Establishing desirable micronutrient fortificants for complementary foods for infants and young children: examples from three Asian countries

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Outline

- Selection of the desirable fortificant levels
  1. Measuring food intakes
  2. Calculating nutrient intakes
  3. Adjusting distribution of observed intakes to usual intakes
  4. Assessing prevalence of inadequate & potentially excessive nutrient intakes
  5. Estimating fortificant levels
- Selection of the food vehicle & fortificants
- Enabling strategies to overcome constraints
- Conclusions
Rationale

- Traditional foods for young children are often thin cereal or legume-based porridges (6-10% DM) with a low energy & nutrient density

- These porridges fail to meet requirements for iron, zinc, & calcium designated as “problem” micronutrients by WHO

- Fortification programs at the national level are not designed to meet the high nutrient needs of young children with a low gastric capacity

- However, these micronutrient deficits could be overcome by fortifying foods for young child feeding, provided the level & form of fortificants are appropriate
What is the adequacy of Fe, Zn and Ca intakes from complementary foods as % of WHO estimated needs

Intakes based on unfortified CFs

<table>
<thead>
<tr>
<th>Country</th>
<th>Fe (%)</th>
<th>Zn (%)</th>
<th>Ca (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NZ*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indonesia*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philippines*</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mongolia*</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Cambodia**</td>
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</tr>
</tbody>
</table>

Intakes with 40 g of fortified CFs

<table>
<thead>
<tr>
<th>Food</th>
<th>Fe (%)</th>
<th>Zn (%)</th>
<th>Ca (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereal &amp; legumes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Infants 9-11 mos
**Young children 12-23 mos
Study Objectives

• To determine the prevalence of inadequate and potentially excessive intakes of Fe, Zn, and Ca in diets of children aged 6 – 36 months from three Asian countries

• To apply the WHO guidelines* to set appropriate country-specific fortification levels for Fe, Zn, and Ca in cereal-based foods for infant and young child feeding in three Asian countries

* Guidelines on Food Fortification with Micronutrients. WHO/FAO, 2006
Methods

1. Measure intakes of foods & nutrients via 1-day record or recall
   - ensure at least some repeats (30-40 per age stratum)

2. Adjust distribution of observed intakes to *usual* nutrient intakes by using IMAPP

3. Assess prevalence of inadequate & excessive intakes of Fe, Zn, & Ca in diets

4. Use WHO recommended guidelines* to establish desirable levels of fortification for Fe, Zn & Ca in cereal-based foods for infants & young children

5. Guidelines for selection of the food vehicle & fortificants

* Guidelines on Food Fortification with Micronutrients. WHO/FAO, 2006
1. Dietary datasets used

- **The Philippines: national survey**
  - 2 days: 1 x 24 hour recall plus in-home 1 day diet record
  - Fe & Ca intakes

- **Mongolia: 5 capital towns**
  - 1x 24 hour recall
  - Fe, Zn, Ca intakes

- **Cambodia: 1 district**
  - 1x 24 hour recall
  - Fe, Zn, Ca intakes

- Philippines: n=1333
  - 6-36 mo

- Mongolia: n=179
  - 12-36 mo

- Cambodia: n=177
  - 12-36 mo
2. Adjusting distribution of observed intakes to usual intakes using IMAPP

- Apply *internal* estimates of within-person variance provided $\geq 2$ days of nutrient intake data on at least a sub-sample for each age group are available
  - performed for Fe & Ca intakes from Filipino dataset of non-breastfed children
- Apply *external* estimates of within-person variance when only 1-day of intake data available
  - performed for Fe, Zn, & Ca intakes from Cambodian & Mongolian datasets

- Use IMAPP to remove within-person day-to-day variation from daily intakes. IMAPP can also remove effects of day of the week, season, & other factors
Adjusting distribution of observed daily intakes to usual intakes by removing within-person variance via IMAPP
Median *usual* intakes of Fe, Zn, & Ca (mg/d) for children in three countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Age (6 - 12 mos)</th>
<th>Iron</th>
<th>Zinc</th>
<th>Calcium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philippines**</td>
<td>6 - 12 mos</td>
<td>2.9 ± 0.22</td>
<td>ND</td>
<td>325 ± 28.2</td>
</tr>
<tr>
<td>Philippines**</td>
<td>12 - 36 mos</td>
<td>2.4 ± 0.06</td>
<td>ND</td>
<td>161 ± 4.5</td>
</tr>
<tr>
<td>Mongolia</td>
<td>12 - 36 mos</td>
<td>4.0 ± 0.14</td>
<td>4.9 ± 0.19</td>
<td>214 ± 11.4</td>
</tr>
<tr>
<td>Cambodia**</td>
<td>12 - 36 mos</td>
<td>6.1 ± 0.25</td>
<td>6.0 ± 0.2</td>
<td>201 ± 11.4</td>
</tr>
</tbody>
</table>

*Values expressed as median ± standard error after adjustment to “usual” intake; ND: Not determined; ** not breast fed*
3. Determination of prevalence of inadequate & potentially excessive intakes using IMAPP

- **Cut-point method used for Zn & Ca**
  - used for nutrients with a symmetrical requirement distribution
  - prevalence based on number of persons in the group (as %) with USUAL intakes \(<\) EAR for inadequate or \(>\) UL for excess

- **Full probability approach used for Fe**
  - applied to Fe as the requirement distribution is skewed
  - used to determine the prevalence based on number of persons in the group (as %) with USUAL intakes \(<\) EAR or \(>\) UL

- **Neither method identifies which individuals have intakes below their own requirement**
Determining prevalence of inadequate & excessive intakes by cutpoint method

Frequency

Usual intake (mg/d)

Area estimates prevalence of inadequate intakes

Area estimates prevalence of excessive intakes

EAR

UL
Impact of adjusting distribution of observed intakes to usual intakes on prevalence of inadequate intakes via EAR cut-point method
Selecting EARs & ULs

• EARs from WHO/FAO (2004) were used for Fe and Ca

• EAR from IZiNCG (2004) used for Zn
  – EAR for Zn given for two diet types:
    » mixed/refined vegetarian diets with phytate-to-zinc molar ratios of < 18: used for this study
    » unrefined cereal-based diets with phytate-to-zinc molar ratios of ≥ 18

• ULs for Ca & Fe from WHO/FAO (2006)

• UL for Zn adopted by IZiNCG from Institute of Medicine (2001)
<table>
<thead>
<tr>
<th>Country</th>
<th>Age Group</th>
<th>Iron*</th>
<th>Zinc*</th>
<th>Calcium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philippines</td>
<td>6 - 12 mo</td>
<td>80%</td>
<td>ND</td>
<td>30%</td>
</tr>
<tr>
<td>Philippines</td>
<td>12 - 36 mo</td>
<td>83%</td>
<td>ND</td>
<td>89%</td>
</tr>
<tr>
<td>Mongolia</td>
<td>12-36 mo</td>
<td>70%</td>
<td>&lt;1%</td>
<td>98%</td>
</tr>
<tr>
<td>Cambodia</td>
<td>12 - 36 mo</td>
<td>41%</td>
<td>20%</td>
<td>95%</td>
</tr>
</tbody>
</table>

Probability approach for Fe; EAR cut-point method for Zn & Ca; *Moderate bioavailability & IZiNCG EAR; ND: Not determined
Prevalence of excessive intakes

<table>
<thead>
<tr>
<th>Country</th>
<th>Iron*</th>
<th>Zinc*</th>
<th>Calcium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philippines</td>
<td>&lt; 1%</td>
<td>ND</td>
<td>No UL</td>
</tr>
<tr>
<td>6 - 12 mo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philippines</td>
<td>&lt; 1%</td>
<td>ND</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>12 - 36 mo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mongolia</td>
<td>&lt; 1%</td>
<td>11%</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>12-36 mo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cambodia</td>
<td>&lt; 1%</td>
<td>1%</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>12 - 36 mo</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

UL for Fe is 40 mg; UL for Zn is only 7 mg; UL for Ca 12-36 mo is 2500 mg
4. Establishing fortificant levels via IMAPP

- **Zinc & calcium**
  - Usual intake distributions were repositioned so 2.5\(^{th}\) percentile for each usual intake distribution equaled EAR. With this target, only 2.5\% of target population had intakes < EAR

- **Iron**
  - Iterative process
  - Incremental amount of Fe added to usual intake distribution until only 2-3\% of the population had inadequate intakes (i.e. target prevalence of inadequacy)

- **Check prevalence of excessive intakes post-fortification**
  - Simulate effect of consumption of fortificant level on distribution of usual intakes to avoid high proportion above UL (not more than 1\%)
Figure 2. Repositioning the median of the distribution of usual intakes at baseline so that the 2.5th percentile for the distribution of usual intakes post-fortification equals the Estimated Average Requirement (EAR). The difference between the median intake post-fortification and the baseline median intake is termed the 'nutrient gap' and represents the amount of fortificant needed.
Level of fortification (per daily ration) for a low prevalence of inadequate intakes (2-3%)

<table>
<thead>
<tr>
<th>Country</th>
<th>Age Group</th>
<th>Iron* (mg/day)</th>
<th>Zinc* (mg/day)</th>
<th>Calcium (mg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philippines</td>
<td>6 - 12 mo</td>
<td>9.1</td>
<td>ND</td>
<td>313</td>
</tr>
<tr>
<td>Philippines</td>
<td>12 - 36 mo</td>
<td>9.8</td>
<td>ND</td>
<td>389</td>
</tr>
<tr>
<td>Mongolia</td>
<td>12-36 mo</td>
<td>8.0</td>
<td>0</td>
<td>323</td>
</tr>
<tr>
<td>Cambodia</td>
<td>12 - 36 mo</td>
<td>6.5</td>
<td>0.6</td>
<td>318</td>
</tr>
</tbody>
</table>

ND: No data on Zn intakes; *Assuming moderate bioavailability for Fe & Zn
## Fortification levels per 100 g dry weight of cereal-based food vs. corn-soy blend

<table>
<thead>
<tr>
<th>Country</th>
<th>Age (6–12 mo)</th>
<th>Fe (mg)</th>
<th>Zn (mg)</th>
<th>Ca (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philippines</td>
<td></td>
<td>22.8</td>
<td>ND</td>
<td>783</td>
</tr>
<tr>
<td>Mongolia</td>
<td>12–36 mo</td>
<td>13.3</td>
<td>0</td>
<td>538</td>
</tr>
<tr>
<td>Cambodia</td>
<td>12–36 mo</td>
<td>10.8</td>
<td>1</td>
<td>530</td>
</tr>
<tr>
<td>Fortified corn-soy blend</td>
<td>12–36 mo</td>
<td>17.1</td>
<td>15.4</td>
<td>734</td>
</tr>
</tbody>
</table>
5. Selecting the food vehicle and fortificants

Candidate food vehicle depends on:

whether the potential food vehicle is consumed by most of the children or by those in greatest need

centrally processed

Effective fortificants must be:

Readily absorbed
Resistant to dietary inhibitors
Safe- listed in Codex
Acceptable
Stable

No adverse effects on:

- sensory properties of the food vehicle;
- absorption of other micronutrients
Limitations of three country study

- Data from Cambodia & Mongolia were not based on a nationally representative sample
- Contribution of micronutrients from breast milk for the Mongolian toddlers was not taken into account (but low)
- EAR cut-point method is less reliable when the prevalence of inadequate intakes approaches 0 or 100%
- Approach is reliant on EARs which are not well defined for infants and young children
Enabling strategies to overcome possible constraints to fortification of CFs

- Use public education & social mobilization to create consumer demand
- Select appropriate and bioavailable fortificants
- Monitor effectiveness of fortified complementary foods
- Obtain support from international partners in designing standards and laws for fortification of CFs
- Create public-private partnerships where appropriate
- Establish adequate regulatory monitoring by governments to ensure quality assurance at level of production & point of purchase
- Introduce public health measures to reduce widespread infection which compromises micronutrient absorption
Conclusions

• IMAPP can determine distribution of usual nutrient intakes when estimates of within-person variation are available
• IMAPP programme can then establish fortification levels
• Desirable fortificant levels for 3 Asian countries for Ca & Fe (per 100 g) were similar to those for fortified corn-soy blend for children 12 to 36 mo
• Fortificant levels appeared negligible for Zn despite a high prevalence of low serum Zn
  – discrepancy in part because criteria for defining EAR & biochemical cutoffs are not the same
  – discrepancy may also be due to chronic infection in poor absorption of Zn
  – need to better define EAR for Zn & low plasma Zn cutoffs for young children.
Acknowledgments

• Mongolian data: Dr Rebecca Lander, Dept of Human Nutrition, University of Otago
• Cambodian data: Victoria Anderson MSc, Dept of Human Nutrition, University of Otago
• Filipino data: Dr Regina Pedro- FNRI, Philippines

IMAPP can be downloaded free from:
www.side.stat.iastate.edu

Thank you for your attention