

Forecasting the Effect of Pre-Exposure Prophylaxis (PrEP) on HIV Propagation with a System of Differential–Difference Equations with Delay

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The HIV/AIDS epidemic remains a global health challenge with no definitive cure. Following the World Health Organization’s 2014 recommendations, a preventive treatment called Pre-Exposure Prophylaxis (PrEP) has been implemented worldwide, particularly in France since 2016, to reduce HIV transmission. In this study, we introduce a novel compartmental epidemiological model that accounts for the limited duration of protection offered by PrEP. The PrEP compartment is modeled using an age-structured hyperbolic equation, while a differential equation governs the initiation of PrEP usage, resulting in a nonlinear differential–difference system with discrete delays. We perform a local stability analysis and establish the system’s global dynamics. Numerical simulations, based on data from the French population of Men who have Sex with Men (MSM), demonstrate the model’s accuracy. Specifically, we show that coupling a logistic time dynamic with a Hill-function-like formulation provides an excellent fit to the data. Additionally, we extend the model by considering the force of infection among PrEP users as a variable influenced not only by the infected population size but also by political and economic factors. This approach reflects the reality that economic and political constraints limit access to PrEP for a fraction of the population. Finally, we investigate the dynamics under a non-monotonic recruitment rate. These findings allow us to project the potential trajectory of the HIV epidemic in France, assuming sustained PrEP usage within the population.

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