Food is Medicine and the Role of Precision Nutrition in Maternal and Child Health

First National Seminar on Personalized / Precision Nutrition for Sustainable Health: From Theory to Practice

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Maternal and child health and nutrition (MCH)

Populations

- Pregnant women
- Breastfeeding mothers
- Women of reproductive age
- Infants, children, adolescents

Focus

- Lower-middle income countries (LMIC)

Burden of over- and undernutrition

Undernutrition
- Stunting, wasting, underweight
- Thinness, short adult stature
- Micronutrient deficiencies
  - Vitamin A, iron, zinc among others

Overnutrition
- Overweight and obesity
- Alterations in metabolic health indicators

Double-burden of malnutrition
- co-existence of undernutrition + overnutrition

Consequences:
Impairments in immune function
Increased morbidity from infectious diseases
Poor growth
Lower cognitive function
Increased risk for metabolic diseases
Death

Achieving global targets

- **Maternal and early life nutrition is …**
  - a **key determinant** of health in children in the **first 1000 days** *and* then **1000 weeks of life**
  - critical to achieving SDGs
- **Major investments** in design and implementation of programs that can be considered '**Food is Medicine**', e.g.,
  - Intermittent iron supplementation to target anemia
  - Large-scale food fortification to target multiple micronutrient deficiencies

Achieving global targets

What do these programs need to succeed?

1. Identify & target at-risk groups, particularly in LMICs
2. Monitor progress and impact
3. What is the next step?

Accurate assessment of nutritional status in women, infants, and children is critical to track progress of existing programs, identify gaps, and measure efficacy of interventions

Next step

- **Precision Nutrition for MCH**
  - Integrating multiple data types to **predict outcomes e.g., glucose response** using AI, usually a machine learning (ML) algorithm
    - United States NIH *Nutrition for Precision Health (NPH) Initiative*
    - Better understand the multiple and multi-level risk factors for adverse health outcomes to inform care, prevention, and treatment guidelines

Individual-level data:

Anthropometry
Biochemical
Clinical
Dietary
Social
Environmental
Genetic
Metabolome
Proteome
Microbiome

Precision Nutrition (**PN**) in Maternal Child Health (**MCH**) Questions

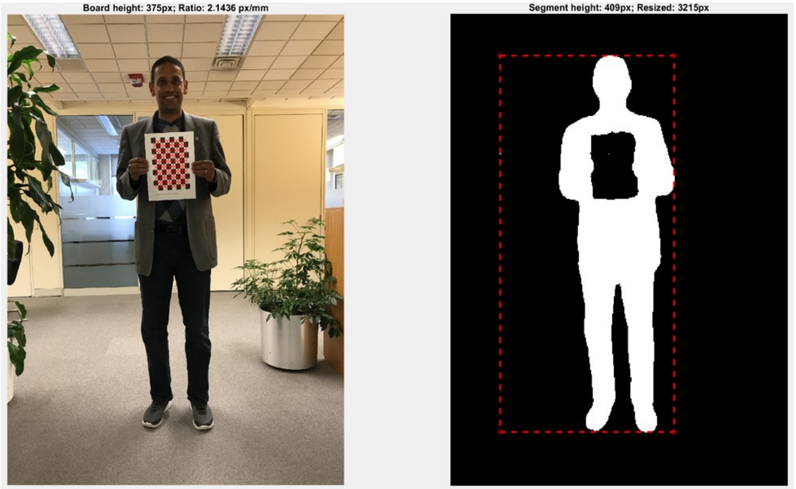
1. What are the **challenges** of current methods for nutrition status assessment?
    1. **ABCD**: Anthropometry, Biochemical, Clinical, Dietary
2. Where can **PN improve** on these challenges?
3. How has **PN already been used in MCH contexts** for assessment?
4. How could **PN potentially** be used for assessment in MCH settings?
5. Has PN been used to **predict response** or address a clinical outcome in MCH?

Nutritional Status Assessment

- **Anthropometry & Body Composition**
  - Challenges of current tools:
    - **Simple tools:** Time-consuming, challenging to perform in certain populations (e.g., young children), susceptible to human error, usually require manual data transfer/entry
    - **Complex tools:** Require adequate training, are costly to purchase and maintain, requires controlled conditions, may not be suitable for certain populations

Nutritional Status Assessment

- **<u>Newer option</u>:** Mobile-friendly (portable) **optical imaging devices**
  - Quickly measure surface area, circumferences, volumes, lengths, areas by taking a scan/photo/video
  - Transfer data to cloud
  - **Automated processing** of image data via machine learning
  - ***Key:*** *high quality images/videos*



Predicting height from image. Lokshin et al., 2018 - World Bank

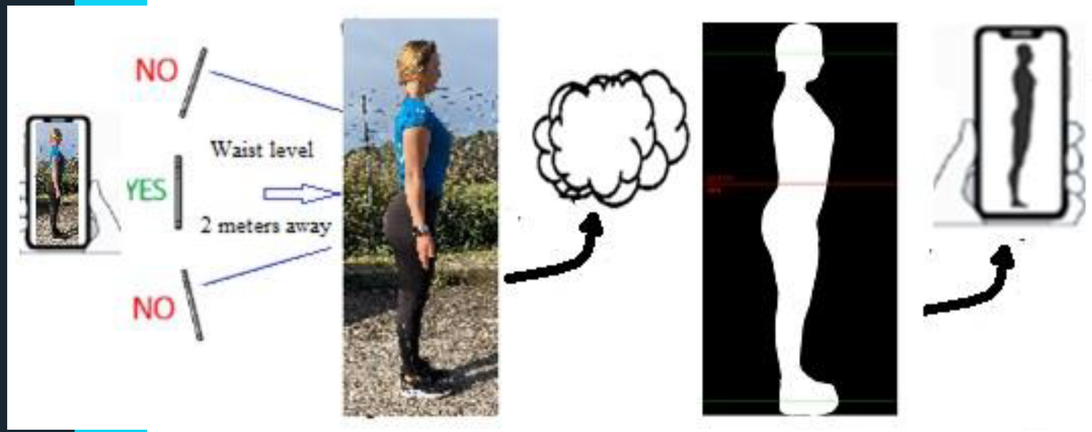
Nutritional Status Assessment

<u>Examples of precision nutrition in MCH context:</u>
Anthropometry & Body Composition

- **Smartphone image/video:**
  - **Children (<5 y):** predict height / detect stunting, using convolutional neural network-based method from depth images in India (Trivedi et al., 2021)
  - **Adults:** predict fat mass by training with single 2D standing lateral images; ML model comparable to DXA to identify obesity phenotype (no differences by gender) in USA (Farina et al., 2022)

Fig. 1. (from left to right) (a) Back video of a child. (b) Point cloud data. (c) Depth image.

Predicting height from video footage. Trivedi et al., 2021



Predicting body composition from image. Farina et al., 2022

Nutritional Status Assessment

- **Biochemical**
  - Challenges of current methods:
    - Limited range of biomarkers that reflect intake or clinical outcomes
    - Accurate reflection of nutrients under homeostatic control or affected by inflammation
    - Invasive
    - Logistics (e.g., cold chain)

Nutritional Status Assessment

- **<u>Potential use of PN in MCH contexts</u>: Biochemical**
    - **Novel biomarkers:** Specific gut microbiota abundances (aka fecal biomarkers/signatures) associated with specific foods using previous trial data and ML algorithm in US-based adults (Shinn et al. 2020)
    - **Portable devices:** Direct integration of data from e.g., portable flurometers, in the field, into ML model

Adapted from Huey et al., 2022

Nutritional Status Assessment

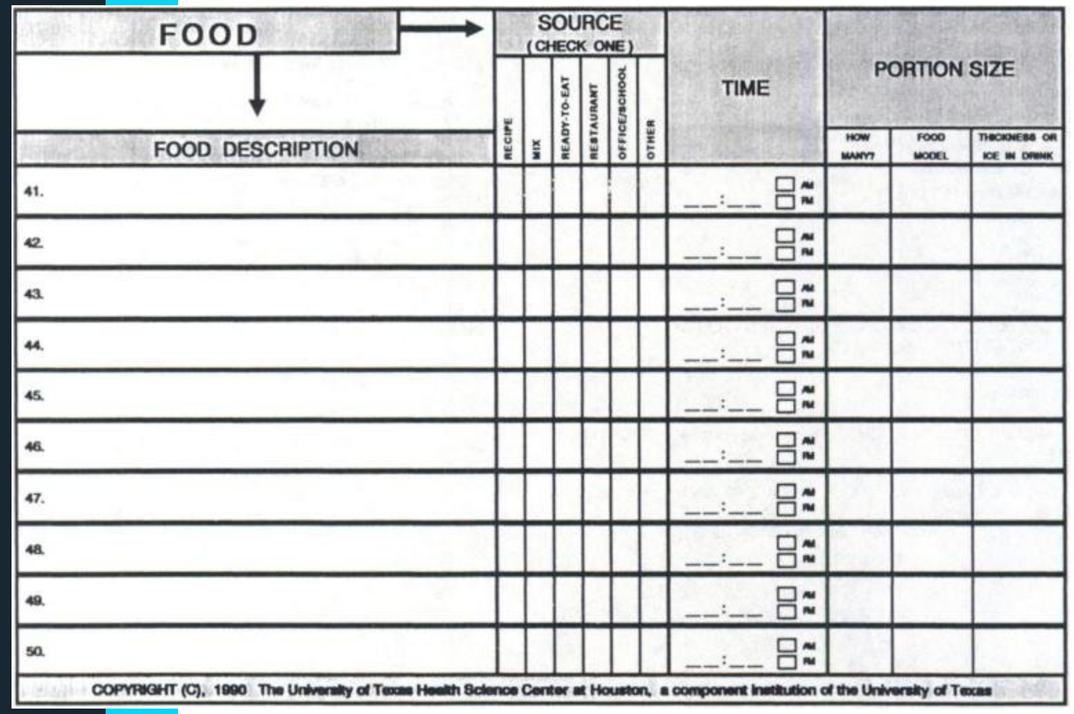
Examples of precision nutrition in MCH contexts: Clinical

- **Challenges** of some current methods
- **How ML/AI** can address these challenges

• **LDL measurement**: Friedewald equation to estimate not valid in certain clinical presentations (e.g., HIV)	• Discern novel patterns in large cohorts using ML support vector machine algorithm with greater accuracy in USA *(Tong et al., 2022)*
• **Intrauterine growth restriction (IUGR):** difficult to detect early to prevent adverse outcomes	• Random forests ML classifier determined the key predictors of IUGR in Ethiopia & India *(Bekele 2022; Deval et al. 2022)*
• **Atherosclerotic cardiovascular disease:** understanding the predictive value of multiple, interacting dietary components	• Bayesian kernel machine regression flexible ML approach incorporated nonlinear and interactive relationships to determine sex differences in dietary risk factors *(Zhao et al., 2021)*

Nutritional Status Assessment

- **Diet**
  - Challenges of current tools (FFQ, 24h recall, diaries):
    - Measurement error, day-to-day variability, resource/time/training burden for both personnel and participants
      - **FFQ:** averaging over long periods



FOOD → / FOOD DESCRIPTION ↓	SOURCE (CHECK ONE)						TIME	PORTION SIZE		
	RECIPE	MIX	READY-TO-EAT	RESTAURANT	OFFICE/SCHOOL	OTHER		HOW MANY?	FOOD MODEL	THICKNESS OR ICE IN DRINK
41.							__:__ AM PM			
42.							__:__ AM PM			
43.							__:__ AM PM			
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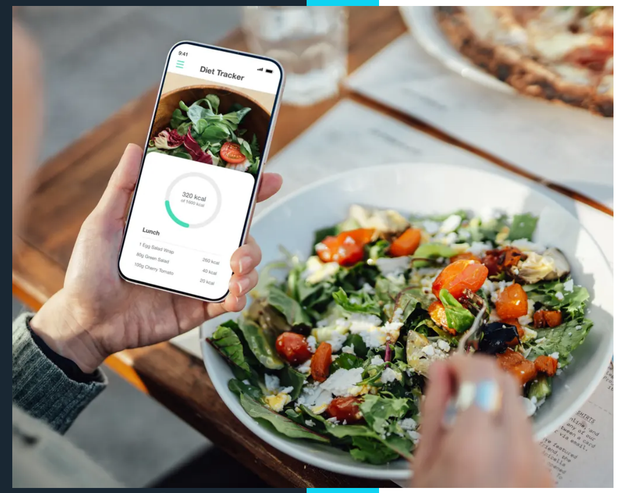
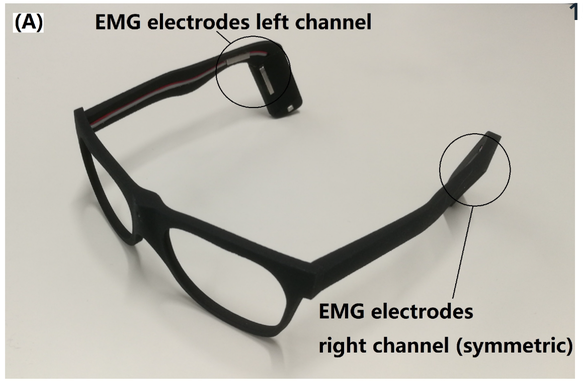
Paper-based 24h Recall Example

Nutritional Status Assessment

- **<u>Potential use of PN in MCH contexts</u>: Diet**
  - Novel methods:
    - Wearable devices
    - Image assessment
    - Novel biomarkers
  - (Require validation in MCH contexts)



Smartphone image assessment (Sempionatto et al. 2021)



Wearable sensor to detect chewing (Zhang et al. 2020)

Wearable camera (Alshurafa et al., 2021)

Real-life example of PN in MCH

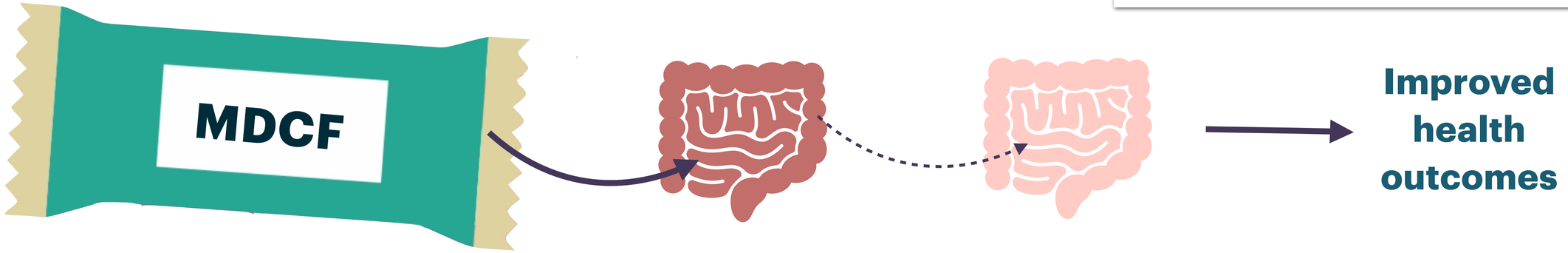
1. A ready-to-use therapeutic food (RUTF) specifically designed to target the gut microbiome in young children in Bangladesh **improved WLZ, bone growth, neurodevelopment, inflammation** in the context of moderate acute malnutrition
2. Shows importance of gut microbiome composition

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

A Microbiota-Directed Food Intervention for Undernourished Children

Robert Y. Chen, B.S., Ishita Mostafa, B.D.S., M.P.H., Matthew C. Hibberd, Ph.D., Subhasish Das, M.B., B.S., M.P.H., Mustafa Mahfuz, M.B., B.S., M.P.H., Nurun N. Naila, M.B., B.S., M.P.H., M. Munirul Islam, M.B., B.S., Ph.D., Sayeeda Huq, M.B., B.S., M.P.H., M. Ashraful Alam, M.P.H., Mahabub U. Zaman, M.P.H., Arjun S. Raman, M.D., Ph.D., Daniel Webber, M.D., Ph.D., Cyrus Zhou, B.S., Vinaik Sundaresan, B.S., Kazi Ahsan, M.B., B.S., M.P.H., Martin F. Meier, B.S., Michael J. Barratt, Ph.D., Tahmeed Ahmed, M.B., B.S., Ph.D., and Jeffrey I. Gordon, M.D.



Summary

1. Precision nutrition-based approaches hold promise for use in MCH and LMIC contexts
    1. **Benefit:** Objectivity and automation of AI/ML
    2. **Challenge:** Bigger datasets, computer science skillset
2. PN methods have examined Anthropometry and Clinical assessment in MCH
3. PN methods remain to be used for Biochemical and Diet assessment in MCH

While still in the early phase, promising data in young children show the importance of PN—specifically the **individual gut microbiome**—in **designing optimized dietary interventions** addressing both nutritional needs as well as clinical outcomes—i.e., Food is Medicine

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