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Studying the effect of pre-exposure prophylaxis on the dynamics of different populations susceptible to HIV

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Pre-exposure prophylaxis is a useful method for the preventing the transmission of HIV to susceptible individuals. What target population would provide the biggest impact on HIV dynamics? To answer this question, we present a differential equation model stratified by behavioural risk and sexual activity. Some susceptible individuals have higher rates of risky behaviour that increase their chance of contracting the disease. Similarly, infected individuals with risky behaviours are at higher risk of transmitting the disease to a susceptible individual. We further divide the infected population by their diagnosis status. We define model parameters for both the urban case, or high-density sexual network, and the national case, or mixture of low- and high-density sexual network. Our results indicate that the undiagnosed high-risk infected group is the largest contributor to the epidemic. Our model suggests that when pre-exposure prophylaxis is applied to the susceptible populations, its effectiveness extends outside of the group that is taking the drug, providing herd immunity. Our models suggest that a strategy targeting the high-risk susceptible population would have the largest impact. We also find that such a protocol has similar effects for the national and the urban case, despite the smaller sexual network found in rural areas. To further analyze the effect of herd immunity and network density, we simulate our model using a random walk. The parameters are summarized and reduced to include sexual contact rate, behaviour riskiness, medication adherence, and diagnosis rate. These parameters are described using probability distributions, and the status of an individual at each iteration is determined by random draws from those distributions and a control equation. Susceptible individuals' adherence to pre-exposure prophylaxis modifies their transmission risk term. We simulate under both urban and national network conditions, as well as low-density or rural sexual network conditions. The effect of different adherence distributions is also analyzed over varying proportions of susceptible individuals on pre-exposure prophylaxis medications. We hope this method will better illuminate the herd immunity effect provided by targeting high-risk susceptible individuals on different sexual networks.

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