Estimating immunity to wild poliovirus type 1 in South Africa

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Overview

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2. Data sources
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Model structure

- $S_{(i)}$: Fully susceptible
- $V_{H(i)}$: Humoral immunity only
- $G_{(i)}$: Gut (mucosal) and humoral immunity

Age classes are represented by $(i)$
Aim

• Estimate levels of gut and humoral immunity to WPV1 at the district level, in five-year age bands

• Provide initial conditions to SACEMA’s poliovirus transmission model

• Help motivate for and inform public health interventions such as catchup campaigns
### Vaccination for wild poliovirus type 1

#### Vaccination schedule

<table>
<thead>
<tr>
<th>Age of child</th>
<th>Vaccine type</th>
</tr>
</thead>
<tbody>
<tr>
<td>At birth</td>
<td>OPV 0</td>
</tr>
<tr>
<td>6 weeks</td>
<td>OPV 1</td>
</tr>
<tr>
<td>10 weeks</td>
<td>IPV 2</td>
</tr>
<tr>
<td>14 weeks</td>
<td>IPV 3</td>
</tr>
<tr>
<td>18 months</td>
<td>IPV 4</td>
</tr>
</tbody>
</table>

- **IPV** promotes **Humoral** immunity
- **OPV** promotes **Gut (mucosal)** immunity

*Image source: Bing image generator*
Data Sources

- **NDoH**: IPV1-4 and OPV0-1 doses at district-level 2009 – July 2022; missing some years
- **WCDoH**: birth-dose BCG and IPV1 at facility-level in WC 2009 – July 2022
- **Schoub et al. 1998**: 1995 nationally representative seroprevalence survey of 12 - 35 month old children (province-level)
- **Statistics South Africa**: district-level live births 1998-2020
- **Thembisa model**: population size estimates per province, per age
Overall workflow

Vaccination & population data

Bootstrap dose numbers

Distribute doses

Apply efficacy

District-level immunity estimates
Bootstrap for missing doses

Data from NDoH was incomplete; e.g.,
- All provinces: no OPV0 data for 2009-2019

1. Compute ratios of OPV0 / OPV1 doses administered for years with complete data
2. For each missing data, sample a ratio
3. Multiply ratio by number of OPV1 doses to get number of OPV0 doses
Distribute doses

ORGANIZED

RANDOM

OPV0

OPV1

OPV0

OPV0
Putting the pieces together

- Assume fixed per-dose efficacy for bOPV and tOPV
- Specify independently 1- 2- 3- and 4-dose efficacy for IPV
- Calculate number of children with gut and humoral immunity per birth year
- Calculate proportion immune per age group (0-4, 5-9, etc.)
- Calculate proportion immune for humoral immunity only:
  - \( \text{prop}_\text{hum} \times (1-\text{prop}_\text{gut}) \)
Estimating immunity prior to 2009

- Assume same as 1993
- Interpolated immunity
- Data from the 1995 seroprevalence survey
- Data from NDoH: OPV0-1 doses at district-level → estimate of proportion with gut immunity
Results

City of Johannesburg Metropolitan Municipality

Proportion immune

Age group

Earliest known doses

Serosurvey

Immunity type
- Mucosal immunity
- Any immunity
Age-structured immunity estimates

City of Cape Town Metropolitan Municipality

Pietermaritzburg District Municipality

Zwelitsha Emfuleni Municipal District Municipality

Garden Route District Municipality

Ekuruleni Metropolitan Municipality

Sakhululwana District Municipality

Immunity type

- Mucosal immunity
- Any immunity
Proportion of under-5’s with gut or humoral immunity to WPV1
Proportion of under-15’s with gut or humoral immunity to WPV1
Discussion

- Concerning risk for widespread AFP
- 10-24 year olds at highest risk
- Younger children mostly protected but gap in gut immunity could amplify an outbreak
- Wider age range should be considered for catchup campaigns
Limitations

• Missing data
  • Routine vaccination pre-2009
  • Catchup campaigns

• Live births

• Efficacy assumptions

• Assume doses administered < live births
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Next steps

• Incorporating data on catchup campaigns
• Improving live births estimates
• Validation on intermediate results
  • Zero-dose babies
  • WHO/UNICEF estimates of national immunization coverage
• cVDPV2
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Estimating immunity given dose distribution

- Assume fixed per-dose efficacy for bOPV and tOPV
- Specify independently 1- 2- 3- and 4-dose efficacy for IPV
- Compute number immune based on annual doses given
- Divide by annual live births to get proportion immune
- Use province-level population size estimates to combine birth years into age groups