Dietary zinc intakes in low income and developed countries

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Outline

• Steps for assessing “usual dietary Zn intakes”

• How to determine the prevalence of inadequate and potentially excessive intakes of Zn

• Using these methods to assess inadequate and excessive intakes of Zn for:
  – Infants & young children
  – Older children aged 4 to 14 years
  – Pregnant women

• Factors associated with inadequate & excessive Zn intakes

• Conclusions
Steps to assess the prevalence of inadequate or excessive Zn intakes

1. Select sample representative of the study population
2. Measure food intake: using appropriate method & design
3. Convert foods to nutrients
4. Determine distribution of `usual’ zinc intakes via PC-SIDE
5. Evaluate dietary adequacy via cutpoint method
   - Apply appropriate EAR for risk of inadequate intakes
   - Apply appropriate UL for risk of excessive intakes

See IZiNCG Technical Brief No. 3
2: Measure food intake using design appropriate for study objective

• Level 1: Average intake of a group
  – Single recall/record per person

• Level 2: Proportion of population ‘at risk’ to inadequate or excessive intakes
  – Repeat recalls/records (on non-consecutive days) on each individual
  – OR Repeat on sub-sample only (30-40) per stratum

• Level 3 or 4: ‘Usual’ intakes of individuals for ranking (level 3) or correlation (level 4)
  – Multiple recalls or records
3: Convert foods to nutrients

NB: Zn content of plant-based staples depends on soil Zn

• Compile local food composition database with values for zinc and phytate
  – Analyze staple plant-based foods
  – Compile best estimates of Zn & phytate from other sources

• Useful resource: WorldFood Dietary Assessment System

• Calculate phytate: Zn molar ratio of diets to estimate bioavailability of Zn

NB there should be NO missing values in a food composition database
4. Adjusting distribution of observed to usual intakes via PC-SIDE

- Adjust 1-d intakes to usual intakes w. PC-SIDE
  - use internal or external within-person variance
- Select appropriate EAR & UL
- Use cutpoint method to assess:
  - % inadequate intakes
  - % excessive intakes

Elevated risk >25% < EAR for Zn

See IZiNCG Brief No. 3
Selecting appropriate EARs & ULs for Zn

- IZiNCG (2004): provide EARs; NOAEL for Zn
  - EAR for mixed/refined vegetarian diets; Phy:Zn: 4 to 18
  - OR unrefined cereal-based diets; Phy:Zn > 18
- WHO (2005): give EARs & UL’s
  - EAR based on three levels of Zn bioavailability
- Country-specific EARs & ULs if available
  - eg: IOM DRV’s; UK DRI’s etc
  - Bioavailability: based on habitual diets

  - NB: Bioavailability not taken into account for UL
5. Determining prevalence of inadequate & excessive intakes by cutpoint method

Frequency

Usual intake (mg/d)

Area estimates prevalence of inadequate intakes

EAR

UL

Area estimates prevalence of excessive intakes
Study groups and objectives

Study groups
- Infants (7-12 mos) & children aged 1-4 y
- Older children
- Pregnant women

Objectives
1. To determine usual Zn intakes and phytate: zinc molar ratios of the diets
2. To assess the prevalence of inadequate and excessive intakes of Zn
3. To examine factors associated with inadequate and excessive intakes of Zn
## Infants and children aged 1-4 y: methods

<table>
<thead>
<tr>
<th>County (n)</th>
<th>Age</th>
<th>Description</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mongolia*</td>
<td>1 - 3 y</td>
<td>Ulaanbaatar + 4 provincial capitols: random sample</td>
<td>1- 24HR*</td>
</tr>
<tr>
<td>(179)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cambodia*</td>
<td>1- 3 y</td>
<td>Urban poor, Phnom Penh: convenience sample</td>
<td>1- 24HR*</td>
</tr>
<tr>
<td>(177)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bangladesh</td>
<td>2 - 4 y</td>
<td>2 Rural agricultural districts; random sample</td>
<td>1X WR; 1-24HR</td>
</tr>
<tr>
<td>(480)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NZ *(176)</td>
<td>1- 2.2 y</td>
<td>3 urban centers of S Island : random sample</td>
<td>3 x 1 WRs</td>
</tr>
<tr>
<td>Non-Breast fed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada (128)</td>
<td>3 y</td>
<td>5 areas in Ontario: convenience sample</td>
<td>3 x 1 ER</td>
</tr>
<tr>
<td>USA (3908)</td>
<td>&lt; 1; 1- 3 y</td>
<td>CSFII Nation-wide survey Over sampling low-income</td>
<td>2 x 24HR</td>
</tr>
<tr>
<td>Non-Breast fed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*External within-person variance used
# Intakes of infants & children 1-4 y: results

<table>
<thead>
<tr>
<th>Country</th>
<th>Zn intake (mg/d)</th>
<th>Phy:Zn molar ratio</th>
<th>Cu intake (mg/d)</th>
<th>Zn:Cu* molar ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mongolia 1-3y</td>
<td>4.9 ± 0.19</td>
<td>4 ± 3</td>
<td>0.48 ± 0.43</td>
<td>12.0 ± 4.9</td>
</tr>
<tr>
<td>Cambodia 1-3y</td>
<td>2.9 ± 1.6</td>
<td>6 ± 3</td>
<td>0.66 ± 0.40</td>
<td>5.0 ± 3.4</td>
</tr>
<tr>
<td>Bangladesh 2-4y</td>
<td>2.5 (2.1, 2.9)</td>
<td>11</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NZ S Island 1-2y</td>
<td>4.8 ± 1.5</td>
<td>-</td>
<td>1.68 ± 0.51</td>
<td>10.2 ± 4.5</td>
</tr>
<tr>
<td>Canada 3y</td>
<td>6.8 ± 0.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>USA 1-3y</td>
<td>7.6 ± 3.3</td>
<td>5 ± 3</td>
<td>0.71 ± 0.29</td>
<td>11.0 ± 4.0</td>
</tr>
<tr>
<td>USA &lt; 1 y</td>
<td>6.6 ± 3.3</td>
<td>3 ± 2</td>
<td>0.67 ± 0.21</td>
<td>9.8 ± 2.5</td>
</tr>
</tbody>
</table>

*Zn:Cu close to < 10:1 = ratios of EARs for Zn & Cu except Mongolia*
## Older children - 4 to 14 y: methods

<table>
<thead>
<tr>
<th>Country: (n)</th>
<th>Age</th>
<th>Description</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malawi (321)</td>
<td>4-7 y</td>
<td>Subsistence HHs</td>
<td>2 x 24 HR</td>
</tr>
<tr>
<td>Canada (126)</td>
<td>4-5 y</td>
<td>Ontario; 5 areas; Convenience</td>
<td>3 x 1 ER</td>
</tr>
<tr>
<td>USA (2668)</td>
<td>4-5 y</td>
<td>CSFII nation-wide survey</td>
<td>2 x 24 HR</td>
</tr>
<tr>
<td>NZ (671) (908)</td>
<td>5-9 y</td>
<td>National survey: Over sampling low-income</td>
<td>1 x 24 HR + repeats</td>
</tr>
<tr>
<td>NE Thailand (228)</td>
<td>5-13 y</td>
<td>10 Low SES schools</td>
<td>1 x 24 HR*</td>
</tr>
</tbody>
</table>

* External within-subject variance used
## Intakes of older children: results

<table>
<thead>
<tr>
<th>Country</th>
<th>Zn intake mg/d</th>
<th>Phy:Zn Molar ratio</th>
<th>Cu intake mg/d</th>
<th>Zn:Cu Molar ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malawi 4-7y</td>
<td>6.7 ± 3.8</td>
<td>21 ± 12</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Canada 4-5y</td>
<td>7.0 ± 0.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>USA 4-5y</td>
<td>9.1 ± 3.7</td>
<td>6 ± 3</td>
<td>0.85 ± 0.34</td>
<td>10.9 ± 3.8</td>
</tr>
<tr>
<td>NZ S Island 5-9y</td>
<td>8.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NZ S Island 9-14y</td>
<td>10.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NE Thailand 5-8y</td>
<td>4.1</td>
<td>&lt;1</td>
<td>0.96 ± 0.42</td>
<td>5.4 ± 1.8</td>
</tr>
<tr>
<td>9-13y</td>
<td>4.4</td>
<td>1.01 ± 0.46</td>
<td>5.2 ± 2.1</td>
<td></td>
</tr>
</tbody>
</table>

Zn:Cu close to < 10:1 = ratios of EARs for Zn & Cu
Prevalence of Zn intakes below EAR (%)

- **Older children 4 to 8.99 y**
  - Thailand: 45%
  - USA: 32%
  - Canada: 22%
  - New Zealand: 22%

- **Infants (7-12 mo) & children 1-4 y**
  - Mongolia: <1%
  - Cambodia: 20%
  - Bangladesh: 22%
  - USA infants: 22%
  - New Zealand: 4%
  - Canada: 45%
<table>
<thead>
<tr>
<th>Country</th>
<th>Group</th>
<th>Prevalence %</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>Older children</td>
<td>3</td>
</tr>
<tr>
<td>Canada</td>
<td>4 to 8.99 y</td>
<td>4</td>
</tr>
<tr>
<td>Thailand</td>
<td>Infants (7-12 mo) &amp; children 1-4 y</td>
<td>86, 51, 25, 8, 11</td>
</tr>
</tbody>
</table>
# Zn intakes of pregnant women: methods

<table>
<thead>
<tr>
<th>Country: (n)</th>
<th>Age</th>
<th>Description</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malawi (141)</td>
<td>14-45y</td>
<td>Subsistence farming HHs</td>
<td>2 x 24HR*</td>
</tr>
<tr>
<td>Ethiopia (99)</td>
<td>27.8 ± 4.6</td>
<td>Subsistence farming HHS</td>
<td>1 WR + repeats</td>
</tr>
<tr>
<td>Egypt (50)</td>
<td>17-36 y</td>
<td>Rural village</td>
<td>2 X WR per mo for 6 mo</td>
</tr>
<tr>
<td>USA (104)</td>
<td>24.4 ± 5.3</td>
<td>Low income of Mexican descent</td>
<td>1 X 24HR at 20 wk gestation</td>
</tr>
<tr>
<td>USA (244)</td>
<td>22.8 ± 5.4</td>
<td>Low income African-American</td>
<td>FFQ</td>
</tr>
</tbody>
</table>
## Usual Zn intakes & Phy:Zn molar ratios of diets of pregnant women

<table>
<thead>
<tr>
<th>Country</th>
<th>Zn intake mg/d</th>
<th>Phy:Zn molar ratio</th>
<th>% with intakes &lt; EAR</th>
<th>% with intakes &gt; UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malawi</td>
<td>9.0</td>
<td>17</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>5.7**</td>
<td>19</td>
<td>99</td>
<td>0</td>
</tr>
<tr>
<td>Egypt</td>
<td>9.4</td>
<td>15</td>
<td>36</td>
<td>?</td>
</tr>
<tr>
<td>US Mexican*</td>
<td>9.7</td>
<td>-</td>
<td>24</td>
<td>?</td>
</tr>
<tr>
<td>US African-American*</td>
<td>13.2 ± 5.6</td>
<td>-</td>
<td>6</td>
<td>?</td>
</tr>
</tbody>
</table>

**Staples is Enset: very low in Zn; * Low income; IZiNCG EAR=10 mg; UL=40 mg**
What are the factors associated with inadequate intakes of Zn?

1. Low zinc intakes
   - diets based on roots & tubers: enset (Ethiopia), cassava, sweet potatoes, sago
   - diets low in cellular animal foods: rich sources of Zn
   - low energy intakes (Ethiopia, Thailand)

2. Poor bioavailability of zinc
   - unrefined cereals/legumes: high phytate diets (Malawi)
   - low in cellular animal foods: rich in absorbable Zn

3. Environmental factors
   - low soil Zn: NE Thailand; Egypt; Iran; Turkey; Bangladesh; Pakistan
   - low Zn content of staples grown on low Zn soils
     » maize>beans>rice>sorghum
Major food sources of Zn (as %) for non breast fed children from Mongolia, NZ, Malawi, & US

- **Mongolia 1-3 y**
  - Meat: 10%
  - Cereal: 20%
  - Infant formula: 5%
  - Dairy: 3%

- **NZ 1-2.2 y**
  - Meat: 5%
  - Cereal: 15%
  - Infant formula: 10%
  - Dairy: 25%

- **Malawi 4-7y**
  - Meat: 5%
  - Cereal: 70%
  - Infant formula: 5%
  - Dairy: 10%

- **US 4-5y**
  - Meat: 10%
  - Cereal: 30%
  - Infant formula: 10%
  - Dairy: 5%

- **US 1-3y**
  - Meat: 10%
  - Cereal: 20%
  - Infant formula: 15%
  - Dairy: 5%

- **US<1y**
  - Meat: 5%
  - Cereal: 60%
  - Infant formula: 30%
  - Dairy: 5%
Prevalence of inadequate intakes of Zn (as %) in relation to diet type

- Low in bioavailable Zn
- Low soil Zn
- Low Zn (enset) + bioavailable
- Leavened wheat bread
- Omnivorous diets
What are the factors associated with potentially excessive intakes of Zn?

1. Use of Zn-containing supplements in young children:
   USA: 20%; Canada: 3%; NZ: 0%
2. Consumption of Zn-fortified foods
   - Zn-fortified formula (ZnFF)
     - USA: 84%; NZ: 15% 1-2.2 y
   - Ready-to-eat Zn-fortified breakfast cereals
     - USA: 78%; Canada: 24%; NZ: 0%
3. Higher protein intake: Canada
4. Higher energy intake: Canada; US; Mongolia
Percent of non-breastfed infants & young children from US, Canada, & NZ consuming Zn-fortified foods (FFs)

- NZ 1-2.2y: 15%
- Canada 3-5y: 30%
- US 4-5y: 62%
- US 1-3y: 65%
- US <1y: 98%
Percentage of total Zn intake from Zn-fortified foods among infants & young children consuming Zn fortified foods from US, Canada, & NZ

- NZ 1-2.2y: 32%
- Canada 3-5y: 6%
- US 4-5y: 25%
- US 1-3y: 24%
- US<1y: 84%
Conclusions

• Countries differ in their risk for inadequate & excessive intakes of zinc

• Infants & young children from low income countries are at high risk of Zn intakes below the EAR

• Infants & young children from North America are at high risk of Zn intakes above the UL

• Consumption of zinc-fortified foods in North America, notably zinc fortified formula & zinc-fortified breakfast cereals, are associated with high risk of zinc intakes > UL

• No evidence that there is a health risk for infants & young children with zinc intakes > UL

• Need to collect data on intakes & biomarkers of copper status and immune function in studies of children consuming zinc fortified foods
Thank you!

Please visit the IZiNCG web site:
www.izincg.org