahead, we believe there is a need to widen the range of ingredient solutions to better capture evolving consumer needs and reflect emerging evidence on the determinants of poor growth. For instance, we need to think more creatively about potential codelivery of solutions to improve gut health, as simply adding micronutrients into the diets of children with chronic infection or environmental enteric dysfunction will not solve micronutrient malnutrition in these subgroups. The range of emerging solutions from bioactive peptides to polyphenols with prebiotic properties to oligosaccharides that have demonstrated impact on non-communicable diseases in developed-world markets may also play a significant role in improving micronutrient utilization. In fact, early research on the effect of prebiotics on iron absorption, particularly in complementary foods, has shown promise.

Additionally, with the renewed interest in the role of proteins in growth and development, the pendulum seems to be swing-

ing back, this time recognizing that deficiencies in both macro- and micronutrients contribute to poor linear growth and weight gain and therefore that both need to be considered part of the solution. This coincides with a strong resurgence in protein research by the private sector, driven mainly by developed-world interests in satiety for weight control, glycemic management for diabetes, and the impact of specific amino acids on cell growth and digestibility for better differentiation. Newer plant-based and alternative protein sources, with lower costs and lighter environmental profiles, are becoming widely available and show promise to be adapted to a range of applications.

“Consideration should be given to expanding the use of nutrient-dense, natural ingredients grown in the developing world”

Consideration should be given to expanding the use of nutrient-dense, natural ingredients grown in the developing world, such as spirulina, to help reach fortification goals. These types of ingredients have the potential to deliver proteins and micronutrients simultaneously; they have components, such as provitamin A, that are less vulnerable to degradation from heat and humidity compared to the retinyl palmitate that is added to foods, and they pose fewer safety issues when it comes to increasing fortification levels. While an ingredient such as spirulina does confer a change in color, specific varieties are flavorless, and therefore hold strong potential for integration into ready-to-use therapeutic foods and lipid-based nutrient supplements, for which both proteins and micronutrients are needed. Moreover, demand is growing among consumers in middle- and lower-middle-income countries for “natural” ingredients and products, which are perceived to be healthier. Innovations to improve manufacturability at scale are critically needed to drive down costs and expand sources of raw materials for fortification programs.

Ultimately, innovations to improve nutrition should be driven by a deep understanding of the unmet nutritional needs, aspirations, behaviors, and preferences of consumers who remain underserved by markets and face limited access to affordable, nutritious foods. For an increasing proportion of lower-income consumers in Africa and Asia, processed foods represent a significant percentage of the daily calories consumed. There is a considerable opportunity to enhance the nutritional profile of widely consumed packaged foods through innovations that improve nutrient density, while simultaneously reducing saturated fat, salt, and sugar intake from these foods. These types of products can complement the more traditional approaches of forti-

fyng staples and basic condiments, and can increase nutrient intakes across the food basket.

Systems innovations

A more consumer-driven approach to innovation should put greater focus on systems innovations. Consumers – and the food system in which they are immersed – are, by definition, dynamic. Therefore, a data-driven feedback loop needs to be established that regularly assesses consumption patterns and resulting nutrient intake, and then optimizes the impact achievable through fortification by calibrating combinations of nutrients and levels, the mix of products that are fortified, and the economic cost and benefit to society. New ways to source and analyze data, whether through big-data approaches or innovative means such as crowdsourcing product information through mobile platforms, provide potential alternatives to relying on stand-alone data collection efforts that are time- and resource-intensive.

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“New ways to source and analyze data provide potential alternatives to relying on stand-alone data collection efforts”

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In the past, systems innovations that integrated certification and procurement schemes enabled access to high-quality mi-



We bear a collective responsibility for transforming our food systems to provide more nutritious and affordable foods to consumers in low- and middle-income countries

cronutrient premix supply at lower prices and favorable credit terms. The next generation of innovation in quality systems has tremendous potential to leverage the data revolution and artificial intelligence in order to enable data-driven decision-making. Smart dosifiers are already being implemented in small-scale commercial maize mills in Tanzania to largely automate fortification. This type of equipment transmits data to a cloud-based system to remotely monitor fortification levels. Paired with the technology innovation is a business model innovation that subsidizes the cost of the micronutrient premix through cost-savings generated by other value-added services. Such models could offer insights into new ways to approach monitoring in larger-scale systems for specific value chains. Another promising opportunity area is the application of blockchain technology to ensure traceability and accountability throughout the value chain so that the appropriate micronutrient levels are maintained within food products from factory to fork. Finally, building upon the growing global trend toward personalized health and nutrition, IT-enabled *in vitro* diagnostics could lead to better targeting to ensure the right nutrients are reaching the right people for the greatest impact.

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“The next generation of systems innovations has tremendous potential to leverage the data revolution and artificial intelligence to enable data-driven decision-making”

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Structural innovations

As food fortification programs shift from a focus on the beneficiary to the consumer, structural innovations will be required to enable a new level of coordination and accountability to transform food systems so that they provide greater access to affordable nutrition. This means including partners within the fortification ecosystem with the greatest ability to influence and reach consumers, namely consumer-facing food manufacturers and retailers as well as consumer advocacy groups, to increase their accountability. The evolution in many humanitarian and safety-net programs from food-based to cash- or voucher-based schemes that involve food retailers is a good example of innovation to date that has structural implications for how disparate actors can work together in new ways to meet the needs of underserved consumers and empower them with choice and greater convenience. Bringing these actors together could also be an opportunity to connect those working to address undernutrition,

on the one hand, and obesity and chronic disease, on the other, through a common platform for better-quality food.

The existing food fortification infrastructure has evolved from single-vehicle initiatives to platforms that promote micro-nutrient fortification across a range of food vehicles. This infrastructure includes multisectoral alliances of public- and private-sector stakeholders to oversee implementation of national food fortification programs, industry associations, technical partners supporting policies and programs, and the scientific research community. In the future, this infrastructure could be leveraged and broadened to include, for example, entities involved in protein research, manufacturing, and sales. This also creates an opportunity for convergence with the new ecosystems that are now emerging for food innovation, including start-ups and social enterprises, food- and agriculture-focused venture capital funds, and a host of accelerators and incubators.

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**“There is an opportunity
for convergence with the new
ecosystems that are now
emerging for food innovation”**

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Conclusion

In conclusion, current thinking about food fortification must evolve to incorporate macrotrends, emerging research, the convergence of certain health needs across rich and poor countries alike, and innovation from other sectors. A radical transformation of existing food systems is required to better serve lower-income consumers at risk of malnutrition, involving layers of innovation to reshape underlying systems and structures. No single entity in isolation can bring about this type of transformation. But collectively, we all bear responsibility for making food systems work more effectively for nutritionally vulnerable consumers.

In the end, is fortification a silver bullet? No. Can more be done through fortification to close the gap in nutrient intakes among vulnerable populations? Yes. And is this reason to invest in new ways of thinking about innovation in fortification? Absolutely. This calls for both optimism and urgency.

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Perspective from 2021

The Continuing Evolution of Food Fortification Innovations

Dipika Matthias

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Innovation in food fortification for low- and middle-income countries needs a catalyst, despite a value proposition that is virtually unsurpassed in global health and development. While every dollar invested generates US\$27 in economic returns from averted disease, improved earnings, and enhanced work productivity (Figure 1),¹ the return is less clear for the private-sector implementors involved – namely, the micronutrient manufacturers, premix suppliers, millers, and retailers. Even more challenging is the return on investment for innovators developing new technologies or business models to enhance the effectiveness of fortification. To justify investment, they require committed private- or public-sector buyers, along with a strong enabling environment.

“The Bill & Melinda Gates Foundation recently doubled its investment in food fortification”

Recognizing the enormous potential impact on human capital development,² the lack of global progress on anemia³ and other conditions in which micronutrient deficiency plays a strong role, and the impact of COVID-19 on nutritional health,⁴ the Bill & Melinda Gates Foundation (BMGF) recently doubled its investment in food fortification as part of a US\$922 million commitment to nutrition more broadly over the next 5 years.⁵ Other global actors are also increasing and aligning their investments in food fortification, including a recent, joint announcement between USAID, UNICEF, and BMGF to reach one billion additional people with fortified foods over the next decade.⁶

Progress since 2018

Although these commitments were secured in 2021, steady progress has been made since we wrote our *Sight and Life* ar-

ticle entitled *An Innovation Evolution* in 2018. On technological innovations, consortiums have been formed, clinical trials are poised to launch in early 2022, and technical progress has been made in understanding the viability of expanding the range and levels of micronutrients in vehicles such as bouillon and multiply-fortified salt (double-fortified salt [iron/iodine] and quintuple-fortified salt [iron/B₉/B₁₂/zinc/iodine]). We have also seen strong progress on micronutrient innovations, including improved stability of vitamin A compared with commercially available forms,⁷ as well as enhanced bioavailability of iron compounds⁸ with better sensory profiles for fortified foods, such as rice and double-fortified salt. BMGF is poised to further invest in iron innovations to optimize sensory, safety, and bioavailability attributes to enhance the impact of iron-fortified foods.

On systems innovations, BMGF and partners have conceptualized the design of a cost-effective, digital fortification quality data system within mills to support self-monitoring, reduce government oversight costs, and build critical trust between the sectors to enhance the functioning of programs. GAIN is now poised to lead a consortium of partners towards this vision. Additionally, we are now actively supporting a global data alliance to be led by the Micronutrient Forum, which will focus on better data for designing and managing programs. The alliance will consider leveraging non-traditional secondary sources such as geospatial data from satellites, applying machine learning to estimate critical metrics (such as micronutrient status and coverage of fortified foods), and visualizing program performance at both national and subnational levels. Data will also play a key role in strengthening regulatory systems, including mandatory standards and enforcement legislation to support well-functioning programs.

“We are now broadening the active partners within the fortification ecosystem”

Finally, we are now broadening the active partners within the fortification ecosystem with a view toward building critical

FIGURE 1: The cost-effectiveness of food fortification



a Ozawa, et al. 2016. Return on Investment From Childhood Immunization In Low- and Middle-Income Countries, 2011–20. Uncertainty range 10–25.
 b Unpublished analysis by GAIN/BMGF. Data drawn from: 1) Horton, S., Alderman, H., Rivera, J., 2008. Copenhagen Consensus; 2) Horton, S., Ross, J., 2003. *The economics of iron deficiency*; 3) Sayed, A.R., Bourne, D., Pattinson, R., Nixon, J., Henderson, B., 2008. *Decline in the prevalence of neural tube defects following folic acid fortification and its cost-benefit in South Africa*; 4) *Food Fortification in a Globalized World*, Chapter 31.
 c Immunization Delivery Costs in Low and Middle-Income Countries, April 2019. Fully-vaccinated child defined as those receiving DPT3. Median value of delivery \$24.86. Range \$8.13 – \$96.16. Vaccine costs are approximately \$20 per fully immunized child (BCG, measles, pentavalent, pneumococcal conjugate, rotavirus, inactivated poliovirus). Gavi and UNICEF, 2019.
 d Fewer stillbirths (iodine) and lower maternal mortality rates and neonatal deaths (iron) not included in benefit-cost ratio because work productivity benefits dominate.

Disclaimer: The comparison is illustrative, as the incremental vaccine costs and returns include the basic set of vaccines given to children, while the fortification figures only include the incremental costs of fortifying with iodine, and folic acid. The economics of other micronutrients have not been studied as extensively but are also low cost.

capacities that are currently lacking. For example, we are partnering with Hewlett Packard Enterprise to design and build sustainable back- and front-end systems for the digital QA/QC initiative. As another example, we are facilitating a more active role for premix manufacturers, securing their commitments to both traceable quality in the form of QR codes on premix packages and structured technical assistance to mills. We are also developing a stronger ecosystem for fortification innovation by partnering with technology incubators, such as the World Food Programme Innovation Accelerator and Global

Health Labs, supporting the scale-up of social enterprises such as Sanku and BioAnalyt, and filling structural gaps in micronutrient innovation between academic research and commercialization through translational startups, such as Particles for Humanity.

The innovation evolution for fortification continues

The innovation evolution for fortification continues – from the introduction of iodized salt in the 1990s to digital quality assurance and control that has the potential to level the play-

ing field for millers today. Innovation is as much a process as an outcome of an energized field working towards fulfilling its enormous potential.

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“The internship at *Sight and Life* was my doorway into the world of nutrition. I am still grateful that I had the chance to work with the highly motivated team and to gain insights into their interdisciplinary approach to solving worldwide malnutrition. This experience still impacts my career today, as I am continuing my desk research project about the role of the human right to food for solving malnutrition from my internship and am currently writing a dissertation about the human right to food of indigenous peoples.”

Julie Teresa Mortensen | Intern at *Sight and Life*, June–September 2018; Doctoral Candidate, University of Vienna | Austria

“To me, *Sight and Life* means 35 years of global nutrition excellence. I admire how you discuss and embrace novel scientific insights, support projects to translate these insights into actions, and champion implementation science to learn how we can best deliver evidence-based innovations to those in need. Happy Anniversary!”

Saskia Osendarp | Executive Director, Micronutrient Forum | Washington, DC, USA

“*Sight and Life* has been, and remains, a thought leader in international public health nutrition, making a serious contribution to advance the global evidence base on maternal and child nutrition and serving as a catalyst to strengthen evidence-based actions to address hunger and malnutrition around the globe.”

Jee Hyun Rah | Chief Nutrition, UNICEF Indonesia Country Office | Jakarta, Indonesia

“Over the years, *Sight and Life* has established its name well in nutrition, especially among academics and policy makers. I personally regard the science-led and evidence-based *Sight and Life* publications highly and refer to them often, and I know a lot of my esteemed colleagues value them, too. I look forward to seeing *Sight and Life*’s India chapter grow in the coming years as it deservedly expands its global footprint in nutrition solutions and innovations.”

Rajan Sankar | Senior Advisor, Tata Trusts | Mumbai, India

FIRST PUBLISHED IN:

Vol. 33 (1) | 2019
PP. 108–114





Global Data Visualization Tools to Empower Decision-Making in Nutrition

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Key messages

- > Well-designed data visualization tools (DVTs) can solve certain data challenges facing nutrition stakeholders. DVTs help people understand the meaning of data by placing the most relevant data in easy-to-interpret visualization formats such as bar graphs or maps, and can facilitate data-driven decision-making.
- > The number of DVTs in existence is growing, which may be useful if individual DVTs serve different and complementary purposes. However, there are inefficiencies in the landscape. The global nutrition community of DVT producers and funders could: support coordination to increase synergies and share learnings; convene DVT producers that report on common indicators to reduce divergent messages; and strengthen capacity to interpret and use data for decision-making.
- > Three key insights for those developing DVTs are likely to increase the effectiveness of DVTs: having a clear theory of change about the key decisions (and respective users) that the DVT aims to support and what actions are needed to deliver that change; including more actionable indicators; and ensuring the DVTs' formats align with users' data literacy levels and needs.

This analysis was conducted by Results for Development Institute (R4D) as part of the Data for Decisions to Expand Nutrition Transformation (DataDENT) initiative, which aims to transform the availability and use of nutrition data by addressing gaps in nutrition measurement and advocating for stronger nutrition

data systems. For DataDENT, R4D conducted a landscaping of 22 global data visualization tools in nutrition, as well as a literature review of data visualizations to complement the landscaping. These activities aim to improve the uptake of data for decision-making in nutrition.

Nutrition data users face many challenges

Thanks to the significant investments in the nutrition data landscape over the past decade, more data is available to support the work of nutrition policymakers, implementers, donors, advocates and researchers. Data is collected through routine administrative health information platforms (e.g., District Health Information System 2 [DHIS2]), large-scale household surveys (e.g., Demographic and Health Surveys [DHS], Multiple Indicator Cluster Surveys [MICS] and Standardized Monitoring and Assessment of Relief and Transitions [SMART] surveys) and project evaluation studies or monitoring platforms (e.g., Scaling Up Nutrition Monitoring, Evaluation, Accountability and Learning [SUN MEAL] and Hunger and Nutrition Commitment Index [HANCI]). Hundreds of indicators on nutrition outcomes, intervention coverage, underlying determinants and the enabling environment are collected across global data platforms.

While the increased amount of data available represents real progress, challenges still remain. Through the DataDENT engagement with nutrition stakeholders, we have identified that they are confronted with many challenges including:

- > accessing data at the right geographical level (e.g., subnational level) or trend data to track progress across indicators;
- > having clarity on which indicators (and corresponding definitions) are most critical for the decisions they need to make; and
- > analyzing and interpreting data to inform decision-making.

FIGURE 1: Four typologies of data visualization tools: dashboards, scorecards, indices and profiles**Dashboards**

Present the most critical performance indicators for a particular goal on a single screen – often used for operations or management purposes

Example: UNICEF/WHO Global Breastfeeding Interactive Dashboard

**Scorecards**

Compare performance across indicators to display status and monitor progress – often used for advocacy and accountability purposes

Example: African Leaders Malaria Alliance

**Indices**

Calculate several indicators into a single indicator (or composite score) to rank geographies or other units – often used for advocacy and accountability purposes

Example: Access to Nutrition Index

**Profiles**

Provide a snapshot of how a geographic region is doing in a particular sector – often used to spread awareness across broad audiences

Example: Global Nutrition Report Country Profiles

Well-designed data visualization tools (DVTs) can help address some of these challenges.

Data visualization tools: a critical tool to help decision-making in nutrition

Our brains have limited capacity to prioritize and process large quantities of data in raw form.¹ Not only do we process visuals more rapidly than text, but data is often more persuasive when presented in graphs rather than in tables.²

“Data visualizations help people understand the meaning of data by placing them in a visual context”

Data visualizations such as bar graphs and scatter plots help people understand the meaning of data by placing them in a visual context. DVTs – scorecards, dashboards, indices and profiles – are interfaces between data and data users that are meant to facilitate decision-making by providing the most critical data for decision-making in a format that is easy to interpret (Figure 1).

A common DVT example in everyday life is the car dashboard (Figure 2). While there is a lot of information about how a car works, the car dashboard curates the most important actionable indicators that drivers need to facilitate decision-making (e.g., the speedometer tells the driver how fast they are going to help monitor speed).

The landscape of global data visualization tools in nutrition

DataDENT reviewed 22 active global DVTs (defined as DVTs that are publicly accessible and cover multiple countries) in nutrition to understand how these contribute to the nutrition landscape. We developed a framework to review DVTs against four parameters:

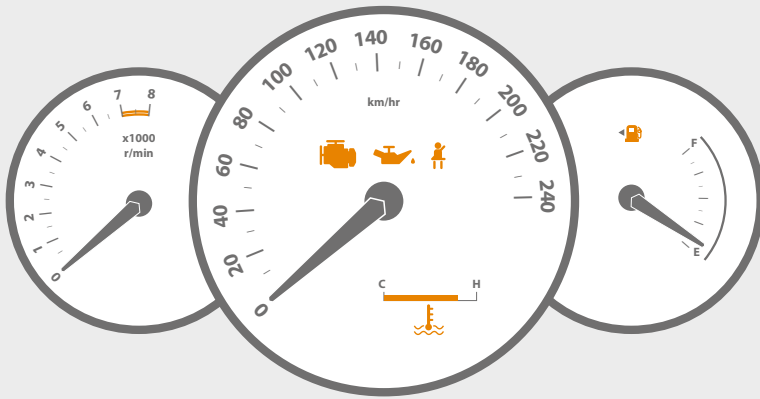
- > goals and audience (i.e., accountability, and planning, implementation and monitoring tools);
- > domains and indicators (e.g., intervention coverage, nutritional status);
- > output structure (i.e., chart types used to visualize data); and
- > dissemination (i.e., timing and method of dissemination).

Based on the DVT review, we conducted consultations with select DVT producers to develop case studies (Figure 3).

We characterized global DVTs into two categories:

- > **Accountability DVTs** – e.g., the Joint Child Malnutrition Estimates interactive dashboard – aim to hold governments accountable for delivering on political commitments or outcomes. These DVTs usually focus on outcome indicators.
- > **Planning, implementation and monitoring (PIM) DVTs** – e.g., the Vitamin A Supplementation Dashboard – provide

FIGURE 2: An everyday example: car dashboard versus statistics in a table

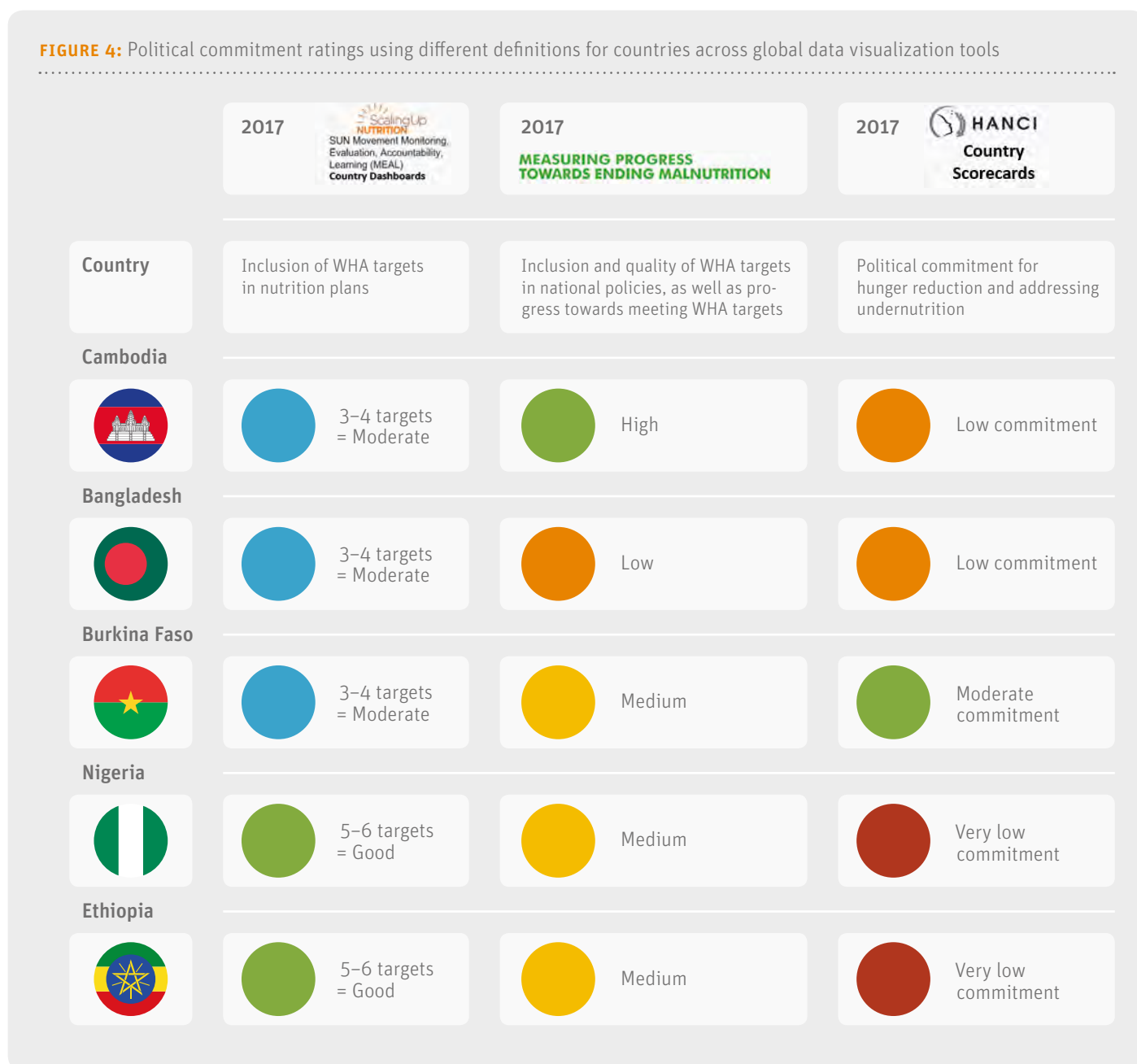


Feature	Status
Rotations per minute	0–8,000
Speed	0–240 km/hour
Engine	Operating, malfunction
Oil	Operating, maintenance needed
Seat belt	Fastened, unfastened
Engine temperature	Cold, hot
Gas	Full, empty

FIGURE 3: Global data visualization tools in nutrition reviewed for landscaping

The figure displays a grid of 20 global data visualization tools in nutrition, organized into five rows of four items each. The tools are:

- Row 1:** HANCI Country Scorecards; The State of Acute Malnutrition; Nutrition for Growth Accountability Tool; Country Indicators
- Row 2:** GLOBAL HUNGER INDEX; ScalingUp NUTRITION SUN Movement Monitoring, Evaluation, Accountability, Learning (MEAL) Country Dashboards; Investing in Nutrition; Global Scorecard of Iodine Nutrition
- Row 3:** Global targets tracking tool; NLi Nutrition Landscape Information System Country Profiles; Countdown Country Dashboards; THE WORLD BANK Nutrition Country Profiles
- Row 4:** GLOBAL FOOD SECURITY INDEX 2017; ACCESS TO NUTRITION INDEX™; Global Fortification DATA EXCHANGE; National Anemia Profile
- Row 5:** MEASURING PROGRESS TOWARDS ENDING MALNUTRITION; GLOBAL NUTRITION COUNTRY PROFILE; GLOBAL BREASTFEEDING SCORECARD; State of the World's Children Report Dashboard
- Row 6:** UNICEF / WHO / World Bank Group Joint Child Malnutrition Estimates Interactive Dashboard; Vitamin A supplementation interactive dashboard

FIGURE 4: Political commitment ratings using different definitions for countries across global data visualization tools

data to support a range of stakeholders in planning, implementation and monitoring progress. These DVTs tend to include more actionable indicators.

These two categories are not mutually exclusive, and many global DVTs fall into both categories (e.g., the SUN MEAL country dashboards).

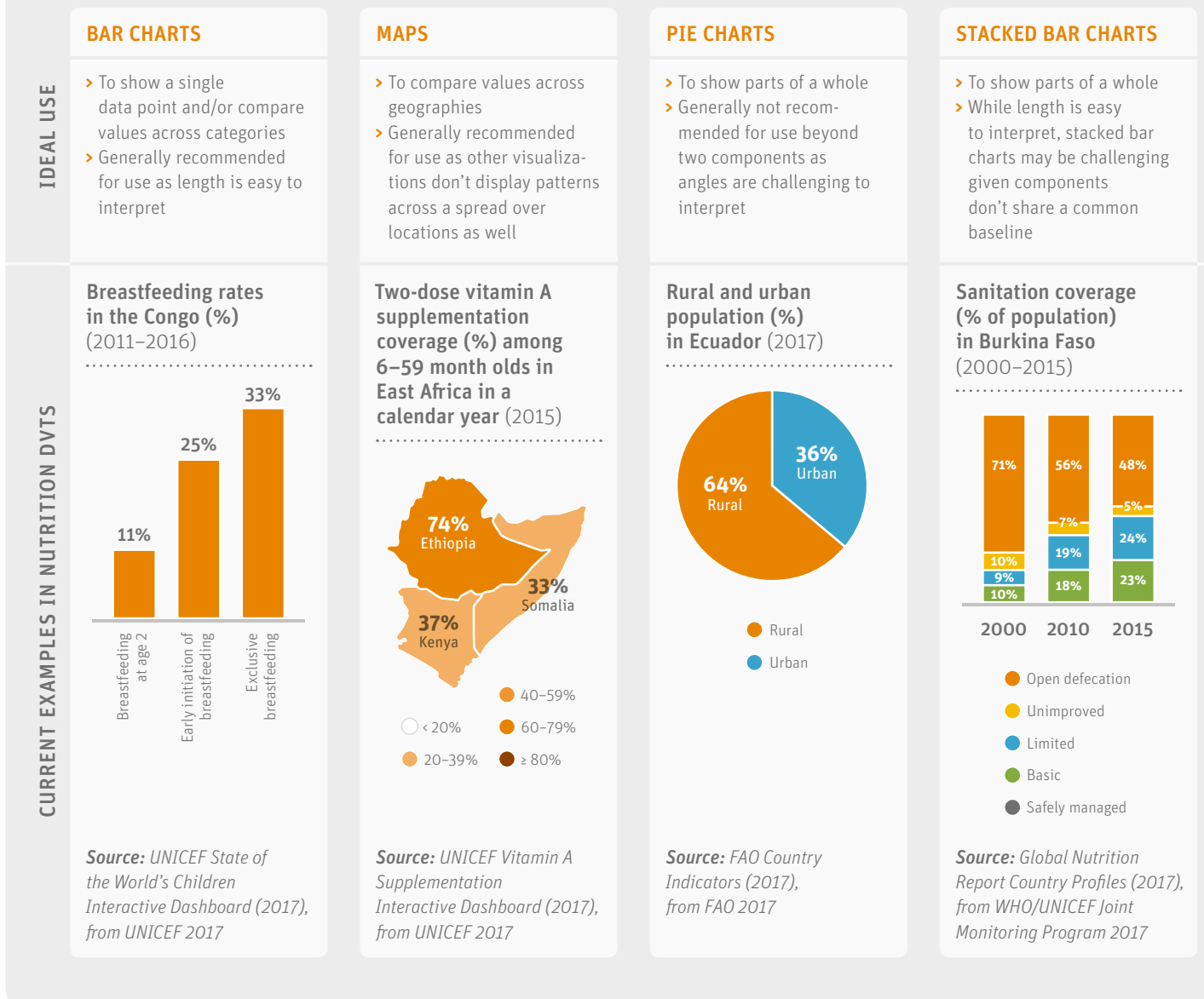
Navigating the growing global data visualization tools landscape

The number of global DVTs in nutrition is increasing. From July 2017 to June 2018, at least 14 global nutrition DVTs were either launched or else refreshed. This growing number may be useful if these DVTs serve different and complementary purposes.

But the proliferation may result in fatigue and confusion if there is overlap. Our analysis reveals inefficiencies in the landscape, mainly due to two challenges.

First, many DVTs report the same or similar nutrition indicators with varying definitions (which may be due to a lack of global standard definitions) and years. This can be challenging for funders, country decision-makers or advocates: How can they assess needs and program progress with such different indicators? For example, iron folic acid (IFA) supplementation during pregnancy is a commonly reported indicator across DVTs. Across five DVTs released between 2015 and 2018 reporting data from the 2010 DHS Burkina Faso, four different definitions (any IFA, < 60 days, 60–89 days and 90+ days during pregnancy) were used, resulting in four different statistics ranging from 23 per-

FIGURE 5: Ideal use of data visualizations and current examples in nutrition data visualization tools



cent to 93 percent. However, in this case, there is currently no global standard definition for this indicator, which impacts the range of definitions reported.

Second, DVTs use different methodologies and definitions to report similar topics. For example, DVTs commonly use traffic-light color coding based on different definitions. The SUN MEAL, Measuring Progress Towards Ending Malnutrition Scorecard and HANCI include metrics on political commitment for countries but use different definitions. SUN MEAL measures the *existence* of World Health Assembly (WHA) targets in nutrition plans; Measuring Progress Towards Ending Malnutrition Scorecard tracks the *existence and quality* of nutrition targets in national policies, as well as progress towards meeting WHA targets; and HANCI measures *political commitment* to hunger reduction and addresses undernutrition. This results in different

ratings, and when viewed together for the same country, likely sends conflicting messages to decision-makers (Figure 4).

Tools in action: three key insights from nutrition data visualization tools

1. Very few DVTs have clear and focused theories of change about the decision(s) they are trying to influence

Making data publicly available to development partners and policymakers with the expectation that it will be used – sometimes known as the ‘build-it-and-they-will-come’ approach – is common. DVTs in nutrition track many domains, including nutrition policies, financing for nutrition, healthy diets, interventions and progress towards global goals, with little clarity about the DVT’s goals and the pathway for change that the DVT is trying

DOT PLOTS

- > To show distribution of data points on a scale
- > Generally recommended for use as dots on a line are easy to interpret

TABLES

- > To show data points in an organized structure
- > While commonly used, it is not the most engaging visualization method

Attendance of 4+ ANC visits and skilled birth attendant by wealth quintile in Cambodia (2014)

Attendance of 4+ ANC visits

61% — 28 — 89%

Skilled birth attendant

75% — 23 — 98%

Rich / poor gap (% points)

20% poorest — 20% richest

Source: Countdown to 2030 Country Dashboards (2017), from DHS 2014

Anemia prevalence in Afghanistan

Indicator	Year	Value	Source info
Anemia in children < 5 years (Hb < 110 g/L) (%)	2011	44.0%	WHO
Anemia in Nonpregnant women (Hb < 120 g/L) (%)	2016	42.4%	WHO GHO
Anemia in pregnant women (Hb < 110 g/L) (%)	2016	38.2%	WHO GHO

Source: WHO Nutrition Landscape Information System (2017), from WHO 2011

to achieve among its targeted audience (which we define as the DVT’s ‘theory of change’).

Without clarity on goals and theory of change, can DVTs prioritize the information they provide and support actions appropriately? Is it possible to assess whether these DVTs are effective?

DVTs with a focused theory of change seem more poised to achieve their goals based on our initial consultations. For instance, the African Leaders Malaria Alliance (ALMA) scorecard is often lauded as a successful DVT for three key reasons. First, it focuses on malaria and targets a select group of decision-makers (i.e., African Heads of States). Second, ALMA measures a select number of the most critical actionable indicators that align with its objectives. Its actionable indicators are flagged with color coding and upward/downward arrows and recommendations

are provided to facilitate action. Finally, it has a strong engagement strategy: Heads of States are provided with quarterly progress reports; ALMA regularly adapts its approach based on user feedback; and, when requested, ALMA facilitates connections to provide technical assistance.

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“Outcome indicators such as stunting and wasting present the ‘state of nutrition’, but are insufficient to support decision-making needs”

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2. DVTs could include more actionable indicators to support decision-making

Outcome indicators such as stunting and wasting present the ‘state of nutrition’, but are insufficient to support decision-making needs. Indicators such as coverage of stunting prevention interventions (e.g., IFA supplementation during pregnancy or complementary feeding counseling) provide the necessary information to take action and improve stunting outcomes.

We define actionable indicators as providing data that can be acted upon to improve performance and management at the program and systems levels. Actionable indicators typically include policy/enabling environment and intervention coverage indicators.

While most DVTs report some actionable indicators, more actionable indicators could be included to support decision-making as per the DVT’s theory of change. There are three ways to achieve this:

- > if relevant, use actionable indicators that are already collected (and sometimes reported in other DVTs), e.g., *attendance of antenatal care visits (at least four visits)*;
-
- > if needed, collect new actionable indicators, e.g., *annual meeting frequency of multisectoral coordination bodies or existence of a multisectoral nutrition-costed plan*; and
-
- > for unavailable data, report blank data to trigger discussions on the need for data collection.

3. There are different ways of visualizing data; the choice should be based on the DVT’s goals, as well as users’ decision needs and data literacy levels

Across nutrition DVTs, several types of visualization are used, including: bar charts, maps, stacked bar charts, pie charts and dot plots – all of which serve different purposes in responding to users’ needs (Figure 5).²⁻⁴

It is critical that visualizations align with the DVT's goals as well as users' data literacy levels and decision needs. A study was conducted on reproductive, maternal, newborn and child health, and nutrition decision-makers (defined as program implementers and policymakers) in Tanzania. These decision-makers generally preferred simple visualizations such as bar graphs and pie charts.⁵ The study also noted statistical capacity was limited and recommended statistical training to improve data interpretation of advanced data analyses and visualizations. In contrast, nutrition stakeholders with high data literacy and advanced statistics backgrounds may have an easier time leveraging complex DVTs, such as the Global Burden of Disease (GBD) Compare tool, which allows users to change the inputs of risk factors and disease causes against different outcomes (e.g., disability-adjusted life years).

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“The growing number of global DVTs in nutrition is a positive reflection of the greater emphasis on data for decision-making, but also a challenge”

Call to action

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The growing number of global DVTs in nutrition is a positive reflection of the greater emphasis on data for decision-making, but also a challenge, given the inefficiencies in the DVT landscape.

DVTs can facilitate decision-making among nutrition stakeholders and be powerful instruments for change. However, to increase effectiveness, our initial findings recommend that DVTs should:

- > **have a clear theory of change**, articulating which decisions (by which users) the DVT aims to support and what supporting actions are needed to deliver change;
 - > **include actionable indicators** that align with the DVT's theory of change, including indicators with little to no data for advocacy purposes; and
 - > **test data visualization formats with targeted users** to ensure formats align with users' data literacy levels and decision needs.
-

More broadly, there are three potential opportunities for the global community of DVT producers and funders to improve the efficiency of the landscape:

- > **Support coordination** among the global DVT community to increase synergies, reduce inefficiencies, and share learnings across DVTs.
- > **Convene DVT producers that report on common indicators** to reduce differences in definitions and divergent messages.
- > **Strengthen capacity** of targeted users to interpret and use data for decision-making.

Finally, complementing this review, we will be conducting user research among nutrition stakeholders to identify their data needs and how global DVTs respond to them. We will also conduct a DVT landscaping exercise with user research in India to understand how DVTs support country decision-makers in nutrition.

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Perspective from 2021

Designing Effective Data Visualization Tools for Monitoring and Accountability

The Nigeria Governors’ Forum Nutrition Scorecard

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 Results for Development Institute,
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of using data to inform decision-making and improve advocacy among Nigeria’s Governors. The NGF has prioritized nutrition within its health agenda, and the nutrition scorecard (Figure 1) is a recently launched data visualization tool (DVT) that will hold the state Governors accountable to key nutrition commitments, including:

The Nigeria Governors’ Forum (NGF)¹ is a nonpartisan policy hub dedicated to promoting good governance and development at the subnational level. The Forum has a strong track record

- > To set up or revitalize State Committees on Food and Nutrition (SCFN);

FIGURE 1: The Nigeria Governors’ Forum Nutrition Scorecard

Data Source	Data Provided by State Committees on Food and Nutrition (SCFN)					Routine Administrative Data
Indicator	SCFN quarterly meeting chaired by SCFN Chair	75% of quarterly funding for SCFN workplan released	MSPAN Approved	State list of prioritized programs shared	Six months maternity leave with full pay for civil servants	US SAM Quarterly Coverage Target: 75%
State A	● ↑↓	● ↑↓	● ↑↓	● ↑↓	● ↑↓	15% ● ↑↓
State B	● ↑↓	● ↑↓	● ↑↓	● ↑↓	● ↑↓	5% ● ↑↓
State C	● ↑↓	● ↑↓	● ↑↓	● ↑↓	● ↑↓	10% ● ↑↓
State D	● ↑↓	● ↑↓	● ↑↓	● ↑↓	● ↑↓	0% ● ↑↓
State E	● ↑↓	● ↑↓	● ↑↓	● ↑↓	● ↑↓	30% ● ↑↓

Source: Results for Development Institute

- > To establish state-level multisectoral strategic plans of action on nutrition (MSPAN);
- > To increase budgetary spending on nutrition interventions; and
- > To promote maternity protection for civil servants.

“The Nigeria Governors’ Forum has prioritized nutrition within its health agenda”

The collaborative design team, with members from the NGF health policy unit and DataDENT, engaged Governors, state- and federal-level multisector nutrition bodies, as well as development partners, to identify commitment indicators and other scorecard components. From the conception of the theory of change through to the launch and presentation of the first round of data, the design team noted several key reflections which expand on the insights from a global tool landscaping carried out by DataDENT, and which may help to inform other producers interested in developing similar DVTs for monitoring and accountability.

1. Start with a clear theory of change, including an explicit understanding of who the target user group is and how the tool will influence their actions.

In line with the findings from the landscaping, it was important to map out three critical elements of the scorecard’s theory of change:

- > The target audience;
- > The key decisions that they make; and
- > The pathway to change.

From the onset of the DVT development process, the design team had several rounds of discussions to specify that the primary scorecard users would be the Governors and their support staff, who would review the updated scorecard during a brief slot in the regular NGF quarterly meeting agenda. The team envisioned that the process of developing the scorecard, together with regular data collection and presentation, would promote the prioritization of nutrition in the states’ development agenda, while the process of comparing progress across states would drive competition among the Governors to maintain a good ranking by taking actions in respect of the commitments. In addition, the scorecard would shine a light, and provide guidance, on the most cost-effective strategies for exponential impact on nutrition for states to prioritize.

2. Select actionable indicators that reflect progress in both the policy presence and quality dimensions of the commitments.

The design team chose indicators that reflected not just the presence of a policy in support of the commitment, but also the quality of policy implementation. For example, the multisectoral plan commitment required that the plans be both multisectoral (i.e., included the participation of at least two nutrition-related government ministries and agencies) and costed. Likewise, the maternity protection commitment related to placing creches in government offices required states not only to have creches but also to ensure that these creches have a breastfeeding space, handwashing station, and a ratio of 1:5 nannies to children as outlined in Nigeria’s National Policy on Child Centers.

3. Directly engage target users in selecting or ‘co-creating’ indicators, as the process of indicator specification itself can influence policy design and implementation.

For scorecard indicators, the design team consulted both federal- and state-level government stakeholders and development partners to identify barriers to progress, and then proposed indicators focused on those obstacles. For example, one barrier to the SCFN commitment was a lack of regular meetings in states with an SCFN. The SCFN commitment indicator identifies whether the committee met during the previous quarter with the chairperson present. By creating this indicator, the status of regular occurrence of the SCFN meetings will be publicly reviewed on a quarterly basis. The co-creation process improved the actionability and engendered ownership of the indicator by the decision-makers who use the scorecard. In this case, the design team developed unique fit-for-purpose indicators that are actionable by the Governors; however, in other scenarios, it may be preferable to align indicators with established national or global definitions.

“The Governors prefer a simple visualization for tracking their state’s performance”

4. Visualization features should respond to the target audience’s needs.

In the case of the NGF nutrition scorecard, the design team chose a scorecard over other types of DVTs because it was familiar and easier for the Governors to comprehend, and would also facilitate cross-state comparisons of performance. The design

team selected indicators that were actionable by the Governors and developed binary definitions (yes/no), displayed using two colors for easy comprehension. In addition, the design included key indicators for all four commitments on a single page. The design team received feedback that the Governors do not have a lot of time to review the DVT in detail and prefer a simple visualization from which they can easily extract their state's performance against the performance of other states.

A comprehensive case study, detailing the entire process of developing the scorecard, is available via Gates Open Research² and is currently under peer review.

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FIRST PUBLISHED IN:

Vol. 34 (1) | 2020
PP. 90-95



Social Marketing to Sustainably Influence Nutrition Behaviors

Nutri'zaza's strategy for triggering adequate consumption of complementary foods to prevent malnutrition in Madagascar

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Key messages

- > The bottom-up creation of a social offering improves its chances of success.
- > Focusing on consumer satisfaction and convenience, while at the same time respecting local food habits, is more effective than simply communicating a health promise.
- > Developing innovative distribution networks to increase the availability of products close to the poorest families is key.
- > Social marketing makes it possible to reach vulnerable populations.

Madagascar, a vulnerable and challenging environment¹

Every year, 9 million children worldwide die before the age of five. Directly or indirectly, one out of every two of these deaths is due to malnutrition. Malnutrition is especially devastating during the first 1,000 days of life, from an infant's conception to its second birthday. Even when it does not kill, malnutrition causes irreversible damage that lasts into adulthood (high morbidity, physical

and mental disabilities). This damage is passed on from one generation to the next, and has serious consequences for development. Malnutrition during this period is partly caused by the inadequate intake of nutritionally appropriate foods that are complementary to breast milk, and it can lead to food-borne diseases (diarrhea, parasitic infections) and/or the reduced bioavailability of micronutrients. The timely use of appropriate complementary foods and/or food supplements is generally recognized as a necessary prerequisite for preventing malnutrition. However, encouraging mothers to buy or prepare appropriate food products at the appropriate time is a challenge that has often been addressed without major success in developing countries.

“The manufactured complementary food products available on the market are generally of poor quality or else unaffordable, and 80 percent of urban Malagasy families live on less than US\$1.90 a day”

In Madagascar, 47.8 percent of children under 5 years suffer from chronic malnutrition (and up to 60 percent in some poor urban areas), which equates to more than 900,000 children. Feeding practices do not meet their needs, and the manufactured complementary food products available on the market are generally of poor quality or else unaffordable, and 80 percent of urban Malagasy families live on less than US\$1.90 a day.

How can this public health issue be addressed in a sustainable manner? Nutri'zaza's ambition is to ensure affordable and quality complementary foods for children aged 6–24 months are available to vulnerable populations with low purchasing power, and thereby to sustainably improve the consumption of adequate food and ultimately to help prevent malnutrition in infants and young children (Box 1).

BOX 1: Nutri'zaza: a Malagasy social business in the nutrition sector

Nutri'zaza is a social business that was set up in 2013 to build on the results of 14 years of nutrition projects led by GRET (a French development nongovernment organization) with its partners (IRD, Antananarivo University, TAF and Malagasy institutional stakeholders). Its aim is to improve infant feeding practices in poor neighborhoods in urban areas of Madagascar.^{1,2}

Consumer insights drive social marketing approach

To build an appropriate social marketing strategy with a high qualitative value proposition, consumer knowledge is key. Nutri'zaza regularly performs in-depth quantitative and qualitative diagnoses and analyses of consumer insights, including the global aspirations and needs of consumers, so as to develop a better offering in the long run. In Madagascar, the main findings of this work helped Nutri'zaza inform the development of a coherent strategy.^{1,3,4}

> **Nutrition knowledge:** More than 90 percent of mothers are convinced as to the importance of food diversification. However, almost 50 percent of them declared that this is difficult to achieve in practice (because of limited time, the



A Malagasy mother and child participating in a nutrition education session, in Antananarivo, the capital of Madagascar

low nutrient content of homemade food, the low all-year-round availability of some necessary types of food and the lack of budget to buy appropriate ingredients). Only one in every three mothers has a good knowledge of fortified foods.

> **Food practices and cultural perception of food:** Complementary food given to children – the traditional meal 'Vary sosoa' – is mainly composed of rice and water, and is of very low nutritional quality. Although nutritionally poor, rice is the star product in the perception of Malagasy, and in all respects: that of culture (rice is a staple food consumed daily); that of identity (in Malagasy, 'to eat rice' means simply 'to eat'); and that of nutrition (rice is considered as the perfect food that meets all dietary needs). Few people can afford to cook rice three times a day (because of lack of time or budget), so they prefer to buy out-of-home, ready-

TABLE 1: Local needs identified and expectations expressed

Local needs identified	Expectations expressed
Inadequate feeding practices from 6 months ('Vary sosoa')	Feeding and practices adapted to the nutritional needs of children aged 6–24 months
Low knowledge of infant and young child feeding	Knowledge of how to feed children better
Constraints in preparing meals with unprocessed raw material	Meals that are easy and quick to prepare and/or ready to eat
Poor sanitary conditions (especially water quality)	Ready-to-cook product
Time-consuming preparation for mothers and caregivers	Recipes adapted to the local food habits and constraints (with emphasis on the presence of rice and local flavors/tastes)
Insufficient financial means	Meals that are affordable for the majority of those sections of the Malagasy population who have low purchasing power
Difficulty accessing healthy food, especially in poor areas of urban cities	High-quality local product accessible near residential areas, and high proximity to consumers



A Malagasy child consuming a local porridge, in Antananarivo

to-eat rice donuts or tea for their children. Eighty percent of children aged 6–24 months do not reach the acceptable minimum food intake, and only 28 percent receive the minimum number of recommended meals per day (according to WHO standards).

- > **Habits and purchasing behavior:** Parents generally buy food products on a daily basis in small grocery stores and in very small quantities. Consumption away from the home is common, especially because of the cost of preparing food at home. More than 80 percent of the population living in urban areas have a daily food budget of MGA200–500 per child per day (US\$0.06–0.13).
- > **Needs and expectations:** According to Malagasy mothers, the ‘perfect food’ has to be safe, accessible in terms of price, available close to home, composed of local ingredients (especially rice), quick and easy to prepare, adapted to local food tastes, in line with nutritional requirements for the child’s growth (at



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A flyer for the Koba Aina product range

least in terms of vitamin content) and easy to digest. Above all, Malagasy mothers want to please their children with the best food they can afford, not the cheapest (Table 1).

“Malagasy mothers want to give their child the best food they can afford, not the cheapest product on the market”

Nutri’zaza’s value creation and social offering

To address these contextual issues, Nutri’zaza, with the technical support of GRET NGO and its partners, developed an innovative strategy to manufacture locally available, easy-to-use fortified products and to market them to low-income families with young children, while at the same time raising awareness of good feeding practices.

One key driver forms the basis of Nutri’zaza’s social marketing strategy: focusing on consumer satisfaction and convenience while meeting local food habits (Box 2). This strategic orientation is more effective than simply communicating a health promise.^{1,2,5}

The product offered, *Koba Aina* (‘flour of life’ in Malagasy), is a ready-to-cook flour made from corn, soy, rice, sugar and peanuts, and fortified with 25 vitamins and minerals. It is used in the preparation of porridge and is similar to the traditional local rice flour. It is a complete infant flour (1 sachet = 1 meal) and is locally produced by TAF mainly from local raw materials (90 percent). *Koba Aina* is adapted to suit the nutritional requirements of infants and young children aged 6–24 months in addition to breast milk. It is also adapted to the eating habits of the local population, compliant with international quality standards and affordable for low-income populations. The consumption of one serving per day in place of one traditional meal, combined with the rest of the diet (including breast milk), covers the total daily recommended nutritional intake for children aged 6–24 months.

“The innovation lies also in the associated service that is offered to consumers with a view to achieving better compliance”

The innovation lies also in the associated service that is offered to consumers with a view to achieving better compliance. The product is available in two different formats (as ready-to-eat



A restaurant for babies in a poor urban area of Antananarivo

BOX 2: The social marketing mix

Product: *Koba Aina* fortified product (see above, 'social offering')

- > *Koba Aina* is a ready-to-cook flour fortified with 25 vitamins and minerals, which is used in the preparation of porridge.
- > It is compliant with international quality standards and local habits and tastes.
- > It is sold in three formats: unpackaged (as ready-to-eat porridge), in a one-portion-size 35 g sachet and in 1–50 kg bulk packaging.
- > The 35 g sachet comes in three flavors: natural, strawberry and banana.
- > The mascot – a bag of rice from Madagascar with a smiley face – highlights the values of the brand (quality, nutrition, local identity). The name *Koba Aina* ('flour of life'), the slogan ("I love my child, I give him *Koba Aina*") and all other communication messages have been chosen to reflect mothers' perceptions and expectations regarding infant food.

Place: three distribution channels facilitate the sale of the product in urban zones across Madagascar (Nutri'zaza):

- > The social market: 123 sales agents (well known to the community) sell the ready-to-eat porridge in urban zones as door-to-door ambulant vendors or through *Hotelin-jazakely* ('restaurants for babies'). Parents can also come to buy the porridge already prepared or instead can let their children eat it in the restaurant. This option (33 percent of sales volumes as at December 2018) also provides an opportunity for parents to monitor the baby's growth and to obtain advice.

- > The traditional market: around 8,000 retail outlets, including small and medium-size grocery stores, pharmacies and supermarkets, sell the 35 g sachet. Fifteen wholesalers also flood the market (accounting for 46 percent of sales volumes as at December 2018).
- > The institutional market, via NGOs and public institutions. Unbranded *Koba Aina* is sold to social institutions in order to reach populations in the E category (people living on less than US\$0.19 a day) by them offering free or subsidized products (accounting for 21 percent of sales volumes as at December 2018).

Price: unsubsidized to end consumers

- > Through the social network (restaurants for babies and door-to-door): MGA300 for one ladle/meal = €0.075.
- > Through the traditional network (retail): MGA500 per 35 g small sachet (one-portion pack/meal) = €0.125.
- > Through the institutional network (public organizations): free for the end consumers, and sold to the institutions at a lower price than via the other channels.

Promotion:

- > Media: advertising spots on TV and radio, sponsoring, documentaries, game contests online, national fairs.
- > Below-the-line marketing: sales agents in the neighborhoods (as the main communication vector), events on local markets (mobile animation) or with retailers and wholesalers, trade animators in regions, goodies.
- > **The message is not based on 'the cheapest solution for the poor.' Communication focuses on the fact that this is a local solution made from rice, and that it is convenient, available near your place, tastes good, of high quality and affordable. Its emphasis is on the pleasure given to the child, and the main aspiration is: "I love my child, I give him *Koba Aina*!"**

porridge served by the ladle and also as a 35 g sachet of flour), and is distributed in various ways:

- > via the traditional network comprising more than 8,000 direct sales outlets and wholesalers;
- > via a genuinely innovative social network, the 36 *Hotelin-jazakely* ('restaurants for babies');
- > via a door-to-door service at the heart of 123 neighborhoods in Madagascar; and

- > via the institutional network of public organizations conducting nutrition projects.

In parallel with the intensive commercial promotion, families receive appropriate messages from public actors on infant and young child feeding through a complete behavior change communication strategy focusing on complementary feeding and developed in line with government nutrition policies. This choice of combining both actions (social marketing run by Nutri'zaza and nutrition education run by public actors) is mainly driven by the very specific category of product being addressed (complementary foods for children aged 6–24 months). Indeed, following the WHO's International Code of Marketing of Breast-milk Substitutes and the recent resolutions of the World Health Assembly (May 2016), a private company cannot communicate nutrition education messages to this specific target group.^{6,7} This combination is essential to ensure the consumption of *Koba Aina* becomes part of a set of adequate food practices to prevent malnutrition among children.

Key learnings

Based on Nutri'zaza's experience, the social marketing of locally manufactured complementary foods appears to be a solution to provide quality and affordable foods that are fast and easy to prepare to as many people as possible. When accompanied by a complete behavior change communication strategy that increases awareness of appropriate feeding practices, social marketing

BOX 3: Nutri'zaza's social marketing strategy in numbers

- > More than 47 million meals of *Koba Aina* have been sold since 2013, which means more than 8,000 children under 5 are reached daily.
- > 600,000 families have access to *Koba Aina* near their home (all points of sales combined). More than 120 neighborhoods are currently covered by the door-to-door service in 45 districts, among which 36 restaurants for babies are operational and more than 8,000 direct sales outlets are active.
- > The monthly penetration rate, which is defined as the rate of children aged 6–24 months consuming at least one serving of *Koba Aina* (120 g of porridge made from 35 g of flour) per month, is around 62 percent (as at the end of 2017).
- > Low-income consumers (from the D category) buy the ready-to-eat porridge that is sold door-to-door using a ladle.
- > The 35 g small sachets that are available in the

traditional network reach families from the C to B categories, even when some of them live in neighborhoods where they could purchase ready-to-eat porridge delivered at home.

- > The brand awareness rate reaches the extremely high level of 90 percent in and around areas with restaurants for babies.



Nutri'zaza selling agent of *Koba Aina*, in Antananarivo

enables the appropriate consumption of the product in combination with other recommended practices and effectively improves nutritional impact.

Koba Aina is the only complete flour that is produced in Madagascar from 90 percent of local raw materials and is also specifically adapted to prevent malnutrition according to WHO standards among the crucial target group of children aged 6–24 months. It is two to four times less expensive than other industrial products available on the market and its price represents 4–8 percent of the budget of a family receiving a national minimum salary. Finally, *Koba Aina* is the only high-quality product sold in a convenient ready-to-eat format either via the door-to-door service or at the brand-dedicated baby restaurants.

Key figures show the current impact of Nutri'zaza's social marketing strategy (See **Box 3**).

Several lessons learnt can be shared as global recommendations:^{1,2,4,8–10}

1. Using social marketing to introduce a new adequate complementary food, in combination with a behavior change communication strategy focusing on relevant infant and young child feeding behaviors, influences more sustainable nutrition behaviors and triggers the adequate consumption of food.

2. Social marketing enables poor populations to be reached: the affordability of a high-quality product can be proven among C and D customers who are ready to pay more to get adequate food for their child if the product is perfectly adapted to their needs (in terms of the format of the selling units, content and distribution).
3. The bottom-up creation of a social offering improves the chances of success: in-depth diagnosis and regular analysis of the context, acceptability among the population and distribution network enable a better offering to be developed.
4. Offering a real-value proposition focusing on satisfaction (i.e., for the child), convenience and immediate emotional benefit (i.e., for the mother), while also meeting local food habits, leads to better adoption of the product by the target group than if only a health promise is made. “Mothers want to give their child the best food they can afford, not the cheapest product on the market.”
5. Developing innovative distribution networks to increase the reputation and availability of products very close to the poorest families is key: a door-to-door service facilitates the use of a product in a context where many families do not have the facilities to prepare homemade meals and where some meals are usually eaten at home.
6. Developing a premium range (35 g small sachet) in parallel with a low-price product (porridge ladle) increases trust and the reputation of the product, triggers demand and ensures the product becomes aspirational for all target groups.
7. Combining research and action over a sufficiently long time span is key to find suitable and innovative solutions for each context and target group. Continuous monitoring and evaluation are also essential to ensure that the offering is still adapted to the context and that the messages are still in line with the target group and legal context.

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Perspective from 2021

Nutri'zaza: Stepping up the provision of sustainable, quality, fortified foods to vulnerable people

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In Madagascar, where more than half of children under 2 years of age suffer from chronic malnutrition, finding sustainable, effective, local solutions is still a real challenge. One of the causes of this scourge is the insufficient quality of food for children aged 6–23 months. They often have no access – as a complement to breastfeeding – to sufficient quantities of quality foods that properly meet their nutritional needs, at a price that is affordable for their parents. A similar situation is also observed in the case of children over 2 years of age, who suffer from the lack of a diversified, balanced diet. This is especially reflected in their high consumption of carbohydrate foods and low consumption of micronutrient-rich complete foods. This trend is accentuated by the consumption of snacks that are not suited to their nutritional needs.

“Food price increases and COVID-19 have together reduced the purchasing power of Malagasy households”

Since 2019, increases in food prices, in combination with the effects of the COVID-19 pandemic, have reduced the purchasing power of Malagasy households, while the impact of climate change has also increasingly generated food and nutritional crises.

Responding to heightened needs

As a key player at the national level in the fight against malnutrition in Madagascar, Nutri'zaza has accelerated its development strategy to respond to this situation (**Box 1**).^{1,2} We have done this by two means.

1. By reinforcing the position of *Koba Aina* as a flagship quality product for children aged 6–24 months

At the end of 2021, despite the difficulties stemming from the COVID-19 crisis, the innovative proximity network was strongly boosted to cover around 120 *fokontany* in which the porridge is distributed via 30 *hotelin-jazakely* ('restaurants for babies') and door-to-door sales by 120 mobile facilitators. Regular Nutri'zaza sales teams were also strengthened, and our commercial organization improved to optimize the presence of the product range in the traditional retail network: more than 8,200 *Koba Aina* points of sale are now active in this circuit. As a consequence of this intensive commercial strategy, *Koba Aina* infant flour is achieving significant results in terms of sales and impact.

In October 2021, *Koba Aina* was also the first and only Malagasy infant flour to be locally certified and to bear the NMG mark of conformity awarded by the Bureau des Normes de Madagascar (Malagasy Standards Office) in addition to meeting international standards: a guarantee of quality for both consumers and producers.³ With the same focus on meeting consumer expecta-

BOX 1: Nutri'zaza's social marketing strategy impact since January 2019

- > 27.5 million rations of *Koba Aina* fortified infant flour sold (Jan 2019–Oct 2021)
- > Around 130 neighborhoods covered by the door-to-door *Koba Aina* service in 45 districts
- > 880,000 children with access to *Koba Aina*
- > Rate of regular customers close to 19 percent
- > 1.78 million *PoBary Aina* fortified cereal bars for children aged 3–5 years sold (Nov 2019–Oct 2021)
- > 289,000 packets of *Moosli Aina* fortified muesli for children aged 6–14 years sold (Aug 2021–Oct 2021)
- > More than 8,200 direct points of sale distributing the fortified foods range (including stores, grocery stores, supermarkets)
- > Since 2013, the year of its creation, Nutri'zaza has sold more than 75 million rations, based on local raw materials and local food companies



PoBary Aina for preschool children (aged 3 to 5 years)



Moosli Aina for school-age children (aged 6 to 14 years)

tions and reaching more households, a new phase of research and development on *Koba Aina* is underway in partnership with TAF, a Malagasy food company.

2. By launching an intense research and development phase to expand the fortified foods range

In light of the nutritional situation of children over the age of 2 years, and given that consumption of a snack is a daily habit, Nutri'zaza chose to develop nutritious snacks as a complement to diversified diets and regular physical activity. These healthy

snacks are well suited to children's nutritional needs. Two new products – one for preschool children (aged 3 to 5 years) and the other for school-age children (aged 6 to 14 years) – have been launched. These are *PoBary Aina* (a cereal bar made from chocolate-coated puffed rice, enriched with 19 vitamins and minerals) and *Moosli Aina* (a chocolate-orange muesli recipe made from puffed rice and sorghum, with 21 vitamins and minerals).

These products are the result of the multisectoral collaboration between Nutri'zaza, GRET, the Labasan laboratory, the University of Antananarivo, and Chocolaterie Robert, a Malagasy company. Technical constraints were compounded by con-

straints in terms of target consumers' expectations and the need to be specifically positioned with regard to other competing products available on the market. These two new products have been very well received since their launch, placing them in the top five most popular snacks for children in Antananarivo, the capital of Madagascar.

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03. The Malagasy standard NMG 103-5 applies to infant formula intended for consumption by children from 6 to 24 months, and possibly beyond. It was designed on the basis of international references and national regulations. It describes the required characteristics in terms of nutritional and sanitary quality.

“*Sight and Life* has been an invaluable support in my work. I rely on them for keeping me up to date on the latest science and how it is translated into effective programs, and for staying abreast of important colleagues’ activities – not to mention for inspiration!”

Kathy Spahn | CEO, Helen Keller International (HKI) | New York, NY, USA

“*Sight and Life* publications help foster a sense of community around the issue of micronutrients, especially for women and children, among practitioners, academics and policymakers alike. Nutrition International’s work is focused on moving evidence into action, and working together with partners who initiate important discussions on these topics is invaluable.”

Joel Spicer | President and CEO, Nutrition International | Ottawa, Canada

“*Sight and Life* is a mission of hope and inspiration, working with partners to shine a light on evidence-based, context-appropriate solutions to address the global challenge of hunger and all forms of malnutrition. The commitment lives on to enable better lives for those in need. Happy 35th Anniversary!”

Emorn Udomkesmalee | Senior Advisor, Institute of Nutrition, Mahidol University | Nakhon Pathom, Thailand

“*Sight and Life* has the same aim as the SUN Movement – ending malnutrition in all its forms. So your work could not be more relevant to us. You bring together a wide range of actors – always the best approach. We continue to count on strong collaborative action for nutrition solutions.”

Gerda Verburg | United Nations Assistant Secretary-General; Coordinator of the SUN Movement | New York, NY, USA

“*Sight and Life*, staying true to your original goal to reduce child blindness and mortality, while evolving to promote healthful and sustainable diets throughout impoverished societies ... Thank you for decades of collaboration, innovating, thinking and serving as a trusted voice across academia, industry and governments in our global community.”

Keith P. West | George G. Graham Professor of Infant and Child Nutrition, and Director of the Program and Center for Human Nutrition, Department of International Health, Johns Hopkins Bloomberg School of Public Health | Baltimore, MA, USA

Imprint

Sight and Life magazine

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Publisher: *Sight and Life*

Editor: Klaus Kraemer

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Communication consultancy, project management

and text writing: Jonathan Steffen Limited, Cambridge, UK

.....

Design concept, layout, graphics and final artwork:

S1 Grafik Design, Rebstein (St. Gallen), Switzerland

www.s1-buero.com

.....

Proofreading: Rosemary Boddington, Cambridge, UK

.....

Printer: Burger Druck, Waldkirch, Germany

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Opinions, compilations and figures contained in the signed articles do not necessarily represent the point of view of *Sight and Life* and are solely the responsibility of the authors.

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ISBN 978-3-9525058-4-7

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