Stunting, infant and child nutrition and South Asia

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http://picn.ucdavis.edu/
Outline

• Challenges to meeting nutrient needs during the first 1000 days: a long-standing dilemma
• Strategies to meet nutrient needs during the first 1000 days
• Impact of prenatal nutrition interventions
• Impact of postnatal nutrition interventions
• Conclusions
The first 1000 days: a critical window

- Age of greatest vulnerability to malnutrition and infection, leading to stunted growth and development
- Long-term physical and mental damage
Challenges to meeting nutrient needs during the first 1000 days: a long-­standing dilemma
## Nutrient Needs During Pregnancy and Lactation

(% increase over needs of non-pregnant, non-lactating women)

<table>
<thead>
<tr>
<th>Nutrient</th>
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<th>Lact</th>
</tr>
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<td>Zinc</td>
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</tr>
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</table>
Challenges to meeting nutrient needs during the period of complementary feeding (6-24 mo)

- Small amounts of food consumed
- High nutrient needs for growth and development
- Therefore, food needs to be very high in nutrient density (amount of nutrient per 100 calories)
Amount of food consumed by an American adult male (~2800 kcal)

Photos:
- [Image](http://www.driedfruitguy.com/organic/images/banana1.jpg)
- [Image](http://www.cklsinfo.com/clipart/food/meals/oatmeal.png)
- [Image](http://tn0.google.com/images?q=tbn:CBfOs4-oIhM)
- [Image](http://www.pachd.com/free-images/food/images/orange-juice-01.jpg)

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- [Image](http://tn0.google.com/images?q=tbn:F5nsAAs_IDbRkM)
- [Image](http://www.indiaplaza.com/content/giftstoindia/mcdonalds/fries.jpg)
- [Image](http://tbn3.google.com/images?q=tbn:qJVHcqVGClJB8M)

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- [Image](http://tbn3.google.com/images?q=tbn:qJVHcqVGClJB8M)
Amount of complementary food needed for a breastfed infant 6-8 months of age (~200 kcal)
Infants need a nutrient-rich diet—especially at 6-8 months of age

http://www.aliveandthrive.org/resources/technicalbriefs
Nutrient gaps in complementary food diets

• Usual “problem nutrients” are iron & zinc
• Other nutrients (e.g. Vitamin A, B vitamins) often low, depending on types of foods consumed or water/soil content
• In Guatemala, “best case scenario family food menus” for low-income households were inadequate (Vossenaar & Solomons 2012)
• Even “improved” complementary food recipes usually fall short for iron & zinc (Gibson et al. 2010)
• Difficult to construct a diet that meets nutrient needs from unfortified foods [using linear programming] (Santika et al. 2009; Vitta & Dewey 2013)
Inadequate iron & zinc even in a high quality complementary food diet [6-8 month old infants]

Percentage of recommended amount met by diet

**Five food group diet**
- 20 g Staple grain
- 15 g Legume
- 15 g Green leafy veg
- 22 g (1/2) Egg
- 20 g Fish or Chicken

<table>
<thead>
<tr>
<th></th>
<th>Bioavailable Fe</th>
<th>Bioavailable Zn</th>
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</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>37%</td>
<td>82%</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>26%</td>
<td>68%</td>
</tr>
<tr>
<td>Vietnam</td>
<td>36%</td>
<td>71%</td>
</tr>
</tbody>
</table>

Inadequate iron & zinc even in a high quality complementary food diet [9-11 month old infants]

Percentage of recommended amount met by diet

Five food group diet
- 30 g Staple grain
- 20 g Legume
- 20 g Green leafy veg
- 44 g (1) Egg
- 20 g Fish or Chicken

Bioavailable Fe
- Bangladesh: 52%
- Ethiopia: 35%
- Vietnam: 49%

Bioavailable Zn
- Bangladesh: 100%
- Ethiopia: 83%
- Vietnam: 86%

Complementary Food Diets in South Asia

Proportion of children 6-24 months-old fed a minimum adequate diet or minimum number of food groups (diet diversity)

- Afghanistan
- Bangladesh
- India
- Nepal
- Pakistan
- S. Asia

Percentage

- Minimum adequate diet
- Minimum diet diversity
Prevalence of stunting in children under five in South Asia
Heavy reliance on cereal-based diets is not ideal for infants & young children

- Low caloric density when prepared as thin porridge – too bulky for stomach size
- Cereal-based diets are low in many key nutrients
- High levels of “anti-nutrients” such as phytate, which binds iron and zinc and limits utilization of phosphorus
Until ~10,000 years ago, cereals were not commonly consumed, and dietary quality was better than in modern-day diets

<table>
<thead>
<tr>
<th></th>
<th>Pre-Agricultural Diet(^1)</th>
<th>Modern Diet in Low-Income Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Animal protein</strong></td>
<td>Very high [wild game, fish, shellfish, insects]</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Fat</strong></td>
<td>Moderate to high High in omega-3</td>
<td>Low to moderate Generally low in omega-3</td>
</tr>
<tr>
<td>Total fat</td>
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<td></td>
</tr>
<tr>
<td>Fatty acid balance</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Carbohydrate</strong></td>
<td>None to minimal Very high None (honey)</td>
<td>40-90% of energy Low Moderate to high</td>
</tr>
<tr>
<td>Cereals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetables &amp; fruits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refined sugars</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Source: Boyd Eaton & Boyd Eaton III, 2000
Widespread stunting accompanied the introduction of agriculture

- Height of prehistoric humans was similar to that of current well-nourished populations
- Height declined after introduction of agriculture (~10,000 years ago) in many prehistoric societies
- Height increased in industrialized countries during the past ~100-200 years, due to improved nutrition and less infectious disease
- Child stunting remains very common in low-income countries
What did infants eat in pre-agricultural societies?

- Breast milk + premasticated (pre-chewed) foods
- Premasticated foods probably reflected diets of adults, including high proportion of animal-source foods (35-65% of kcal)
- Thus, nutrient density of premasticated foods probably high

Estimated iron intake at 9-11 mo

Breast milk only: 2%
Breast milk + typical CFs: 34%
Breast milk + diverse diet with ASFs: 53%
Breast milk + pre-agricultural diet: 98%

100% RNI

http://www.aliveandthrive.org/resources/technicalbriefs
Estimated zinc intake at 9-11 mo

- Breast milk only: 17%
- Breast milk + typical CFs: 46%
- Breast milk + diverse diet with ASFs: 93%
- Breast milk + pre-agricultural diet: 167%

http://www.aliveandthrive.org/resources/technicalbriefs
Estimated nutrient density of pre-agricultural diet exceeds target nutrient density for complementary foods, 9-11 mo

Strategies for meeting nutrient needs during the first 1000 days
Options for meeting nutrient needs of pregnant & lactating women

• Dietary diversification and selection of nutrient-rich foods
  – May still be difficult to meet iron needs in pregnancy
  – Access & cost are often barriers

• Fortification/biofortification of staple foods (some nutrients)

• Multiple micronutrient supplements
  – Some evidence for improved pregnancy outcomes

• Fortified foods or supplements with both micro- and macronutrients
  – Can provide essential fatty acids & high quality protein, in addition to micronutrients
Options for meeting nutrient needs of breastfed infants & children, 6-24 mo

- Dietary diversification and selection of nutrient-rich complementary foods
  - Challenging to meet iron needs
  - Access & cost are often barriers
- Fortified products
  - Fortified blended foods
  - Home fortification
    - Micronutrient powders
    - Complementary food supplements, e.g. small-quantity lipid-based nutrient supplements (SQ-LNS, ≤ 20 g/d)

What are lipid-based nutrient supplements (LNS)?

• A family of products that deliver vitamins and minerals, essential fatty acids, protein and energy in a lipid matrix. Low moisture content ensures resistance to spoilage.

• Different products have been developed for different uses
  - Plumpy’nut was the first lipid-based product, used for treating severely malnourished children (~1000 kcal/d)
  - Small-quantity LNS (4 teaspoons or ~110 kcal/d) are designed for prevention of malnutrition

• Most formulations have included:
  - Soy or canola oil, peanut paste, milk powder, sugar, vitamins and minerals
Small-quantity LNS compared to energy needs from complementary foods (breastfed) or total energy needs (non-breastfed)

*(Assumes “average” breast milk intake)*
Breast milk intake at 9-10 months

Non inferiority analysis (set at 85 g/d) showed that none of the LNS groups were inferior in breast milk intake.

Kumwenda C, Dewey KG, Hemsworth J, Ashorn P, Maleta K, Haskell MJ. 
Am J Clin Nutr 2014;99:617-23
Impact of prenatal nutrition interventions
How much of childhood stunting is attributable to malnutrition in utero?

In low- and middle-income countries, 20% of stunting in children under five is attributable to small size at birth (SGA)

Prenatal nutrition interventions

A. Multiple micronutrient supplements

*Meta-analysis in 2009 (Fall et al.):*

- Small but significant increase in birth weight (+22 g) but not birth length (+0.06 cm)
- 11-17% reduction in low birth weight
- Impact only evident in mothers with *higher* BMI

*Meta-analysis in 2012 (Ramakrishnan et al.):*

- Increase in mean birth weight (+53 g); data on birth length not presented
- 14% reduction in low birth weight
Prenatal nutrition interventions

B. Balanced protein-energy supplementation

*Meta-analysis in 2003 (Kramer & Kakuma):*
- Increase in mean birth weight (+38 g) but not birth length (+0.1 cm)
- 32% reduction in small-for-gestational-age births
- Larger effect on birth weight in hungry season and in undernourished women

*Meta-analysis in 2012 (Imdad & Bhutta):*
- Increase in mean birth weight (+73 g); did not report birth length
- 32% reduction in LBW and 34% reduction in SGA births
- Larger effect on birth weight in undernourished women
Prenatal nutrition interventions

C. Fortified foods for pregnant women

Lipid-based nutrient supplement (LNS) in Burkina Faso  [Huybregts et al. Am J Clin Nutr 2009]

- LNS: 373 kcal/d & similar micronutrients as MMN tablets
- LNS group (compared to MMN):
  - Birth weight +31 g (p=0.2)
  - Birth length +0.46 cm (p=0.001)
    - effect greater in thin mothers (BMI < 18.5): +1.2 cm
Early findings from randomized trials of home fortification with small-quantity LNS in Africa and South Asia

• Effects of prenatal LNS supplementation on birth outcomes
  • iLiNS*-DYAD trials in Ghana and Malawi
  • Rang-Din Nutrition Study in Bangladesh

Rationale for iLiNS-DYAD and RDNS trials

• Little evidence on impact of *combined* pre- and postnatal nutrition interventions

• Key trials conducted in 1970’s
  – e.g. INCAP trial in Guatemala using a fortified milk-based food (atole)

• Intervention trial with fortified food supplements provided both pre- and postnatally not attempted since

• Approach used in iLiNS-DYAD trials:
  – Combined pre- and postnatal home fortification with small-quantity LNS (LNS-PLW and LNS-Child)
  – Accompanied by messages to reinforce best practices for prenatal care/nutrition and infant & young child feeding
iLiNS-DYAD trial settings
iLiNS-DYAD study design

• Partially double-blind, randomized controlled trial
• Pregnant women <20 wk gestation randomized to receive one of three supplements daily:

<table>
<thead>
<tr>
<th>Group</th>
<th>Pregnancy</th>
<th>Lactation</th>
<th>6-18 mo</th>
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<tr>
<td>IFA</td>
<td>Fe/folic acid</td>
<td>Placebo (Ca)</td>
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<td>MMN</td>
<td>MMN</td>
<td>MMN</td>
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<tr>
<td>LNS</td>
<td>LNS-P&amp;L</td>
<td>LNS-P&amp;L</td>
<td>LNS-20gM to the child</td>
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</tbody>
</table>

- Anthropometry, lab and food frequency data at baseline & 36 wk gestation
- Supplement intake and morbidity data biweekly
<table>
<thead>
<tr>
<th>Nutrient / intervention</th>
<th>IFA-tablet</th>
<th>MMN tablet</th>
<th>LNS P&amp;L</th>
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<tr>
<td><strong>Recipient</strong></td>
<td>Mothers, pregnancy only</td>
<td>Mothers, pregnancy + lactation</td>
<td>Mothers pregnancy + lactation</td>
<td>Infants from 6 to 18 months of age</td>
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<td><strong>Ration / day</strong></td>
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<td><strong>Cu (mg)</strong></td>
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iLiNS-DYAD trials: Effect on birth weight

Unpublished data
iLiNS-DYAD trial in Ghana: Effect on low birth weight

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<thead>
<tr>
<th></th>
<th>Primiparous</th>
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<tr>
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<tr>
<td>MMN</td>
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</tr>
<tr>
<td>IFA</td>
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<td>7.8</td>
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</table>

Unpublished data
iLiNS-DYAD trial in Ghana: Effect on birth length

Unpublished data
iLiNS-DYAD trial in Ghana: Effect on head circumference

Unpublished data
In iLiNS-DYAD Ghana, primiparous women differed from multiparous women at baseline

Primiparous women were:

• Younger
• Had lower BMI & arm circumference
• More likely to be anemic
• More likely to test positive for malaria
Heterogeneity in response to prenatal LNS - Malawi


- Interventions (LNS or MMN) more likely to have positive effect in vulnerable women:
  - Maternal malaria at baseline (23% of sample)
  - Maternal HIV+ (14% of sample)
  - Low maternal education (50% of sample)
The Rang-Din Nutrition Study

Effectiveness of home-fortification approaches in the first 1000 days for preventing maternal and child undernutrition:
A cluster-randomized controlled trial
Cluster-randomized effectiveness trial within a community-based program

- LAMB Community Health and Development Program
  - Prenatal, delivery, postpartum, and child health services
  - Staffed by community health workers, community midwives, and village health volunteers
  - Safe delivery unit in each union
- “Cluster” for RDNS trial = supervision area of a community-health worker
- All newly pregnant women identified during the intervention period received the supplement corresponding to their cluster, regardless of their decision to participate in the evaluation
- Evaluation team separate from LAMB program staff
Research setting: Location

• LAMB is located in the Parbatipur sub-district of Dinajpur

• Research taking place in 11 unions in 2 subdistricts (Chirirbandar and Badarganj) of Rangpur and Dinajpur
Cluster selection from 11 unions

Random assignment to study arms

- X 16 Comprehensive LNS
- X 16 Child LNS
- X 16 Child MNP
- X 16 Control

Intervention period

- LNS-PLW
- LNS-child
- Iron/Folic acid
- MNP-child

Timeline of assessments

- ≤20 wk
- 36 wk
- Birth
- 6 wk
- 6 mo
- 12 mo
- 18 mo
- 24 mo
Recruitment of participants

• Eligibility criteria for the evaluation
  – ≤ 20 weeks gestation
  – Not planning to leave the study area in the next ~3 years

• Village health volunteers and community health workers identified new pregnancies

• Recruitment planned over a 12 month period (Oct 2011 – Sep 2012); ended in Aug 2012 because number greatly exceeded target
Supplements

- LNS for pregnant and lactating women (LNS-PLW): Jononi
- LNS for children (LNS-child): Sonamoni
- Micronutrient powder (MNP) for children only: Pushtikona
Educational messages:
1. Labels on containers for sachets

© Zigzag Agency, Nutriset
Educational messages:
2. Messages on supplement distribution cards
Birth outcome results from RDNS trial in Bangladesh
Participation flow chart

Assessed for eligibility (n=4410)
- Gest age > 140 d 366
- Will move within 3 y 22
- Woman refused 8
- Husband refused 3

Consented, enrolled and interviewed at baseline (n=4011)

IFA (n=2964)
- Loss of pregnancy 8.3%
- Maternal death n=1
- Lost to follow-up 2.5%

LNS-PLW (n=1047)
- Loss of pregnancy 8.3%
- Lost to follow-up 2.1%

Live births (n=2644)
- Infant death 1.8%
- Late measurement 1.6%
- Other 0.5%

Live births (n=938)
- Infant death 1.7%
- Late measurement 2.1%
- Other 0.5%

Anthropometric data (n=2537)

Anthropometric data (n=897)
# Baseline characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>IFA (n=2764)</th>
<th>LNS (n=983)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal age (y)</td>
<td>22.0 ± 5.0</td>
<td>21.8 ± 4.9</td>
</tr>
<tr>
<td>Education (y)</td>
<td>6.7 ± 2.8</td>
<td>6.9 ± 2.8</td>
</tr>
<tr>
<td>Maternal height (cm)</td>
<td>151 ± 5</td>
<td>151 ± 5</td>
</tr>
<tr>
<td>BMI &lt; 18.5 kg/m²</td>
<td>30.0%</td>
<td>31.5%</td>
</tr>
<tr>
<td>Gestational age at enrollment (wk)</td>
<td>13.1 ± 3.4</td>
<td>13.0 ± 3.8</td>
</tr>
<tr>
<td>Nulliparous (%)</td>
<td>39.4%</td>
<td>41.9%</td>
</tr>
</tbody>
</table>
## Birth outcomes - continuous variables

<table>
<thead>
<tr>
<th>Outcome</th>
<th>IFA (n=2537)</th>
<th>LNS (n=897)</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (g)</td>
<td>2589 ± 409</td>
<td>2629 ± 406</td>
<td>0.006</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>47.4 ± 2.1</td>
<td>47.6 ± 2.1</td>
<td>0.064</td>
</tr>
<tr>
<td>Head circumf. (cm)</td>
<td>32.7 ± 1.4</td>
<td>32.8 ± 1.3</td>
<td>0.049</td>
</tr>
<tr>
<td>Weight-for-age Z</td>
<td>-1.57 ± 1.01</td>
<td>-1.47 ± 1.00</td>
<td>0.009</td>
</tr>
<tr>
<td>Length-for-age Z</td>
<td>-1.24 ± 1.13</td>
<td>-1.15 ± 1.09</td>
<td>0.054</td>
</tr>
<tr>
<td>Head circumf. Z</td>
<td>-1.33 ± 1.11</td>
<td>-1.25 ± 1.07</td>
<td>0.039</td>
</tr>
<tr>
<td>BMI Z-score</td>
<td>-1.65 ± 1.02</td>
<td>-1.56 ± 1.04</td>
<td>0.006</td>
</tr>
</tbody>
</table>

* Adjusted for covariates related to the outcome
<table>
<thead>
<tr>
<th>Outcome</th>
<th>IFA (n=2537)</th>
<th>LNS (n=897)</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low birth weight (&lt;2500 g) (%)</td>
<td>39.1</td>
<td>36.8</td>
<td>0.087</td>
</tr>
<tr>
<td>Stunted (LAZ &lt; -2) (%)</td>
<td>22.5</td>
<td>18.6</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ARR 0.82]</td>
<td></td>
</tr>
<tr>
<td>Stunted (LAZ &lt; -2) (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small head circumference (HCZ &lt; -2) (%)</td>
<td>24.7</td>
<td>20.8</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ARR 0.83]</td>
<td></td>
</tr>
<tr>
<td>Small head circumference (HCZ &lt; -2) (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low weight-for-length (BMI&lt; &lt;2) (%)</td>
<td>33.8</td>
<td>30.6</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ARR 0.87]</td>
<td></td>
</tr>
<tr>
<td>Low weight-for-length (BMI&lt; &lt;2) (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small-for-gestational age (% &lt; 10th percentile)</td>
<td>66.7</td>
<td>63.7</td>
<td>0.059</td>
</tr>
</tbody>
</table>

* Adjusted for covariates related to the outcome
Stunting at birth by intervention group, by period of enrollment

Period 1 (n=1186)
- 30% reduction, p=0.0025

Period 2 (n=769)
- NS

Period 3 (n=1476)
- NS

Period 1: Baby born before LNS recall
Period 2: LNS recall in late pregnancy
Period 3: LNS recall in early-mid pregnancy
Stunting at birth by intervention group, by household food security (all periods)

<table>
<thead>
<tr>
<th>Household Food Security</th>
<th>% Stunted</th>
<th>IFA Reduction</th>
<th>LNS Reduction</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very insecure (n=309)</td>
<td>31.5</td>
<td>41%</td>
<td>18.9</td>
<td>0.024</td>
</tr>
<tr>
<td>Mod insecure (n=986)</td>
<td>24.3</td>
<td>28%</td>
<td>17.2</td>
<td>0.03</td>
</tr>
<tr>
<td>Mildly insecure (n=496)</td>
<td>20.6</td>
<td>NS</td>
<td>15.5</td>
<td>NS</td>
</tr>
<tr>
<td>Not insecure (n=1640)</td>
<td>20.2</td>
<td>NS</td>
<td>20.3</td>
<td>NS</td>
</tr>
</tbody>
</table>
Stunting at birth by intervention group, by maternal age (all periods)

<table>
<thead>
<tr>
<th>Age Group</th>
<th>IFA % Stunted</th>
<th>LNS % Stunted</th>
<th>Reduction</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-19</td>
<td>26.6</td>
<td>20</td>
<td>23%</td>
<td>0.02</td>
</tr>
<tr>
<td>20-24</td>
<td>21</td>
<td>17.5</td>
<td>23%</td>
<td>0.06</td>
</tr>
<tr>
<td>25-29</td>
<td>16.8</td>
<td>16.8</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>30+</td>
<td>22.3</td>
<td>20.8</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>
## Birth outcomes - per protocol
(excluding women who reported consumption < 4 days/wk)

<table>
<thead>
<tr>
<th>Outcome</th>
<th>IFA (n=2316)</th>
<th>LNS (n=576)</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low birth weight (&lt;2500 g) (%)</td>
<td>39.0</td>
<td>34.9</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ARR 0.88]</td>
<td></td>
</tr>
<tr>
<td>Stunted (LAZ &lt; -2) (%)</td>
<td>22.6</td>
<td>17.2</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ARR 0.76]</td>
<td></td>
</tr>
<tr>
<td>Small head circumference (HCZ &lt; -2) (%)</td>
<td>24.6</td>
<td>19.9</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ARR 0.80]</td>
<td></td>
</tr>
<tr>
<td>Low weight-for-length (BMIZ &lt; -2) (%)</td>
<td>33.6</td>
<td>28.7</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ARR 0.87]</td>
<td></td>
</tr>
<tr>
<td>Small-for-gestational age (% &lt; 10th percentile)</td>
<td>67.5</td>
<td>62.3</td>
<td>0.055</td>
</tr>
</tbody>
</table>

* Adjusted for covariates related to the outcome
Impact of starting nutrition intervention pre-conception?

Mumbai Maternal Nutrition Project
(Potdar et al., Amer J Clin Nutr 2014)

Daily snack from ≥ 90 d pre-pregnancy until delivery:
• Intervention group: green leafy vegetables, fruit, milk (165 kcal/d; 10-23% of RNI for 6 micronutrients)
• Control group: potato + onion (88 kcal/d)

6513 women randomized
2291 became pregnant
1360 newborns measured
Impact of starting nutrition intervention pre-conception?

Mumbai Maternal Nutrition Project
(Potdar et al., Amer J Clin Nutr 2014)

Results:

- No overall effect on birth weight (+26 g; p=0.22)
- Birth weight increased among infants of women with BMI > 21.8 (+96 g), but not among those with lower BMI
- In those who actually started supplementation ≥ 90 d pre-pregnancy, birth weight was increased by +48 g (p=0.046); effect evident only in those with BMI > 18.6.
- Effects on birth length and head circumference not significant
Impact of postnatal nutrition interventions
Exclusive breastfeeding 0-6 mo

- Large impact on infant survival
- Little evidence of impact on stunting
  - Effect may be more likely in populations with high rates of infection during the first 6 mo postpartum, where promotion of exclusive breastfeeding may reduce infection and thus be more likely to promote linear growth than in populations where such infections are less common
  
- Insufficient evidence to evaluate this question at present
Complementary feeding 6-24 mo

Potential for major impact on stunting but evidence is mixed

Several strategies:

- Educational approaches
- Increasing energy density of complementary foods
- Fortification
- Provision of complementary food
Complementary Feeding - 1

• Educational approaches: mixed results - some studies show substantial potential to reduce stunting

CF Intervention in Peru:

Emphasized 3 key messages, including consumption of nutrient-rich animal-source foods

Conducted in a population where animal-source foods were available & affordable

Figure 4: Cumulative rate of stunting from 0 to 18 months

Penny et al., Lancet 2005;365:1863-72
Cluster-randomized trial on complementary and responsive feeding education to caregivers of rural Indian toddlers


- 60 villages in Andhra Pradesh randomized to:
  - Control: routine ICDS
  - CF group: ICDS + BF/CF education (11 messages)
  - Responsive CF & play group (RCF&PG): ICDS + BF/CF education + skills for responsive feeding & psychosocial stimulation (27 messages)

- N=200 mother-infant dyads per group

- Both intervention groups received bi-weekly visits by trained village women for 12 months (from 3 to 15 months of age)
Cluster-randomized trial on complementary and responsive feeding education to caregivers of rural Indian toddlers


Results:

• Non-significant difference in stunting at 15 mo (37% vs. 28% vs. 36%)

• CF group (but not RCF&PG) had greater length gain than Control group (+0.19 z-score)

• Mental development score higher in RCF&PG children than in Control children (+3.1 points)

• Micronutrient intakes low despite increases in energy & protein from complementary foods
Complementary Feeding - 2

• Interventions to increase energy density – mixed results
  – May be effective when traditional complementary food has low energy density & infant unable to compensate by increasing volume of food consumed or feeding frequency
Complementary Feeding - 3

• Fortification (or improved bioavailability) *alone* generally has little effect on linear growth

• Exception: fortified vs. unfortified milk powder in India (Dhingra et al. 2004)
  – Milk powder provided for 1 year
  – Average age was 23 months at enrollment
  – Children given fortified milk (*n* = 233) had significantly less morbidity and greater weight and height gain than children given unfortified milk (*n* = 232)
    • Children in this trial were more stunted at baseline than children in most other studies.
    • Milk powder does not contain ‘anti-nutrients’ like phytic acid (common in grains and legumes) that can interfere with absorption of critical nutrients.
    • These differences may have increased the likelihood of a positive growth response to a fortified product.
Complementary Feeding - 4

• Provision of complementary food – mixed results
  – May depend on food security of target population
  – May depend on nutrient quality of food provided
  – Two studies directly compared food + education vs. education only (both in S Asia): somewhat greater impact when food included
Complementary Feeding - 5

• Combination of macro- and micro-nutrients may have a larger impact
• Nutrient quality of fortified products is likely to be important
  – Amount and bioavailability of nutrients needed for growth ("type II" nutrients)
  – Inclusion of milk
  – Essential fatty acids
Combined interventions more effective?

- Clinical and subclinical infections and inflammation reduce appetite, impair nutrient absorption, and divert nutrients away from linear growth
- Providing nutrients without addressing these physiological constraints may not be effective
- Adequate nutrition is *necessary* but may not be sufficient
How nutrition may reduce the negative impact of infections on child growth

• Strengthening the immune system
  – May reduce the severity and duration of infections

• Providing extra amounts of nutrients
  – May compensate for poor absorption during infection, losses during diarrhea, reallocation due to immune system activation or reduced appetite during infection
  – Allows for catch-up growth following infection

• Preventing poor appetite caused by micronutrient deficiencies

• Favoring the growth of beneficial bacteria in the gut that enhance gut function and immune defenses
iLiNS-ZINC trial: LNS + morbidity surveillance and treatment reduced stunting in Burkina Faso

Growth:
Stunting prevalence at 18 mo reduced by 25%
[endline prevalence 29% in intervention groups combined vs. 39% in DI group]

Development:
Moderate-to-severe developmental delay reduced at 18 mo:
- 42% reduction in motor delay
- 37% reduction in language delay
- 28% reduction in personal-social delay

Conclusion:
Small quantity LNS along with selected child health services (brief feeding advice, diarrhea and malaria treatment) significantly improved growth and development in young Burkinabe children

[Hess SY; Abbeddou S; Yakes E; Some JW; Prado E; Ouedraogo ZP; Guissou R; Vosti SA; Ouedraogo JB; Brown KH]
Conclusions
Meeting nutrient needs during the first 1000 days is a global challenge

• Pregnant and lactating women and their young children need diets with high micronutrient density.

• In low-income populations, intakes are well below recommended amounts for several key nutrients because diets are dominated by staple foods with low nutrient density and poor mineral bioavailability.

• Gaps in nutritional adequacy in such populations probably date back to Agricultural Revolution ~10,000 years ago. Estimates of nutrient intakes before then suggest much higher intakes of key nutrients than observed today.

• For modern cereal-based diets, it is difficult to meet certain nutrient needs in first 1000 days without fortified products due to high cost of nutrient-rich foods.
...but the challenge can be met

- Several options for improving diets of pregnant & lactating women and their infants
  - Dietary diversification, including increased intake of nutrient-rich indigenous foods
  - Improved complementary feeding practices
  - Micronutrient supplements
  - Fortified foods designed for these target groups
    - Commercially processed fortified foods
    - Home fortification
We need to better understand mechanisms regarding pre- and post-natal stunting

- Consequences of:
  - Clinical and subclinical infection and inflammation, e.g. environmental enteropathy, impaired appetite
  - The microbiome
  - Environmental contaminants, e.g. aflatoxin, household air pollution

- The importance of “Type II” nutrients (required for growth) and other food constituents
- The influence of maternal mental health & caregiver behaviors
- Long-term effects of prenatal nutrition & epigenetic influences
Policy & programmatic implications

• Because a considerable proportion of stunting occurs before birth, nutrition interventions should cover both pregnancy and the postnatal period.

• Nutrition interventions are likely to have a greater impact in reducing stunting if they are delivered as part of a package of interventions that address the multiple causes of stunting.
  – Prevention & control of pre- and postnatal infection and subclinical conditions
  – Care for women & children; stimulation of early child development
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  – Mary Arimond, Project Manager
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• University of Ghana team
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• University of Malawi team
• University of Tampere, Finland team
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