Suggested Reference


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Evidence for the intensive-exposure and cross-sex transmission hypotheses in epidemic poliomyelitis mortality patterns in southern Ontario, 1900–1937

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Introduction
This study evaluates the intensive-exposure and cross-sex transmission hypotheses (Nielsen et al., 2001, 2002a, 2002b) using mortality data from this region of southern Ontario, including the cities of Hamilton and Toronto (Fig. 1).

Traditional polio model
Increased severity linked to increased age at infection.

Intensive-exposure hypothesis
More intensive exposure to the poliovirus (higher dose) leads to increased severity of infection.

• PREDICTION: Poliomyelitis severity (and therefore deaths) will increase with family size.
  • Younger school-age children are more likely to be index cases, bringing infection into the home.
  • PREDICTION: There will be a U-shaped age curve for severe cases (e.g., deaths), due to younger school-age children bringing infection into the home.

Cross-sex transmission hypothesis
Transmission of the poliovirus between sexes increases severity.

• Girls are less likely to be infected by a brother in smaller families while boys are more likely to be infected by their mothers.
  • PREDICTION: There will be a higher sex ratio (excess male deaths) in smaller families.

Two-stage approach
During data analysis, a shift in the mortality pattern over time became apparent, particularly as of the late 1920s (see for example Fig. 3). Therefore, data were divided into two periods for further analysis:

• Stage 1 (1910–1927) including 1910 and 1922 epidemics
• Stage 2 (1928–1937) including 1929/30 and 1937 epidemics

Materials
Causes of death listed in individual death registrations from Wentworth and York Counties from 1900 to 1937.

• Data collection yielded a total 336 polio deaths for analysis.

• Additional information from:
  • Censuses
  • Marriage and birth registrations
  • Passenger lists and border crossings
  • Newspaper articles and obituaries

Methods
Analyses relating to age at death were restricted to those who died within 6 months of illness onset (n = 303).

• Of those aged 0–19, family size could be determined for 48 individuals.

• Statistical tests:
  • Chi-square for sex ratios
  • Unpaired t-test for average family sizes

Results

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
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<tbody>
<tr>
<td>1910–1927</td>
<td>1928–1937</td>
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<table>
<thead>
<tr>
<th>Age at death</th>
<th>Majority &lt;5 years of age</th>
<th>Majority &gt;5 years of age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median = 4 years</td>
<td>Median = 4 years</td>
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</table>

| U-shaped age curve present? | No | Yes |

| Sex ratio (ages 0–19)* | 1.0 (equal) | 1.5 (excess males) |

| Family size (number of children)** | Average = 5.7 ± 2.7 | Average = 2.5 ± 2.2 |
| Median = 4 | Median = 2 |

* Difference is statistically significant (p < 0.050, df = 1, p = 0.022).
** Difference in averages is statistically significant (p = 0.014).

Table 1. Two-stage pattern of polio mortality in Wentworth and York Counties, 1910–1937.

Discussion
These results support the intensive-exposure and cross-sex transmission hypotheses, and tie polio mortality patterns to demographic shifts in the early 20th century.

• U-shaped age curve in the 1928–1937 period.
• Correlation of excess male deaths with smaller family sizes.

The intensive exposure model, adapted from measles, is not an exact match for polio in part because polio has two modes of transmission: fecal–oral and droplet. However, Nielsen et al. (2002a) argue that the role of droplet transmission increased over time, as sanitation and hygiene improvements increasingly precluded fecal–oral spread of the poliovirus. The appearance of the U-shaped age curve only in the later part of the study period may reflect this shift in mode of transmission.

The two-stage pattern observed here is likely associated with multiple factors during a period of rapidly changing socio-ecological conditions, characterized by advances in public sanitation and hygiene, a declining birth rate, and smaller family sizes.

Implications
• This study provides further evidence for the need to consider multiple routes of disease transmission.
• Those who have attempted to adapt the traditional polio model to explain patterns in other diseases should consider the implications of new models of polio’s emergence and shifting epidemiology.

Further research
• Future release of additional records (e.g. birth records) will allow expansion of data for individuals in this sample.
• This will enable testing of Nielsen et al.’s predictions related to the interaction of family size and birth order.
• Expansion of the study to other counties in Ontario would also increase the sample size.
• Future research might consider the role of the microbiome in shaping polio epidemiology.
• Markle et al. (2013) have shown that sex differences in the intestinal microbiota are related to development of autoimmune diseases.
• Recent research suggests that intestinal microbiota play a role in poliovirus infection (Kuss et al., 2011).

Literature cited

Figure references
Figure 1. Map of southern Ontario region.
Figure 2. Number of acute polio deaths by age in Wentworth and York Counties, ages 0–19.
Figure 3. Cumulative number of male vs. female polio deaths and York Counties from 1900–1937 (n = 306).

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