

Title: Beyond instantaneous partnerships: capturing partnership-level herd effects in compartmental models of sexually transmitted infections

Authors: Jesse Knight^{1,2} and Sharmistha Mishra^{1,2,3,4}

¹MAP Centre for Urban Health Solutions, Unity Health Toronto

²Institute of Medical Science, University of Toronto

³Dalla Lana School of Public Health, University of Toronto

⁴Division of Infectious Diseases, Department of Medicine, University of Toronto

Conference: Society for Medical Decision Making: 44th North American Meeting

Category: Quantitative Methods and Theoretical Developments

Submitted: June 6, 2022

Abstract: **PURPOSE.** For decades, standard compartmental models of sexually transmitted infections have simulated sexual partnerships as “instantaneous”. However, this instantaneous approach can bias model dynamics and outputs, such as underestimating the impact of preventing transmission in sex work. We developed a new approach to simulating sexual partnerships in compartmental models which moves beyond the instantaneous paradigm, and avoids these biases.

METHODS. In the instantaneous approach, people change partners at least once per year, or faster for shorter and/or simultaneous partnerships per-person. Then, a fraction of people changing partners become infected, reflecting the cumulative probability of transmission per-partnership/year (Figure a, left). In the proposed approach, we define a rate of transmission per-partnership, reflecting sex frequency; such rates can be summed across simultaneous partnerships per-person. Then, we track the number of people who recently transmitted or acquired infection; we decrease by one the effective numbers of partners among these people, until they form a new partnership, determined by partnership duration (Figure a, right). We integrated the proposed approach, and the instantaneous approach, separately, into a model of heterosexual HIV transmission in Eswatini. After calibrating the model under the proposed approach, we compared modelled HIV incidence under the proposed versus the instantaneous approach, with the same model parameters.

RESULTS. Incidence under the instantaneous approach was consistently greater than under the proposed approach, with relative differences growing over time (Figure b). These differences can be explained mechanistically as follows. As prevalence increases, both approaches capture population-level herd effects: reduced onward transmission from each infection due to *new* partnerships forming between two infected people (assumed to be at random). However, the proposed approach also captures partnership-level herd effects: reduced transmission due to *existing* partnerships continuing between two infected people following transmission. These continuing partnerships cannot be modelled in the instantaneous approach, and so infected individuals are assumed to be immediately at risk of onward transmission. Thus, as partnership-level herd effects accumulate over time, relative differences in incidence under the instantaneous versus the proposed approach also grow over time.

CONCLUSIONS. Modelling sexual partnerships as instantaneous can cause compartmental models of HIV transmission to overestimate HIV incidence, especially in mature and declining epidemics. The proposed approach offers a generalizable solution to move beyond instantaneous partnerships in compartmental models of sexually transmitted infections, and captures key epidemic dynamics related to partnership-level herd effects.

Limits: 134 / 150 title characters

384 / 375 abstract words

Keywords: compartmental models, incidence, sexual behavior, sexually transmitted disease, HIV, herd effects

Figure:

