INDICATORS OF FOOD SAFETY IN LOW- AND MIDDLE-INCOME COUNTRIES

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WHY IS IT SO DIFFICULT TO QUANTIFY THE SOCIETAL IMPACT OF FOODBORNE DISEASES?

• Many hazards
  • Viruses, bacteria, parasites, chemicals, toxins, ....

• Many health outcomes
  • Acute intoxication, diarrhea, birth defects, epilepsy, cancer, ..... 

• Many incubation times
  • Hours – decades

• Many cases unrecognized
  • No medical contact, weak surveillance systems

• Many transmission pathways for most foodborne hazards
  • Food, water, human-human, animal-human, environment

FULLY QUANTIFYING THE BURDEN OF FOODBORNE DISEASE IS VIRTUALLY IMPOSSIBLE BUT MEANINGFUL CHOICES CAN BE MADE
DOMAINS FOR INDICATORS OF FOODBORNE DISEASE

• Health
  • Incidence, mortality, summary measures of public health, ...

• Economics
  • Cost-of-illness, regulatory costs, compliance costs, ...

• Hazard occurrence in food chains
  • Regulatory inspections, randomized surveys, ...

• Food systems inspections
  • Regulatory, voluntary, ....

• Value chain actor behavior
  • Stated, observed, ...

INTERNATIONAL COMPARABILITY IS A MAJOR CHALLENGE
SURVEILLANCE OF FOODBORNE DISEASES

Gibbons et al. BMC Public Health 2014;14:147

Learning from Outbreaks

CDC downloads and verifies outbreak data with state and local health departments, then analyzes and summarizes it.

CDC analysts publish and make outbreak data available for stakeholders.

Health departments investigate and submit data.

CDC downloads, verifies, and analyzes data.

Stakeholders access outbreak data.

State and local health departments contact an investigation and submit data to CDC.

People are exposed to a germ, get sick, and seek treatment.

Possible outbreak

Gibbons et al. BMC Public Health 2014;14:147
CHALLENGES FOR FOODBORNE DISEASE SURVEILLANCE

- Dependent on decisions made in healthcare systems ("eavesdropping")
  - Not consistent between countries, regions or smaller geographical systems
  - Practices change over time (e.g. non-culture dependent diagnostics)
  - Budget limitations
  - Incomplete

- Timeliness
  - Recall bias
  - Food samples no longer available

ESTIMATING THE BURDEN OF FOODBORNE DISEASE REQUIRES SYNTHESIS OF MANY DIFFERENT DATA SOURCES AND (STATISTICAL) IMPUTATION OF MISSING DATA
BURDEN OF FOODBORNE DISEASE

• Illnesses, deaths
• Disability-Adjusted Life Years (DALYs)
  • 1 DALY = 1 healthy life year lost
  • Summary measure of population health
    • Morbidity + mortality
    • Disease occurrence + disease severity
  • DALY = YLD + YLL
    • YLD = Years Lived with Disability
      = Number of incident cases (N) × Duration (D) × Disability Weight (DW)
    • YLL = Years of Life Lost
      = Number of deaths (M) × Residual Life Expectancy (RLE)
  • Document current and future burden (sequelae, chronic exposures)
**Disability-Adjusted Life Years (DALYs)**

\[ 10 + 30 = 40 \text{ DALYs} \]

- **YLD** = Years Lived with Disability = \( N \times D \times DW \)
- **YLL** = Years of Life Lost = \( M \times RLE \)

\[ DW \]

\[ 0 \]

\[ 0.25 \]

\[ 1 \]

\[ 0 \]

\[ 20 \]

\[ 60 \]

\[ 90 \]

\[ Age \]

\[ 40 \times 0.25 = 10 \text{ YLDs} \]

\[ 30 \times 1 = 30 \text{ YLLs} \]

\[ 0.25 \times 10 + 30 = 40 \text{ DALYs} \]
WHO ESTIMATES OF GLOBAL BURDEN OF FOODBORNE DISEASE

• Global estimates for 31 hazards published in 2015
  • 11 acute diarrheal disease, 7 invasive infectious disease, 10 helminths, 3 chemicals
• Estimates for high-income countries for 4 hazards
  • 4 bacterial toxins; 1 allergen
• Estimates for 4 metals published in 2019
  • Methodological differences
FOODBORNE DISEASES ARE A GLOBAL PUBLIC HEALTH PROBLEM

• WHO Foodborne Disease Burden Epidemiology Reference Group (FERG) 2015
  • 31 hazards
  • 600 million illnesses, 420,000 deaths, 33 million DALYs
• FERG 2019
  • 4 metals
  • 1.1 million cases, 56,000 death, 9 million DALYs
• Many more hazards and outcomes are potentially important, but not currently quantifiable
• WHO is developing a strategy to update estimates by 2025 and develop a food safety indicator (World Health Assembly resolution EB146.R9)

https://collections.plos.org/ferg2015
# Global Burden of Foodborne Disease

<table>
<thead>
<tr>
<th>Hazard group</th>
<th>Foodborne illnesses (millions)</th>
<th>Foodborne deaths (thousands)</th>
<th>Foodborne DALYs (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2015 estimates</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>600</td>
<td>420</td>
<td>33</td>
</tr>
<tr>
<td>Diarrheal</td>
<td>549</td>
<td>230</td>
<td>18</td>
</tr>
<tr>
<td>Invasive</td>
<td>36</td>
<td>117</td>
<td>8</td>
</tr>
<tr>
<td>Helminths</td>
<td>13</td>
<td>45</td>
<td>6</td>
</tr>
<tr>
<td>Chemicals</td>
<td>0.2</td>
<td>19</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>2019 estimates</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>1.1</td>
<td>56</td>
<td>9.2</td>
</tr>
</tbody>
</table>

*Different estimation methods

Havelaar et al., PLOS Med 2015;12:e1001923
Gibb et al., Env Res 2019;174:188-194
**FOODBORNE DISEASES ARE UNEQUALLY DISTRIBUTED**

- Children under five years of age
  - ... make up 9% of the world population
  - ... suffer from 38% of all foodborne illnesses
  - ... succumb to 30% of foodborne deaths
  - ... bear 40% of global foodborne DALYs

- People living in the poorest areas of the world
  - ... make up 41% of the world population
  - ... suffer from 53% of all foodborne illnesses
  - ... succumb to 75% of foodborne deaths
  - ... bear 72% of global foodborne DALYs

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Havelaar et al., PLOS Med 2015;12:e1001923
Gibb et al., Env Res 2019;174:188-194
ZOOMING IN ON THE BURDEN OF SPECIFIC FOODS

Animal source foods contribute 35% of the burden of foodborne disease

Dairy products contribute 12% of the burden of animal source foods

Li et al., PLOS One 2019;14:e0216545

Grace et al., J Dairy Sci, accepted
FOOD SAFETY DECISION MAKING

- FERG estimates have been influential in raising global awareness of food safety as a public health problem
  - Food Safety Day – June 7
  - If it isn’t safe, it isn’t food
- Food safety decision making is the responsibility of national governments
  - FERG estimates published at subregional level
  - Country-level estimates are available but need national clearance
  - National priorities may not be fully represented in global estimates
  - National decision makers need training in risk-based decision making
DATA DASHBOARD FOR ETHIOPIA

Dashboard populated with hypothetical data for training purposes
LIMITATIONS OF FERG ESTIMATES

• Data availability and quality
  • Particularly in low-income countries where burden is highest
  • Imputation and expert judgment
  • Presentation at regional level rather than country level
  • Large uncertainty intervals

• Underestimation
  • Limited number of hazards
  • Not all endpoints considered, e.g. malnutrition and stunting, irritable bowel syndrome, chronic (psychiatric) consequences of toxoplasmosis
  • Burden in HIV-positives preventable by food safety interventions
  • Model uncertainty, e.g. multiplicative or additive models for chemicals
  • Public health metrics do not quantify the full societal impact of foodborne diseases, e.g. economic burden
  • Indirect transmission of disease agents from food production systems – One Health
STUNTING

• Affects 25% of children globally, 35% in Africa, 38% in Ethiopia

• Stunting is associated with:
  • Increased mortality from diarrhea, pneumonia, other infectious diseases
  • Impaired cognitive development
  • Reduced income
  • Reduced life expectancy
  • Increased risk of chronic diseases later in life

• Need for interventions to reduce this important cause of morbidity and mortality
JUXTAPOSITION OF NUTRITION AND FOOD SAFETY IMPACTS

Global distribution of stunting

Source: GAIN

Global distribution of foodborne disease

Source: WHO, Adam Ragusea
3 Conditions for Normal Growth and Development

No excess of symptomatic common infections such as malaria, diarrhea, or lower respiratory tract infections.

Diet provides adequate macro- and micronutrients in bioavailable forms.

Dr. Mark Manary
Washington University, St Louis
FOODBORNE DISEASE AND MALNUTRITION

- Enteric (bacterial) infections and mycotoxins are increasingly associated with stunting
  - Environmental enteric dysfunction
  - Foodborne transmission important for many identified hazards

Rogawski et al., Lancet Glob Health 2018; e1319-e28
Trehan et al., Arch Dis Child 2016; 101:741-4
Livestock (poultry, ruminants, pigs) are main reservoirs of *C. jejuni / coli*
Reservoirs of other *Campylobacter* species are less well known; mammals most frequently reported
Very few data from LMIC
Quantification of reservoirs and transmission pathways is critical to define interventions

**Campylobacter species are associated with linear growth faltering and inflammation in LMIC**

*Campylobacter jejuni / coli*

<table>
<thead>
<tr>
<th>Outcome</th>
<th><em>C. jejuni / coli</em></th>
<th><em>Campylobacter spp.</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔHAZ</td>
<td>-0.18 (-0.30, -0.06)</td>
<td>-0.31 (-0.46, -0.15)</td>
</tr>
<tr>
<td>Fecal MPO</td>
<td>0.29 (0.24, 0.34)</td>
<td>0.20 (0.16, 0.24)</td>
</tr>
</tbody>
</table>

CONCLUSIONS

• The global burden of unsafe foods is substantial
• A large share of the burden is borne by children under five years of age and those living in low- and middle-income countries
• Priority hazards differ between regions
• Nutrient-dense foods are more likely to cause foodborne disease than staple foods
• Emerging evidence links foodborne enteric pathogens to poor gut health and stunting
• Control methods do exist for many hazards, and are linked to economic development and effective food safety systems
• Developing a consistent set of food safety indicators requires international collaboration
END

COMMENTS AND OR QUESTIONS