Epidemic Modeling and Facemask Usage

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Evidence from the 2003 severe acute respiratory syndrome (SARS) epidemic and 2009 H1N1 influenza pandemic shows that facemasks can be an effective non-pharmaceutical intervention in minimizing the spread of airborne viruses. Recent studies have shown that the use of facemasks is correlated to an individual's age and gender, where females and older adults are more likely to comply than males or youths. We use the EpiSimS agent-based simulation to model the use of facemasks and quantify their impact on three levels of influenza epidemic. Our results show that facemasks alone have limited impact on the spread of influenza except to the wearer. However, when facemasks are combined with other interventions such as hand sanitizer, they can be more effective. We also observe that monitoring Twitter can be a useful technique to measure compliance. We conclude that educating the public on the effectiveness of masks to increase compliance can reduce morbidity and mortality.

Pharmaceutical interventions such as vaccines and antiviral medication are the best defense for reducing morbidity and mortality during an influenza pandemic. However, the current egg-based vaccine production process can take up to six months for the development and availability of a strain-specific vaccine and antiviral supplies may be limited. Fortunately, alternative strategies, such as non-pharmaceutical interventions, can reduce the spread of influenza until a vaccine becomes available. Facemasks have been used to combat airborne viruses such as the 1918–1919 pandemic influenza, the 2003 SARS outbreak, and the most recent 2009 H1N1 pandemic. These studies indicate that if facemasks are readily available, they may be more cost-effective than other non-pharmaceutical interventions, such as school and/or business closures.

We focus on the use of surgical facemasks and N95 respirators. A surgical facemask is a loose-fitting, disposable device that prevents the release of potential contaminants from users into their immediate environment. They are designed primarily to prevent disease transmission to others, but can also be used to prevent the wearer from becoming infected. If worn properly, a surgical mask can help block large-particle droplets, splashes, sprays, or splatter that may contain germs (viruses and bacteria) and may also help reduce exposure of saliva and respiratory secretions to others. By design, they do not filter or block very small particles in the air that may be transmitted by coughs or sneezes.

A survey paper on demographic determinants of protective behavior [1] showed that compliance in using facemasks is tied to age and gender. They observed that females and older adults were more likely to accept protective behaviors than other population groups. Supporting these ideas, use of facemasks was consistently higher among females than male metro passengers in Mexico City during the 2009 H1N1 pandemic [2]. Limited studies suggest that there is more social stigmatization associated with wearing facemasks in western countries than in Asia. For example, people rarely wear facemasks in public in the US, compared with their use in Japan and China. An article published in 2009 by *New York Times Health* reported that "masks scare people away from one another" resulting in an unintentional social distancing measure or "stay away" factor. During the 2003 SARS outbreak, non-pharmaceutical interventions, where implemented, were seen to follow the epidemic curve [3]. That is, as the perception of SARS increased, more measures were implemented, and as the incidence declined, several measures were relaxed.

Influenza epidemics of varying strengths (high, medium, low) were modeled using EpiSimS [4] [5] to compare the impact of facemask usage on controlling disease spread. These different levels share a similar disease progression. The high-level epidemic is based on the 1918–1919 H1N1 "Spanish flu" outbreak and has high morbidity and mortality, the medium level is based on the 1957–1958 H2N2 Asian flu, and the low level is based on the more recent 2009 novel H1N1 flu. The number of hospitalizations and deaths were extrapolated from the US population during the represented pandemic year to the US synthetic population (based on 2000 census data). The attack rate (percentage of population infected), clinical attack rate (percentage of population symptomatic), hospital rate (hospitalizations out of population), and mortality rate (deaths out of population) are shown for each strength in Table 1. Figure 1 shows each of their respective epidemic curves for the new symptomatic as a function of time.

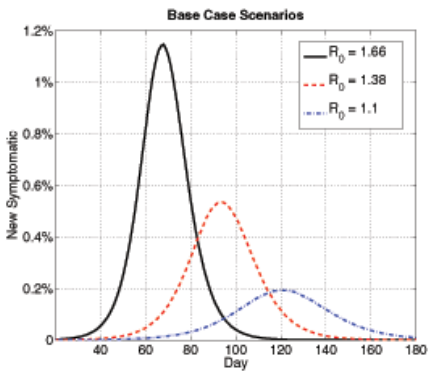

Fig. 1. Base case simulation results for the three different epidemic strengths, showing the percentage of the population that becomes symptomatic per day.

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***Table 1**. Epidemic parameters associated with high, medium, and low strengths of epidemic.*

Epidemic Level	Attack Rate (%)	Clinical Attack Rate (%)	Hospital Rate (%)	Mortality Rate (%)
High	40.0	30.0	0.500	0.300
Medium	30.0	19.7	0.250	0.100
Low	20.0	10.0	0.008	0.015

For any intervention, it is important to measure the rate at which it is actually happening. Non-pharmaceutical interventions, such as the wearing of facemasks, presents special problems in this regard because the decision to comply or not comply is an individual one that takes place away from observation by health providers. The social internet system, Twitter, was used to evaluate two conjectures: (1) that the level of facemask wearing follows the disease incidence level, and (2) that analysis of the public Tweet stream is a feasible technique to measure compliance with facemask wearing (and, by implication, other behaviors relevant to infectious disease). To do so, we analyzed Tweets (with a simple keyword-based approach) published globally between September 6, 2009, and May 1, 2010, roughly corresponding to the H1N1 pandemic flu season in the US. Results are shown in Fig. 2. We compare our Twitter mention and observation counts against influenza-like illness (ILI) data published by the Centers for Disease Control (CDC). The correlation is excellent—0.92 for mentions and 0.90 for observations. We expect future efforts to deepen this capability, providing results segmented by locale or demographics.

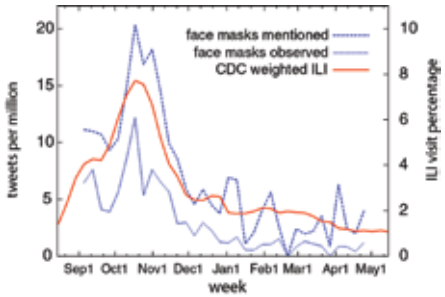

Fig. 2. Comparison of Twitter mention and observation counts against ILI data published by the CDC.

Facemask mitigation strategies were considered for surgical masks and N95 respirators. All scenarios began when 0.01% or 1.0% of the population was symptomatic. Usage was based on age and gender and followed the course of the epidemic. Effectiveness was based on previous testing. Our results show that, in general, facemasks have an impact on reducing the overall incidence and extending the length of the epidemic. Masks alone reduce the clinical attack rate, on average, by over 10% for the entire population and 50% for the population that wears facemasks. Furthermore, the results are consistent with other studies concluding that the earlier interventions are put in place, the greater the impact they have on reducing morbidity and mortality.

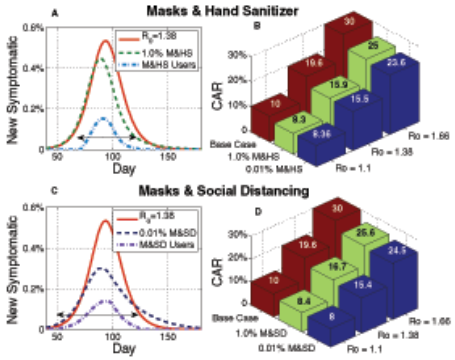

Fig. 3. Results of surgical masks and hand sanitizers (top) and masks and social distancing (bottom).

We compare the impact of combining facemasks with hand sanitizers (M&HS) or with social distancing (M&SD). M&HS are assumed to reduce the transmission rate by 50% and M&SD are assumed to reduce the transmission rate by 30%. Figure 3, parts A and C, shows the epidemic curves when M&HS are implemented after 1.0% of the population is symptomatic and M&SD when 0.01% of the population is symptomatic, respectively. In addition to showing the overall dynamics of these two interventions, we show the epidemic curve for individuals who adopted the specified behavior, but who still became infected. Note that although the clinical attack rate was only reduced by 19% and 21% for these two scenarios, the clinical attack rate for M&HS users was only 3.6% or an 81% reduction. Similarly, the clinical attack rate for the M&SD users is 4.7% or a 76% reduction from the base case. Parts B and D show the clinical attack rate for various assumptions of the M&HS and M&SD scenarios and all the different pandemic levels. Not surprisingly, our results show that facemasks are more effective when coupled with other interventions.

We conclude that for mathematical models of infectious diseases to be useful in guiding public health policy, they need to consider the impact of non-pharmaceutical interventions. Facemasks can be a cost-effective intervention when compared to closures; therefore, public health campaigns should focus on increasing compliance. Additionally, measuring the effect of these campaigns should include analysis of social internet systems and other emerging data sources. The results presented here are useful in providing estimates of the effects of non-pharmaceutical interventions on the spread of influenza.

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