Protective Population Behavior Change in Outbreaks of Emerging Infectious Disease

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Introduction

In outbreaks of emerging infectious disease, a lack of effective drugs and vaccines increases reliance on public health interventions and behavior change to limit human-to-human transmission. Isolation, hospitalization, and barrier-nursing practices are crucial for controlling disease spread in these contexts. In emerging infections, many public health interventions aim at increasing the speed at which infected individuals remove themselves from a susceptible population, limiting opportunities for infection (**Fig. 1**).

Ebola virus disease (EVD), Severe Acute Respiratory Syndrome (SARS), and Middle East Respiratory Syndrome (MERS) are all diseases caused by zoonotic viruses with high mortality and the potential for human-to-human transmission. All have caused significant outbreaks in the past, infecting thousands (**Fig. 2**) with international spread (**Fig. 3**).

$$S \xrightarrow{\beta} E \xrightarrow{\sigma} I \xrightarrow{\gamma} R$$

Fig. 1 – SEIR Model *– Commonly used model for infectious disease epidemiology where individuals are* ***S****usceptible,* ***E****xposed,* ***I****nfected, or* ***R****ecovered. Epidemic containment requires that γI exceed βI. Here we use γ as the time from symptom onset to removal from a susceptible population.*

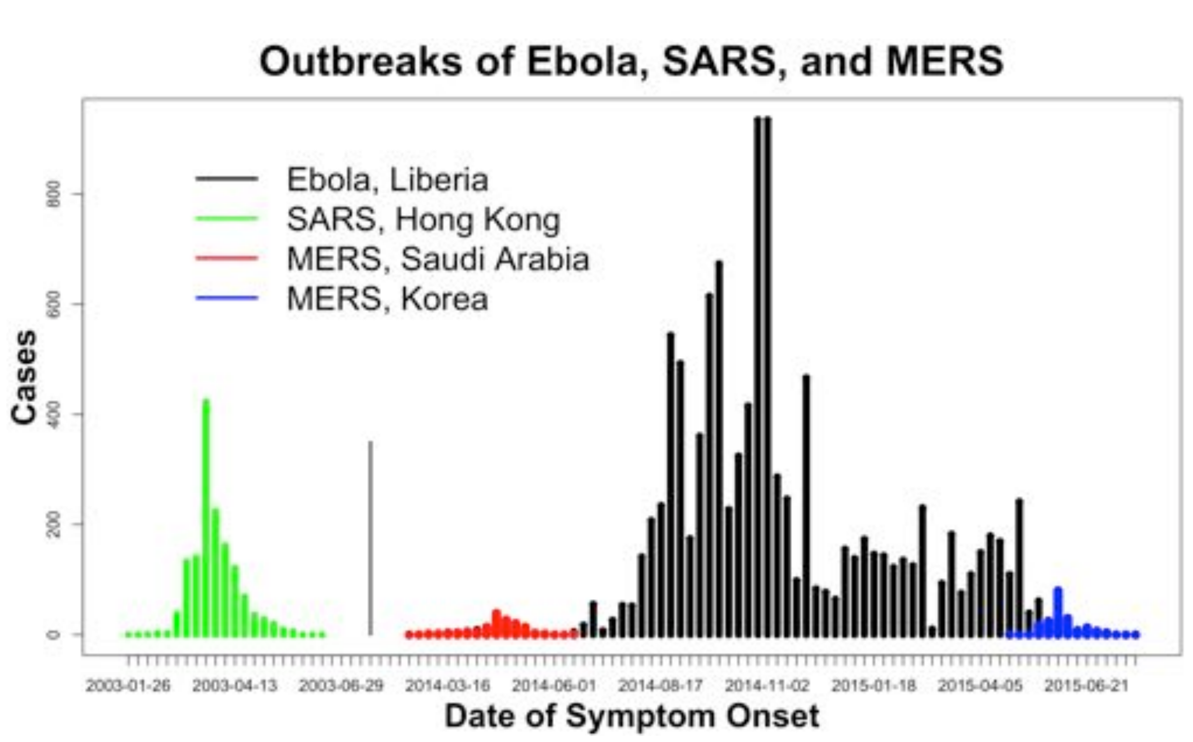

Fig. 2 – Epidemic Curves *– Curves from the Liberian Ebola outbreak, Hong Kong SARS outbreak, Jeddah and Riyadh (Saudi Arabia) MERS outbreaks, and South Korean MERS outbreak show relative outbreak sizes.*

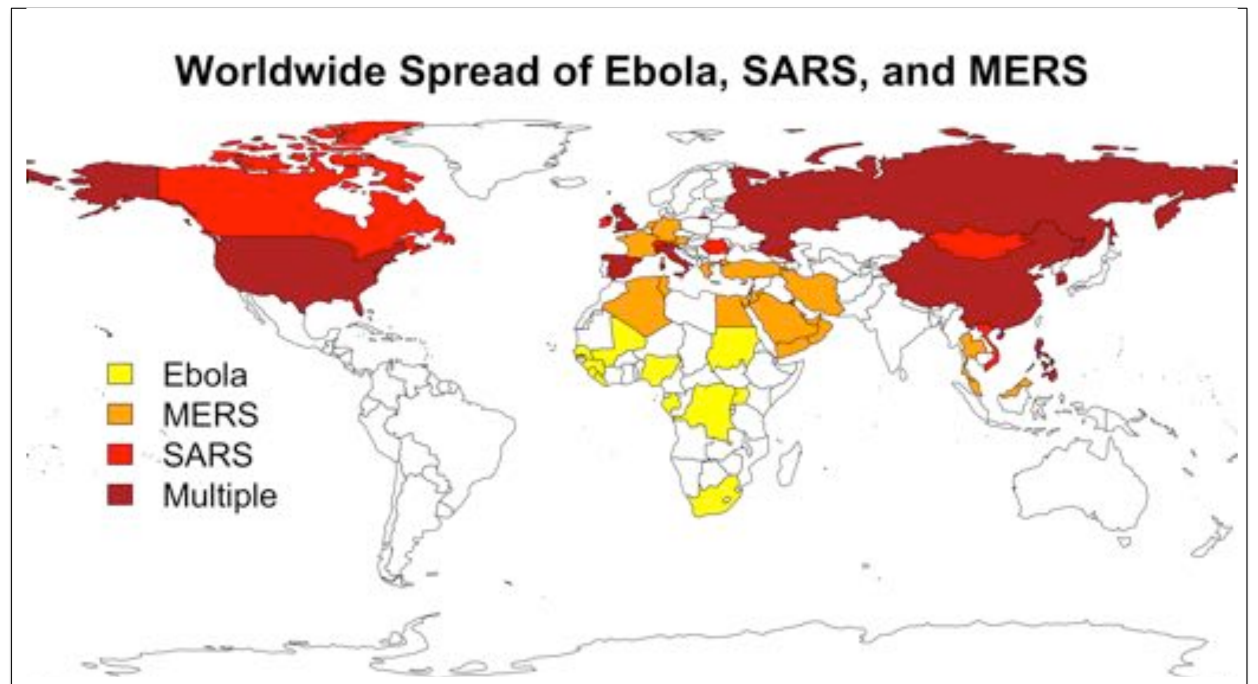

Fig. 3 – Outbreak Map *– Shows local transmission and international travel of Ebola, SARS, and MERS.*

Objectives

1. Quantify changing removal rates, burial practices, and contact tracing in outbreaks of emerging disease.
2. Estimate the rate at which γ (**Fig. 1**) increases in each of seven outbreaks:
   - **a. Ebola –** Liberia, Lofa County, Montserrado County
   - **b. MERS –** Riyadh and Jeddah (Kingdom of Saudi Arabia), South Korea
   - **c. SARS –** Hong Kong

Methods

Organization – Data were collected from collaborators (see acknowledgements). Ebola and MERS data are patient level with symptom onset and hospitalization dates when available. SARS data was previously aggregated by date. The following variables were calculated using R:

- **a.** days, symptom onset to isolation/hospitalization
- **b.** γ (1/days from onset to isolation or hospitalization)
- **c.** days, death to burial (Ebola only)
- **d.** contacts traced per patient (SARS only)

All data were organized by location, epidemic week, and serial interval (time between illness onset of a primary and secondary case – 12 days in Ebola[1], 8 days in SARS[2], and 7 days in MERS[3]).

Visualization and Analysis – Robust linear models (limit the impact of outlying data) weighted by number of cases per serial interval were used to calculate rates of change. Differences between models were characterized with analyses of covariance in reference to each outbreak location.

Results

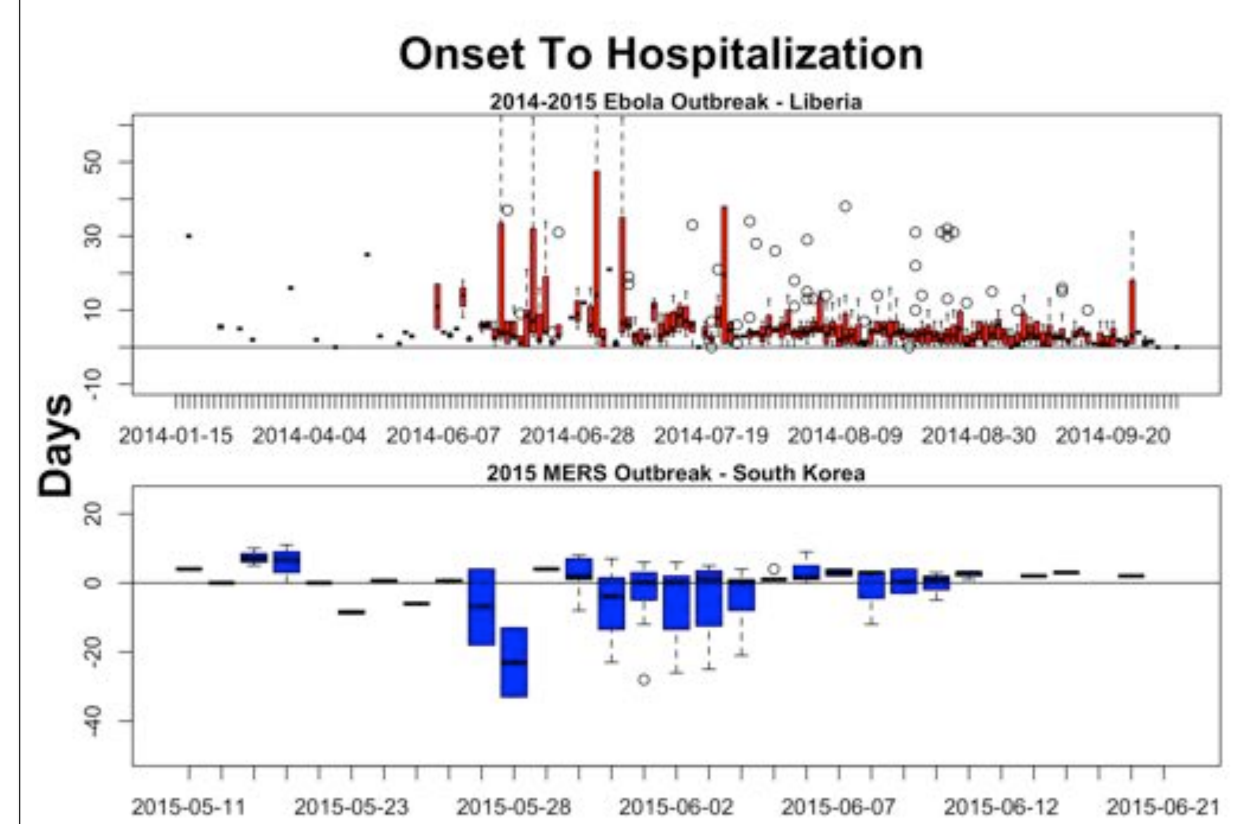

Fig. 4 – Days, Onset to Hospitalization*– Outbreaks with limited hospital transmission vs. extensive nosocomial spread show very different patient level data patterns.*

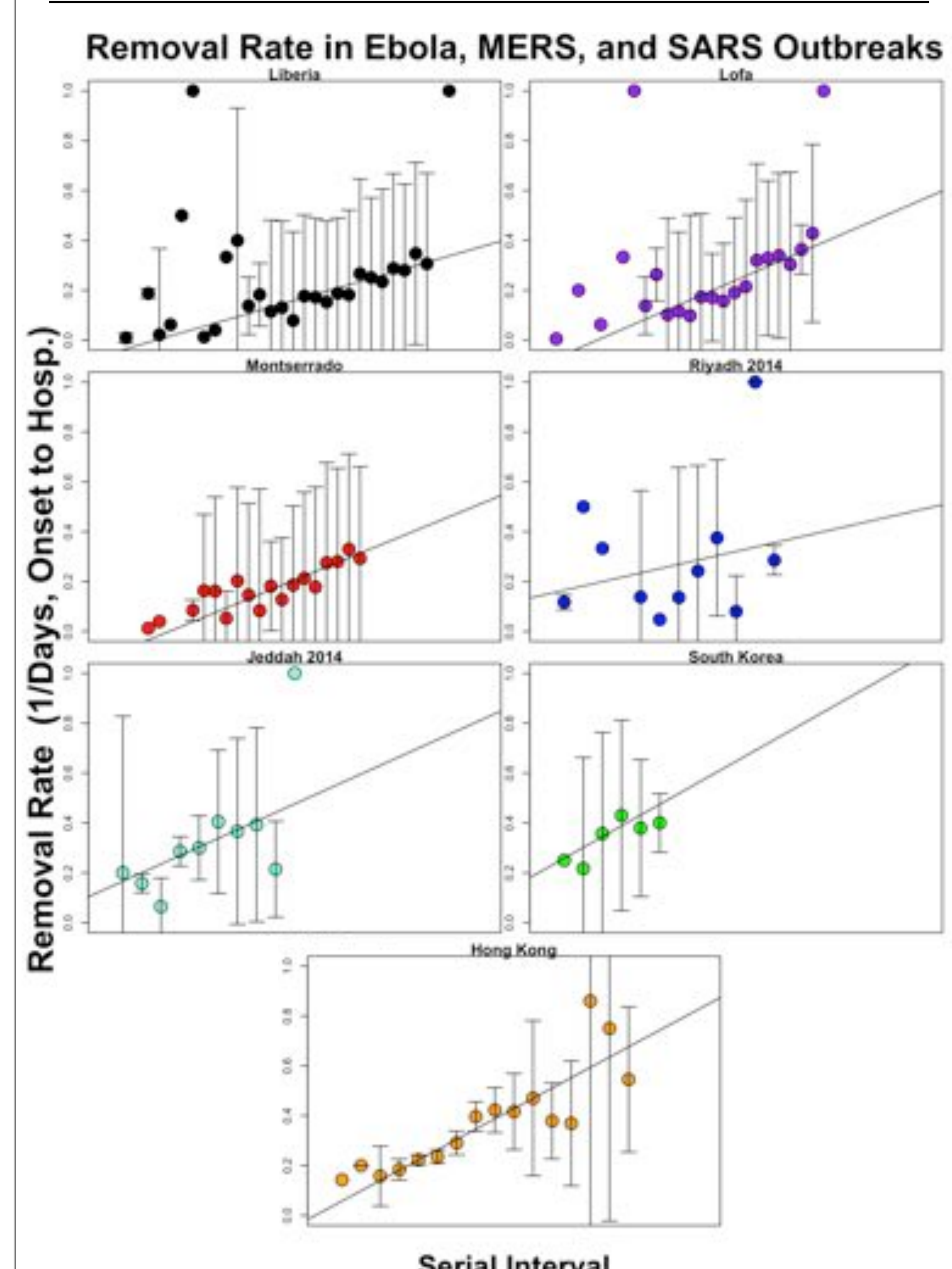

Fig. 5 – Regression Models *– show robust regression models weighted by the number of cases per serial interval. Include only non-nosocomial infection events to focus on community behavior.*

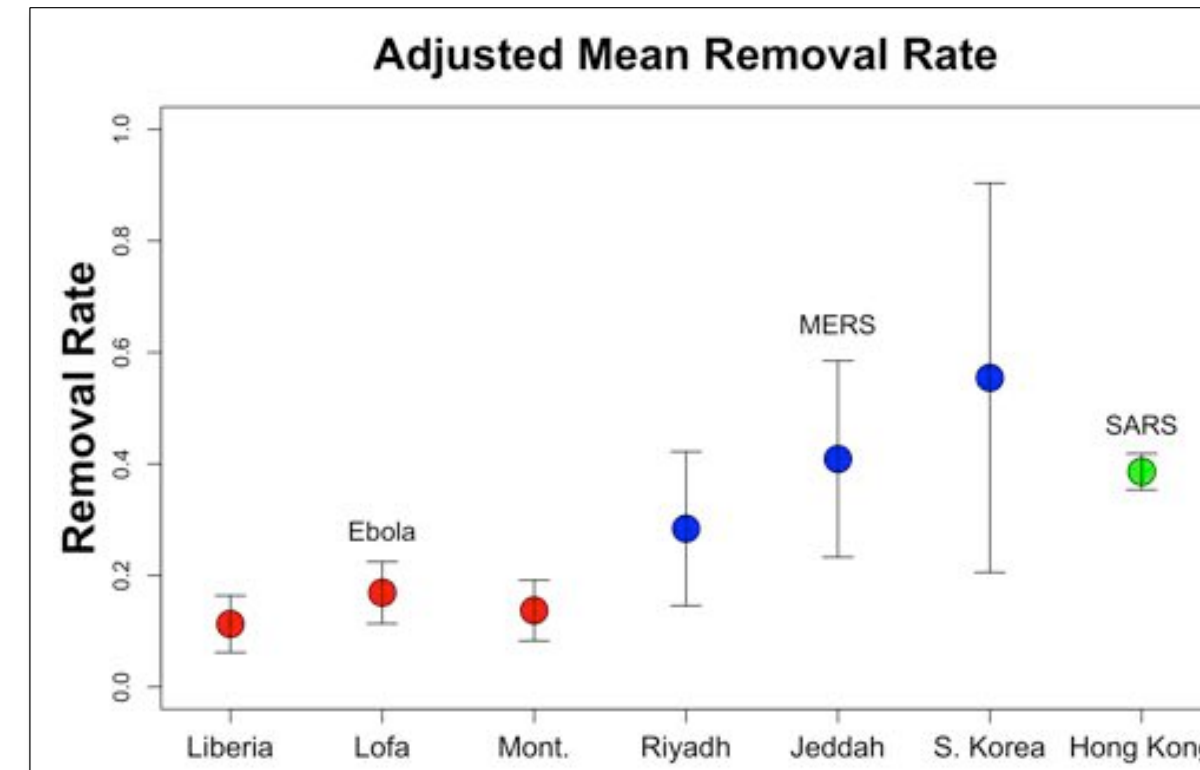

Fig. 6 – Mean Removal Rate by Serial Interval *– Plots are adjusted mean removal rate with 99% CI (from Bonferroni correction for multiple comparisons).*

Conclusions

1. Health behavior development requires that individuals are afraid of potential infection and believe behavior changes will lower infection risk. This requires different public health strategies with community and nosocomial transmission (**Fig. 4**).
2. Although the selected outbreaks are virally and geographically distinct, analysis of changes in removal rate show remarkable similarity (**Fig. 5**).
3. The adjusted mean removal rate of the Hong Kong SARS and Liberian Ebola outbreaks are statistically distinct at 0.386 and 0.113 (**Fig. 6**). Analyzing outbreaks by serial interval instead of epidemic week decreases variation between mean removal rates, indicating that behavior change depends on both viral biology and calendar time.

Acknowledgements

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References – [1]Chowell & Nishiura *BMC Med.* 2014, **12**:196, [2]Wallinga & Teunis *Am. J. Epidemiol.* 2004, **160**:509, [3]Assiri et al *N. Engl. J. Med.* 2013, **369(5)**:407.