Evidence on risk factors of stunting

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Dec 1st, 2016
Outline

Background and motivation
• Methods and data sources
• Results
• Conclusion and next steps
Background and motivation
Background and motivation

[Graph showing the number of children with Z score below -2 from 1985 to 2010 for different regions: Oceania, Southern and tropical Latin America, Andean and central Latin America and Caribbean, Central Asia, Middle East, and north Africa, East and southeast Asia, Sub-Saharan Africa, South Asia.]

Stevens 2012 Lancet
Conceptual model

- Physical and Cognitive Development Ages 0-6
- Educational attainment: highest grade completed
- Net present value of lifetime earnings

**Principal Data Sources**

- Epidemiological studies showing effect of risk factor on physical and cognitive child development
- Longitudinal studies measuring effect of preschool developmental deficiencies on educational outcomes
- Country specific studies measuring returns to completing schooling levels as well as test performance

**Factors**

- Pregnancy and delivery
- Infectious disease
- Nutrition
- Stimulation
- Other genetic and environmental factors
Outline

• Background and motivation

Methods and data sources

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Risk factor selection

- 18 risks selected from an extensive list of modifiable risk factors for stunting based on
  - (i) availability of high-quality exposure data
  - (ii) convincing evidence for a causal impact on stunting
  - (iii) availability of evidence on the effect size on stunting from recent meta-analyses of epidemiological studies

- Grouped into 5 groups based on similarity of risk factor and interventions to address them
### Selected risk factors and clusters

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maternal nutrition and infection</strong></td>
<td></td>
</tr>
<tr>
<td>Maternal short stature</td>
<td>Maternal height &lt;160cm</td>
</tr>
<tr>
<td>Maternal underweight</td>
<td>Maternal BMI &lt;18.5 kg/m²</td>
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<tr>
<td>Maternal malaria</td>
<td>Malaria in pregnancy</td>
</tr>
<tr>
<td>Maternal anemia</td>
<td>Maternal hemoglobin &lt;110g/L</td>
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<tr>
<td><strong>Teenage motherhood and short birth intervals</strong></td>
<td></td>
</tr>
<tr>
<td>Teenage motherhood</td>
<td>Maternal age at delivery &lt;20 years</td>
</tr>
<tr>
<td>Short birth intervals</td>
<td>&lt;24 months between consecutive births</td>
</tr>
<tr>
<td><strong>Fetal growth restriction and preterm birth</strong></td>
<td></td>
</tr>
<tr>
<td>Preterm, small-for-gestational age</td>
<td>Birth before 37 weeks of gestation and weight &lt;10th percentile for gestational age</td>
</tr>
<tr>
<td>Preterm, appropriate-for-gestational age</td>
<td>Birth before 37 weeks of gestation and weight ≥10th percentile for gestational age</td>
</tr>
<tr>
<td>Term, small-for-gestational age</td>
<td>Birth at or after 37 weeks of gestation and weight &lt;10th percentile for gestational age</td>
</tr>
<tr>
<td>Low birth weight</td>
<td>Birthweight &lt;2500g</td>
</tr>
<tr>
<td><strong>Child nutrition and infection</strong></td>
<td></td>
</tr>
<tr>
<td>Childhood zinc deficiency</td>
<td>Deficient zinc intake during childhood based on age- and sex-specific zinc requirements</td>
</tr>
<tr>
<td>Childhood diarrhea</td>
<td>Mean number of diarrhea episodes per year during childhood</td>
</tr>
<tr>
<td>Non-exclusive breastfeeding</td>
<td>Non-exclusive breastfeeding of infants under 6 months of age</td>
</tr>
<tr>
<td>Discontinued breastfeeding</td>
<td>Discontinued breastfeeding of children 6-24 months of age</td>
</tr>
<tr>
<td>HIV infection without (HAART) before 2 years of age</td>
<td>Child HIV infection without initiation of HAART until after 2 years of age</td>
</tr>
<tr>
<td><strong>Environmental factors</strong></td>
<td></td>
</tr>
<tr>
<td>Unimproved sanitation</td>
<td>Lack of access to safe sanitation in the community (based on WHO/UNICEF JMP definition of improved sanitation)</td>
</tr>
<tr>
<td>Unimproved water</td>
<td>Lack of access to clean water in the community (based on WHO/UNICEF JMP definition of improved water source)</td>
</tr>
<tr>
<td>Use of biomass fuels</td>
<td>Use of biomass fuels for cooking and heating</td>
</tr>
</tbody>
</table>
Analytical methods

- Exposure level
- Relative risk
- Optimal exposure

Population Attributable Fraction (PAF)

- Prevalence of stunting and number of stunted children

Attributable Stunting
Analytical methods – data sources

- Exposure level
- Relative risk
- Optimal exposure

Population Attributable Fraction (PAF)

Prevalence of stunting and number of stunted children

Attributable Stunting
Data sources: exposure levels

• Derived prevalence of exposure to each risk factor for ~2010 from published literature, available surveys (e.g. DHS)
  • Teenage motherhood, short birth intervals: 64 countries with recent DHS surveys; sub-regional or regional average when no data were available
  • Child HIV infection: analysis conducted only for 45 countries with available data
Analytical methods – data sources

- Exposure level
- Relative risk
- Optimal exposure

Population Attributable Fraction (PAF)

Prevalence of stunting and number of stunted children

Attributable Stunting
Data sources: relative risks

• From published or de-novo systematic reviews of risk factors with effects on
  • Child HAZ, stunting (HAZ<-2)
  • Poor birth outcomes (low birth weight, small-for-gestational age)

• 12 risk factors had effect sizes on HAZ or stunting

• Mediated risks
  • Maternal malaria, underweight, anemia, biomass fuel use: meta-analyses of effect sizes only available on low birth-weight
  • Non-exclusive breastfeeding, discontinued breastfeeding: meta-analysis of effect size only available on diarrhea
Analytical methods – data sources

- Exposure level
- Relative risk
- Optimal exposure

Population Attributable Fraction (PAF)

Prevalence of stunting and number of stunted children

Attributable Stunting
Data sources: optimal exposure

• Used the Theoretical Minimum-Risk Exposure Distribution (TMRED)
• Assumed to be no exposure for most risk factors
  • Solid fuel use
  • Unimproved water and sanitation
  • Maternal malaria
• For others, the optimal level is less obvious. We used evidence from systematic reviews and meta-analyses to designate the optimal level or category
  • Maternal height
  • Short birth intervals
Analytical methods – data sources

- Exposure level
- Relative risk
- Optimal exposure

Population Attributable Fraction (PAF)

Prevalence of stunting and number of stunted children

Attributable Stunting
Data sources: outcome

• **Stunting prevalence: Nutrition Impact Model Study (NIMS)** (Stevens 2012)
  • Proportion of children under 5 with height-for-age more than 2SD below WHO Child Growth Standard median
  • Converted to stunting prevalence among 2 year olds using relationship between prevalence under-5 and at age 2 from child health surveys
Analytical methods

Population Attributable Fraction (PAF)

Exposure level
Relative risk
Optimal exposure

Prevalence of stunting and number of stunted children

Attributable Stunting
Analytical methods

- Estimated Population Attributable Fraction which quantifies the proportion of current disease burden (here stunting) that is attributable to current and past exposure.

\[
P_{AF} = \frac{\sum_i P_i (R_{Ri}-1)}{\sum_i P_i (R_{Ri}-1) + 1}
\]

- Quantified uncertainty in the outputs by propagating uncertainty in the inputs via simulation.
  - This ignores other sources of uncertainty including whether relative risks can be extrapolated from one population to another.
Analytical methods

• Joint effects of multiple risk factors within the same group:

\[ PAF_j = 1 - \prod_{i=1}^{R} (1 - PAF_i) \]

This assumes no mediation, no correlation and no effect measure modification in multiplicative scale (i.e. similar relative risk)

• Adjusting for mediation for effect of zinc on diarrhea

Zn → Dia → Stunting
Outline

• Background and motivation
• Methods and data sources

Results

• Conclusion and next steps
## Results – proportion of stunting attributable by region and risk cluster

<table>
<thead>
<tr>
<th>Region</th>
<th>Maternal nutrition and infection</th>
<th>Teenage motherhood and short birth intervals</th>
<th>Fetal growth restriction and preterm birth</th>
<th>Child nutrition and infection</th>
<th>Water, sanitation and biomass fuel use</th>
</tr>
</thead>
<tbody>
<tr>
<td>All developing countries</td>
<td>13.8 (11.9, 16.0)</td>
<td>1.9 (1.9, 2.0)</td>
<td>32.5 (30.0, 35.2)</td>
<td>13.5 (5.9, 21.1)</td>
<td>21.7 (19.9, 23.5)</td>
</tr>
<tr>
<td>East Asia and Pacific</td>
<td>10.7 (9.8, 11.9)</td>
<td>1.3 (1.2, 1.4)</td>
<td>24.0 (21.0, 26.9)</td>
<td>10.9 (4.6, 17.2)</td>
<td>13.8 (11.3, 16.3)</td>
</tr>
<tr>
<td>South Asia</td>
<td>19.2 (16.2, 22.4)</td>
<td>2.2 (2.1, 2.3)</td>
<td>40.9 (37.5, 44.2)</td>
<td>12.3 (5.3, 20.1)</td>
<td>24.5 (22.2, 26.9)</td>
</tr>
<tr>
<td>Central Asia</td>
<td>5.9 (5.3, 6.7)</td>
<td>1.6 (1.5, 1.7)</td>
<td>22.6 (19.3, 25.5)</td>
<td>18.9 (8.4, 29.4)</td>
<td>4.2 (3.3, 5.1)</td>
</tr>
<tr>
<td>North Africa and Middle East</td>
<td>7.4 (6.4, 8.5)</td>
<td>1.8 (1.7, 2.0)</td>
<td>24.6 (22.2, 27.3)</td>
<td>12.9 (5.7, 20.6)</td>
<td>6.2 (5.2, 7.3)</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>11.3 (9.4, 13.2)</td>
<td>2.0 (1.9, 2.1)</td>
<td>30.6 (28.1, 33.3)</td>
<td>15.4 (6.9, 24.2)</td>
<td>27.0 (25.1, 29.1)</td>
</tr>
<tr>
<td>Latin America and Caribbean</td>
<td>9.9 (9.1, 10.7)</td>
<td>2.3 (2.2, 2.4)</td>
<td>20.5 (18.4, 23.0)</td>
<td>18.1 (7.9, 27.7)</td>
<td>8.9 (7.9, 9.9)</td>
</tr>
</tbody>
</table>

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Results – cases of stunting attributable to individual risk factors

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Results – cases of stunting attributable by region and risk cluster
## Results by region and risk cluster

<table>
<thead>
<tr>
<th>Region</th>
<th>Maternal nutrition and infection</th>
<th>Teenage motherhood and short birth intervals</th>
<th>Fetal growth restriction and preterm birth</th>
<th>Child nutrition and infection</th>
<th>Water, sanitation and biomass fuel use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PAF (%)</td>
<td>Number stunted</td>
<td>PAF (%)</td>
<td>Number stunted</td>
<td>PAF (%)</td>
</tr>
<tr>
<td>All developing countries</td>
<td>13.8 (11.9, 16.0)</td>
<td>6112 (5047, 7308)</td>
<td>1.9 (1.9, 2.0)</td>
<td>858 (774, 945)</td>
<td>32.5 (30.0, 35.2)</td>
</tr>
<tr>
<td>East Asia and Pacific</td>
<td>10.7 (9.8, 11.9)</td>
<td>786 (678, 896)</td>
<td>1.3 (1.2, 1.4)</td>
<td>96 (81, 110)</td>
<td>24.0 (21.0, 26.9)</td>
</tr>
<tr>
<td>South Asia</td>
<td>19.2 (16.2, 22.4)</td>
<td>3207 (2375, 4113)</td>
<td>2.2 (2.1, 2.3)</td>
<td>361 (287, 437)</td>
<td>40.9 (37.5, 44.2)</td>
</tr>
<tr>
<td>Central Asia</td>
<td>5.9 (5.3, 6.7)</td>
<td>27 (22, 32)</td>
<td>1.6 (1.5, 1.7)</td>
<td>7 (6, 8)</td>
<td>22.6 (19.3, 25.5)</td>
</tr>
<tr>
<td>North Africa and Middle East</td>
<td>7.4 (6.4, 8.5)</td>
<td>190 (155, 226)</td>
<td>1.8 (1.7, 2.0)</td>
<td>48 (41, 54)</td>
<td>24.6 (22.2, 27.3)</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>11.3 (9.4, 13.2)</td>
<td>1729 (1431, 2050)</td>
<td>2.0 (1.9, 2.1)</td>
<td>306 (285, 327)</td>
<td>30.6 (28.1, 33.3)</td>
</tr>
<tr>
<td>Latin America and Caribbean</td>
<td>9.9 (9.1, 10.7)</td>
<td>173 (153, 196)</td>
<td>2.3 (2.2, 2.4)</td>
<td>41 (36, 46)</td>
<td>20.5 (18.4, 23.0)</td>
</tr>
</tbody>
</table>

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Results by country

• See http://www.healthychilddev.sph.harvard.edu/
Outline

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• Results

Conclusion and next steps
Conclusions

• A substantial proportion of stunting in LMICs is attributable to fetal growth restriction and unimproved sanitation.

• Attention should now be focused on improving risk factors before and during pregnancy and on environmental factors.

• Effects on lost productivity due to lower education attainment are substantial (to be discussed in a subsequent presentation).

• Our estimates should be considered as conservative as they don’t include the impact of non-physical growth.
Strengths and limitations

• **Strengths**
  - Comparable and consistent data sources and methods
  - Including only risk factors with strong evidence
  - Extensive review of literature on effect sizes
  - Quantified uncertainty in outcomes

• **Limitations**
  - Using proxy measures for exposure
  - Mediated effects through LBW and diarrhea lead to underestimation
  - Extrapolation of relative risks to all populations
  - Most effect sizes were reported as odds ratios which overestimate relative risks
Next steps

• Incorporating other risk factors whenever global data becomes available: e.g. environmental pollutants like pesticides, diet diversity, food security, maternal smoking.

• Examining the impact of the same risk factors on education and economic outcomes through early childhood development.

• Analysis of interventions that can improve exposure to these risk factors using cost-effectiveness models.

• Subnational analyses of risk factors to examine health disparities.
Acknowledgements

• Funding source: Grand Challenges Canada

• Co-authors: Kathryn G Andrews, Christopher R Sudfeld, Günther Fink, Dana Charles McCoy, Evan Peet, Ayesha Sania, Mary C Smith Fawzi, Majid Ezzati, Wafaie W Fawzi