Seasonal influenza in medical students: an outbreak simulation model based on a social network approach.

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Introduction

There is increasing interest in the effects of social networks on disease dynamics. We simulated the spread of influenza through a population of medical students where transmission was related to the social network structure and vaccination status of individuals.

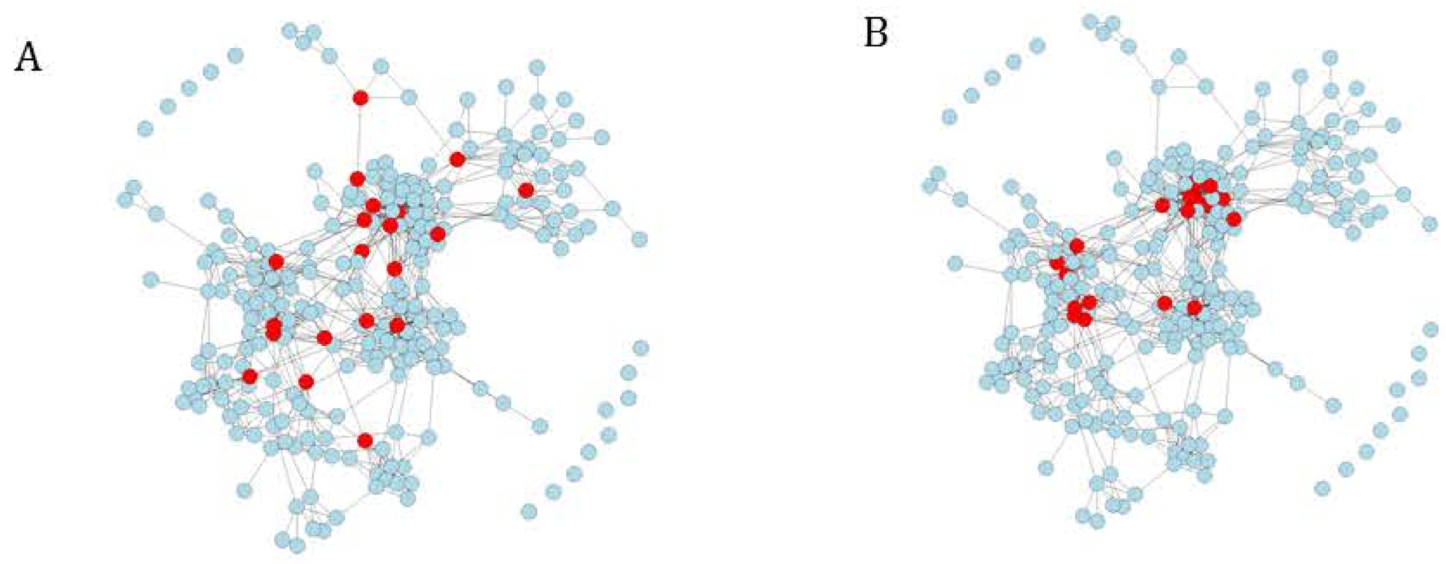
Healthcare workers (HCWs) in the UK are encouraged to have a seasonal influenza vaccine by the Chief Medical Officer (CMO) (1). However, currently only 55% of HCWs are immunised against the influenza virus (2). We investigated how to identify individuals to target for vaccination, in a sporadically-vaccinated population of medical students.

Social network analysis (SNA) is a quantitative method of studying the structure derived from patterns in the relationships among social entities. In social network analysis, between-ness and degree are measures of an individual's 'connectivity' within the network. Between-ness measures to what extent an individual lies between others within the network, thus its ability to act as a 'gatekeeper' (3). Degree refers to the number of connections an individual has, in this case the number of other Lancaster Medical Students they know (4).

Key Points:

- **Using an individual-based model we simulated an influenza outbreak on a medical student social network.**
- **We found that vaccination strategies based on degree and between-ness had similar outcomes.**
- **Both strategies were better than random vaccination.**

Figure 1: The LMS social network, dichotomised at household contacts only, individuals are highlighted in red with the highest between-ness (A) and degree (B) scores. Although there is some overlap, these two measures of connectivity provide us with different sets of influential individuals.



Methods

Participants/setting

All students at Lancaster Medical School, Lancaster University, UK (n=253) were asked to rate the strength of their relationship with all other students from the medical school, on a six point scale from: "I do not recognise this person" to "I live with this person". Students also self-reported their influenza vaccination status. Data were collected during winter 2013/14 using a paper-based questionnaire.

Simulation model

Once influential individuals had been identified using network analysis tools, we tested whether or not vaccinating these individuals would have different effects on the influenza outbreaks within the network. An individual-based outbreak model was developed using R statistical software (5).

By combining the network data with appropriate transmission parameters (see below), we simulated an influenza outbreak within the network and assessed the effects of preferentially vaccinating individuals according to the social network analysis data.

Transmission parameters:

- Relationships: for the purposes of the simulation, students were judged as having significant contact if they lived together or met more than three times a week.
- Vaccine efficacy: the current vaccination approach is reported as 75% effective against influenza (6).
- Transmission probabilities: the literature suggests that 11% of un-vaccinated close contacts become infected with the influenza virus based on the H1N1 equivalent (probability 0.11) (7); this transmission probability was reduced to 0.0286 for students who chose to vaccinate.
- Recovery; the probability of recovery was set at 0.334, based on a recovery time of 3 days and did not vary within the population.

When targeting vaccination within the model we chose un-vaccinated individual's with the highest scores for between-ness and degree to vaccinate to test the effects on the simulated outbreak of influenza. In each experiment the simulation ran 1500 times and was also run with random vaccination. We calculated the percentage number of times each individual was infected out of the 1500 outbreaks (Figure 2).

Findings – part 1

Social Network Analysis

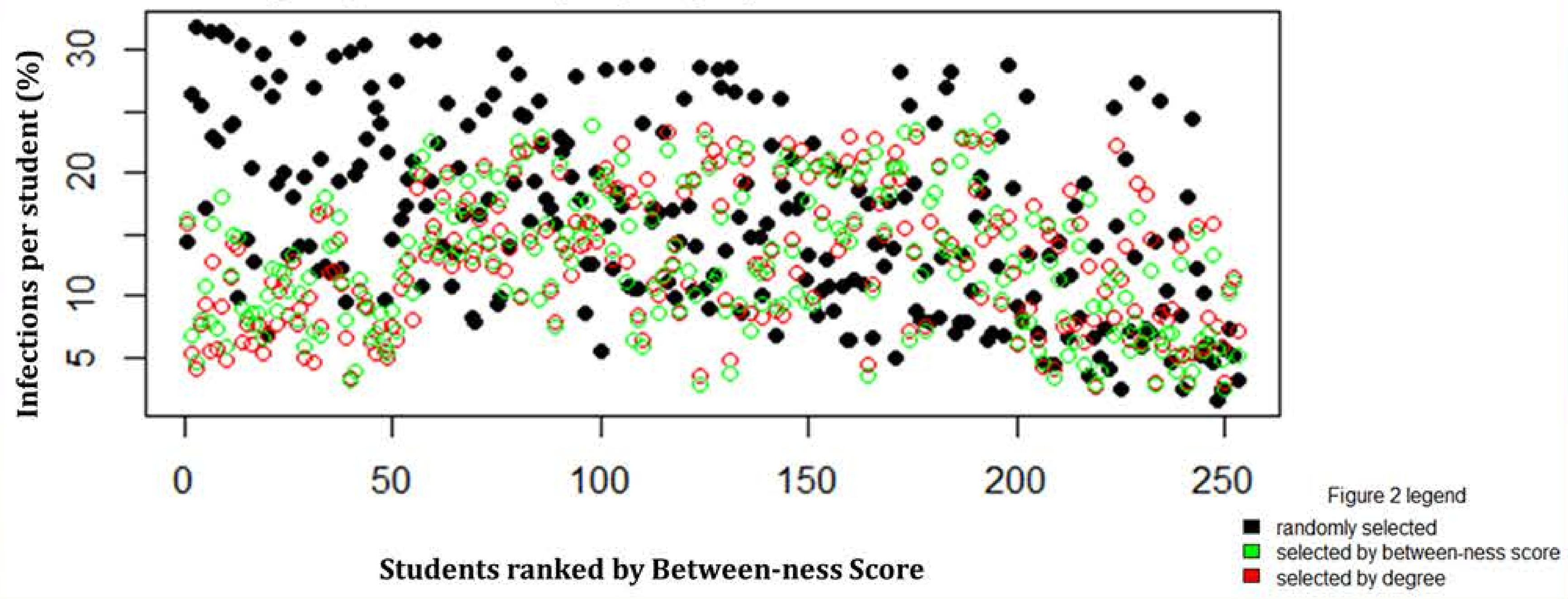
Two hundred and fifteen students (85%) responded. Average vaccine uptake in the LMS is 56%. Non-responders were assumed to have reciprocal relationships with responders; therefore it was possible to construct the entire medical student network. A basic network analysis allowed us to score individuals for between-ness and degree, the highest scoring individuals for each of these measures are shown in red in Figure 1.

Findings – part 2

Simulation model

We found that the outcomes of vaccination strategies based on between-ness and degree quickly converged. As more individuals were vaccinated, the likelihood of individuals contracting the infection tended to be similar, irrespective of vaccination based on between-ness or degree. After vaccination of an additional 8% of the population (20 students) the outcome of the experimental influenza outbreak was similar for both strategies. Both methods of selection were considerably better at reducing the incidence of influenza in the simulations when compared with a random vaccination policy (Figure 2).

Figure 2: A scatter plot showing the percentage number of times each individual was infected during the 1500 flu outbreak simulations, during the conditions: random vaccination (black), vaccination by between-ness (green); vaccination by degree (red).



Discussion /Future work

This study is part of a wider programme of work that advocates the application of social network analysis in epidemiological studies. We suggest that network analysis can highlight subtle details within a population, which can have a disproportionate effect on disease dynamics within a network. Selective vaccination appears to be more advantageous than random vaccination.

The results of the influenza outbreak simulation were similar for vaccination strategies according the degree and between-ness. We suggest that the most suitable method of selecting individuals to vaccinate is based on their degree, as this requires only basic data collection methods and can avoid a full social network analysis.

Continuing this programme of work we intend to use perform a SNA on the influenza vaccination tendencies of a large population of Foundation Doctors during winter 2014//15. We plan to use the modelling techniques developed here to test the CMO's vaccination target of 75%.

Acknowledgments

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References

1. www.gov.uk/government/organisations/public-health-england/series/immunisation (nov, 2014)
2. https://www.gov.uk/government/organisations/public-health-england/series/vaccine-update (nov, 2014)
3. Freeman LC. Centrality in social networks conceptual clarification. Social networks. 1979;1(3):215-39.
4. Skowronski D, Chambers C, Sabaiduc S, De Serres G, Dickinson J, Winter A, et al. Interim estimates of 2013/14 vaccine effectiveness against influenza A (H1N1) pdm09 from Canada's sentinel surveillance network, January 2014. Euro Surveill. 2014;19(5).
5. R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.
6. Nieminen J. On the centrality in a graph. Scandinavian Journal of Psychology. 1974;15(1):332-6.
7. Calatayud L, Kurkela S, Neave P, Brock A, Perkins S, Zuckerman M, et al. Pandemic (H1N1) 2009 virus outbreak in a school in London, April–May 2009: an observational study. Epidemiology and infection. 2010;138(02):183-91.