What's in a Wave: Using COVID-19 Data to Explore the Definition of Epidemic Waves

Joshua Smith-Sreen, MPH,[1] Jorge Ledesma, MPH,[2] Mark N. Lurie, PhD[2]

1. Warren Alpert Medical School of Brown University, Providence; 2. Department of Epidemiology, Brown University School of Public Health

INTRODUCTION

- Epidemic and pandemic wave definitions are crucial public health tools to help predict surges and optimize resource allocation
- Literature offers various wave definitions, many emerging during the COVID-19 pandemic, yet there lacks consensus on their applicability and effectiveness
- Accurately defining and characterizing pandemic waves is vital for enhancing pandemic preparedness and response strategies.
- **Aim:** To apply and evaluate multiple wave definitions using COVID-19 case data from the United States and South Africa

METHODS

- Data Sources: Daily US COVID-19 case data from February 2020 to March 2022 from the Institute of Health Metrics and Evaluation and Johns Hopkins University COVID-19 data repository.
- We identified and operationalized three existing wave definitions using the following approaches:
  - **eR Approach**: waves defined as periods where the effective reproduction number (eR) > 1 for at least 14 days, using a Bayesian framework developed by Cori and colleagues
  - **Fold Approach**: waves defined as periods where the weekly case rate increased by at least one-fold followed by at least a one-fold decrease
  - **Threshold Approach**: waves defined as periods where the weekly case rate per 100,000 population surpassed 49.99, the US Centers for Disease Control threshold for moderate community transmission.
- We generated summary statistics and visualized epidemic curves for comparison

RESULTS

Table 1. Summary characteristics of wave definition approaches applied to United States and South Africa

Approach	Number of Waves, n	Time between Waves, days (IQR)	Wave Duration, days (IQR)	In-Wave Daily Case Rate per 100,000 mean (95% CI)	Between-Wave Daily Case Rate per 100,000 mean (95% CI)
eR approach					
United States	5	83 (42-111)	25 (7-44)	26.4 (23.8, 29.2)	12.5 (10.6, 14.6)
South Africa	5	129 (111-139)	94 (85-109)	11.3 (10.0, 12.7)	2.12 (1.79, 2.49)
Fold approach					
United States	10	25 (7–44)	47 (29–54)	19.7 (17.2, 22.5)	15.9 (13.9, 18.2)
South Africa	9	22 (6-27)	58 (22-106)	5.0 (4.4, 5.7)	2.4 (1.8, 3.1)
Threshold Approach					
United States	2	62	276 (251–301)	30.4 (28.6, 32.3)	3.7 (2.9–4.7)
South Africa	4	94 (73-122)	59 (46-63)	20.0 (19.2, 20.9)	2.89 (1.6, 2.2)

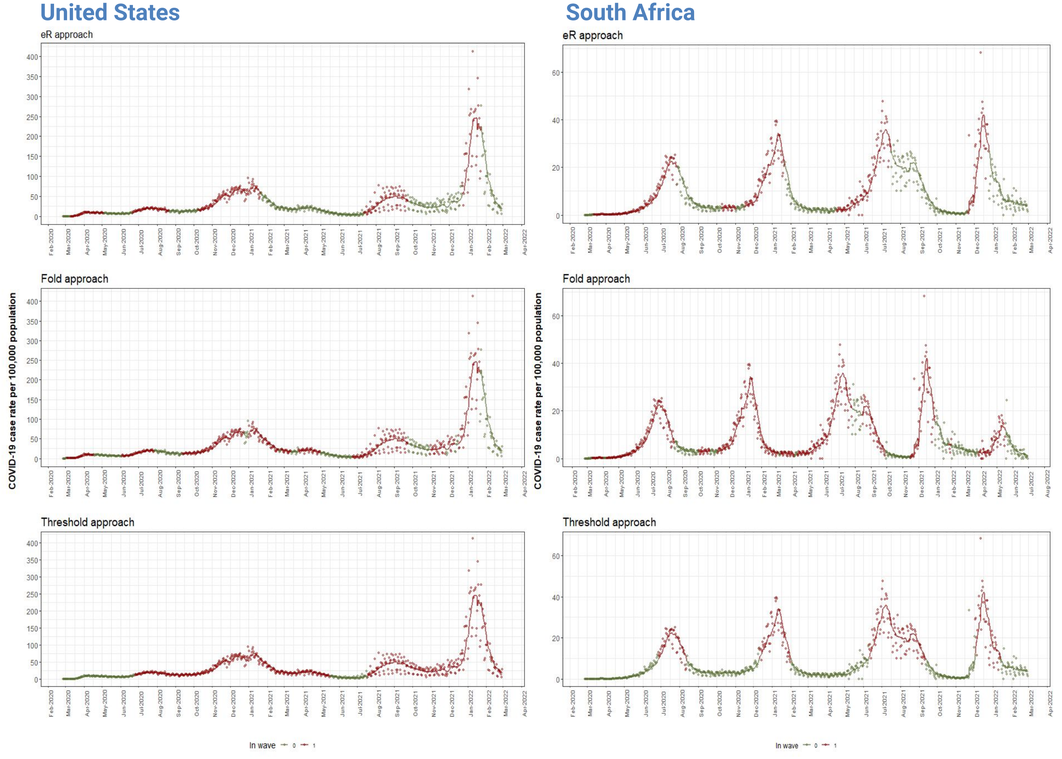


Figure 1. COVID-19 case rate in United States and South Africa with applied wave definitions, Feb 2020-Mar 2022

DISCUSSION

- **Fold Approach**: produced greatest number of waves, suggesting high sensitivity to weekly case rate fluctuations
- **Threshold Approach**: produced highest in-wave average case rate and the lowest between-wave average case rate, suggesting th-pat this approach may not appropriately capture inflection periods
- **eR approach**: may prove most generalizable across diseases given this approach is defined based on innate biology of the pathogen
- **Limitations**:
  a. Each approach is retrospective, requiring existing data, thus limiting their predictive capability
  b. No definition of 'success' was incorporated in this analysis, limiting our ability to recommend a particular approach

CONCLUSION

- The analysis characterized three approaches to defining and quantifying epidemic waves, utilizing example COVID-19 data
- The fold approach appears most sensitive to fluctuation, which if applied in pandemic response settings may lead to overly-rapid policy changes
- The threshold approach may not capture inflection periods, when disease may be spreading
- To build consensus and increase the public health utility of these approaches, further work may include
  a. More robust characterization and application is required across **countries**, **income settings** and **pathogens**
  b. Adjusting data for country-level test positivity and test availability
  c. Identifying predictors of wave features across approaches