Differences in age distribution patterns in urban and rural counties of São Paulo state, Brazil

Magdalene K. Walters[1], John M. Drake[2]

[1.]University of Notre Dame, Notre Dame, IN

[2.]Odum School of Ecology, University of Georgia, Athens, GA

Abstract

In 1997, São Paulo, Brazil experienced a measles outbreak with an unusually high average age of infection. It has since been hypothesized that this high age of infection was due to unvaccinated rural adults traveling to urban communities.[1] This project tested this hypothesis through the use of descriptive statistics and nonparametric analyses of variance. Evidence was found for varying adult transmission patterns between urban and rural communities. Forty-nine counties display a multimodal distribution of age of infection, and the rest were categorized as moderately multimodal or non-multimodal. The average outbreak size was significantly different between the multimodal, moderately multimodal, and non-multimodal counties. Counties which were not multimodal, displayed a high modal age of infection. Small outbreak sizes consistently displayed patterns associated with spread of infection between adults and evidence suggests a correlation between outbreak size and proportion of children infected.

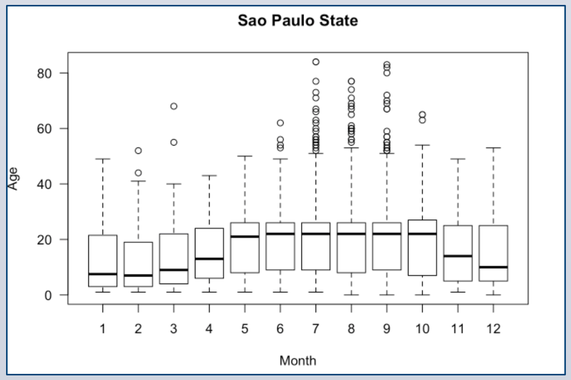
▶ Figure 1. São Paulo's location in Brazil.[2]

Introduction

- São Paulo state, Brazil experienced a large measles outbreak during the 1997 calendar year, with confirmed and clinical cases exceeding 22,000.
- This outbreak displayed an unusually high average age of infection during the middle of its course.
- Classical studies, such as Anderson and May 1985,[3] typically have identified children of primary school age (five to ten year olds) as spreaders and amplifiers of infection in measles outbreaks.
- The older than average age of infection seen in the São Paulo state outbreak contradicts this notion.
- Previous work[2] theorized that this older than expected age of infection was due to the immigration of unvaccinated adults from rural to urban areas.

This study examined how the age structure of an epidemic affects how it progresses in interacting, yet distinct, communities.

Data Visualization



▲ Figure 2. Age distribution of cases throughout the epidemic for Sao Paulo State. The average age of infection rose to approximately 20 years old in months five to ten. As indicated by the small difference between the mean and the 75 percentile, there was a large density of cases from ~20 to ~25 years of age during months 5-10.

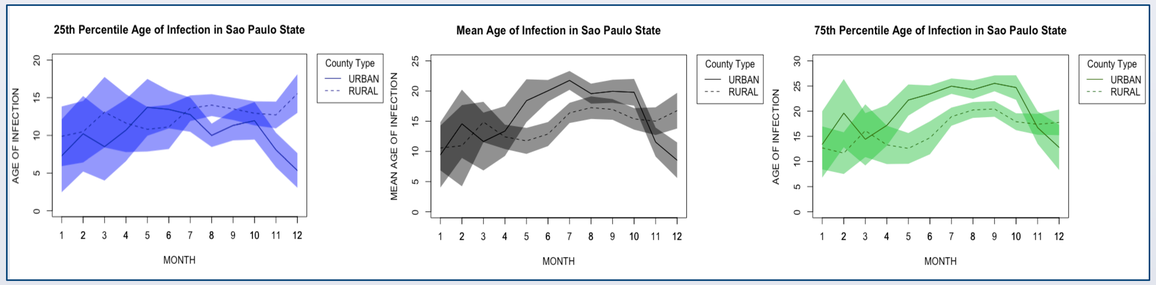
Research Questions

1. **How does the distribution of age of infection differ between urban and rural counties?**
2. **Do unimodal counties share a common mode with multimodal counties?**
3. **Are outbreak size and multimodality related?**

Methods

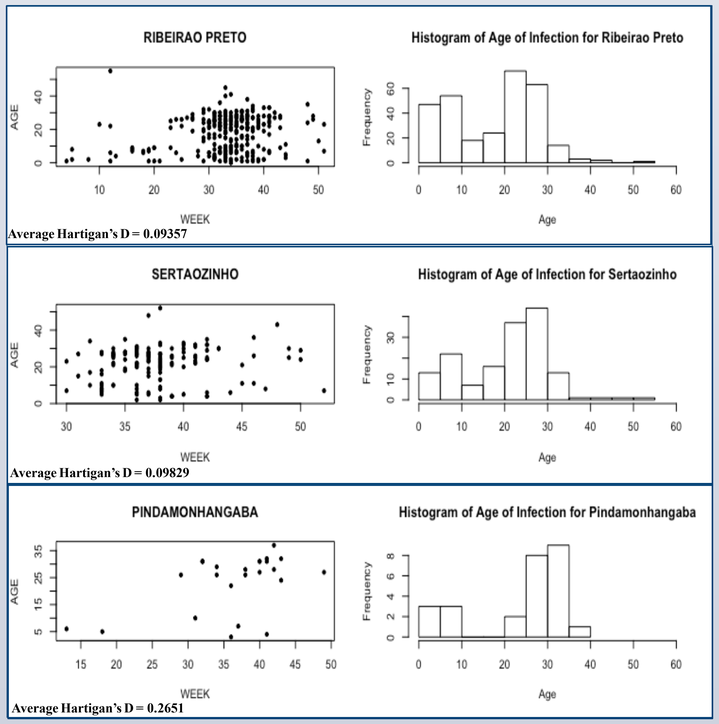
- Used the non-parametric Kruskall-Wallis test and bootstrapped 95% confidence intervals to examine differences of quartile values between urban and rural areas in São Paulo state throughout the course of the outbreak.
- Identified counties which display a multimodal distribution of age of infection with Hartigans' dip test.
- Used Kruskall-Wallis tests to determine if multimodality is related to outbreak size.

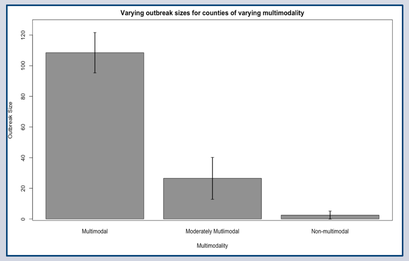
Results



▲ Figure 3. 25th percentile, mean, and 75th percentile values for urban and rural counties in Sao Paulo state. Urban age of infection tended to be higher than rural age of infection for the mean and 75th percentile. These values were found to be significantly different (Kruskall – Wallis one way analysis of variance $p_{mean} = 0.000597$ and $p_{75th} = 0.0008138$) between urban and rural counties. This can be visualized by the white space between bands, which represents the statistically significant difference between the quartile values for each county type. The lower quartile did not display a statistically significant trend when urban counties were evaluated against rural counties ($p_{25th} = 0.2159$). Bootstrapped 95% interval confidence bands are shown for each quartile value.

▶ Figure 4. Age of infection by week and cumulative frequency of age of infection for representative multimodal, moderately multimodal, and unimodal counties. Hartigan's dip test was used to evaluate whether a county displayed a multimodal age of infection. Forty-nine counties were found to be multimodal ($p < 0.025$ when adjusted by Holm-Bonferroni correction), twelve counties were found to be moderately multimodal ($p < 0.05$), and the remaining were determined to be unimodal. Moderately multimodal and unimodal counties consistently displayed a low amount of cases from 10-20 years old. The mean test statistic for each category is displayed.





▲ Figure 5. Median outbreak size for the three classes of multimodality. It was found that outbreak size differed significantly between the varying classes of multimodality (Kruskall – Wallis one way analysis of variance $p < 2.2 \times 10^{-16}$). Bootstrapped 95% confidence intervals for median outbreak size are shown as error bars.

Conclusions

Question One

- Infection did not spread uniformly among adults, but did spread uniformly among children (Figure 3).
- Urban age of infection was consistently older than rural age of infection- **indicating that urban individuals were more prone to avoid artificial and natural immunity against measles.**

Question Two

- When counties were not multimodal, they displayed a mode from 20-35 years of age (Figure 4). **This indicates that adults were the initial infectees when outbreak spread to a new county, and that children did not become infected until later in the county's outbreak.**

Question Three

- Non-multimodal counties experienced a significantly smaller outbreak size than those which were multimodal (Figure 5).
- Non-multimodal counties frequently exhibited a low amount of cases among children (Figure 4).
- **This suggests a correlation between outbreak size and proportion of cases which were children.**

The difference in age of infection among adults in urban and rural communities and high proportion of adult infections at small outbreak sizes supports the hypothesis that adults acted as spreaders of infection during the 1997 measles outbreak in São Paulo state, Brazil.

Future work

- Identify causes for adult susceptibility in urban areas.
- Identify the critical community size for counties in São Paulo state during the 1997 measles outbreak.
- Examine the critical community size's effect on age of infection distribution in counties which do not meet it.
- Determine the correlation between outbreak size and proportion of cases under ten years old (i.e. children).
- Develop a gravity model with parameters which represent the difference in spread between urban and rural communities, the amount of adults in a county, and economic factors which would cause immigration to urban areas.

References

[1.] Cassio De Moraes, José, Maria Claudia Corrêa Camargo, Maria Lúcia Rocha De Mello, Bradley Hersh, and John Glasser. "The 1997 Measles Outbreak in Metropolitan São Paulo, Brazil: Strategic Implications of Increasing Urbanization." *Mathematical and Statistical Modeling for Emerging and Re-emerging Infectious Diseases.* Ed. Gerardo Chowell and James Hyman. 1st ed. N.p.: Springer International, 2016. 269-89. Web.

[2.] "São Paulo." *Encyclopædia Britannica*. Encyclopædia Britannica, Inc., n.d. Web. 14 July 2017.

[3.] Anderson, R. M., and R. M. May. "Age-related Changes in the Rate of Disease Transmission: Implications for the Design of Vaccination Programmes." *Journal of Hygiene* 94.03 (1985): 365-436. Web.

Acknowledgements

Thank you to the Drake lab for guidance and feedback on this project.

Population Biology of Infectious Diseases

REU site @ UGA

Contact: mwalte10@nd.edu