

PrEP Dynamic Deterministic Compartmental Model

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1 Overview

This dynamic deterministic compartmental model evaluates the effect of pre-exposure prophylaxis (PrEP) rollout in a generalized HIV epidemic setting. The system of ordinary differential equations (ODEs) specified by the model are solved using Euler integration using a time step of 0.01 years. The model is written in **R**.

The model simulates an HIV epidemic from 1980 to 2030. The population is stratified according to age, sex, and behavioral risk group and captures demographic, behavioral, and clinical dynamics. HIV-negative individuals experience aging, fertility, and mortality. HIV infection occurs due to sexual mixing between males and females across age and risk groups. Upon HIV infection, individuals enter a transient acute infection stage characterized by high viremia followed by progression through four CD4 count categories. The model allows HIV-negative

persons to initiate and discontinue PrEP, HIV-positive persons to initiate and discontinue antiretroviral therapy (ART), and males to become circumcised either at birth or in adulthood. All members begin initially uninfected. In the first time-step, 0.1% of the population is seeded with HIV infection.

2 State variables

State variables are indicated as $X_{d,k,p}^{a,s,r}$, where:

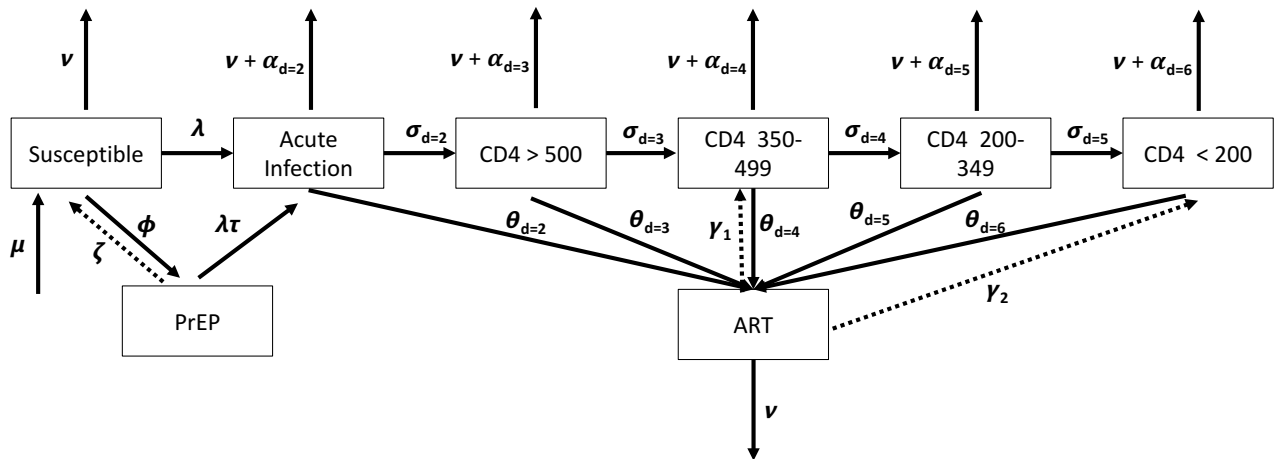
- a refers to age group, where $a = 1$ for ages 0 to 4; $a = 2$ for ages 5-9; ... ; $a = 12$ for ages 55-59.
- s refers to sex and circumcision status, where $s = 1$ refers to females, $s = 2$ refers to uncircumcised males, and $s = 3$ refers to circumcised males
- r refers to behavioral risk group, where $r = 1$ indicates low risk for HIV infection, $r = 2$ indicates medium risk, and $r = 3$ indicates high risk.
- d refers to HIV status, where $d = 1$ indicates susceptible, $d = 2$ indicates acute HIV, $d = 3$ indicates CD4 >500, $d = 4$ indicates CD4 350-499, $d = 5$ indicates CD4 200-349, and $d = 6$ indicates CD4 <200.
- k indicates treatment status, where $k = 1$ indicates not on ART and $k = 2$ indicates taking ART.
- p indicates PrEP status, where $p = 1$ indicates not on PrEP and $p = 2$ indicates taking PrEP.

3 Parameters

- $\mu_d^{a,s=1}$ refers to the fertility rate.
- $\nu^{a,s}$ refers to the background (non-HIV) mortality rate.
- $\alpha_d^{a,s}$ refers to the HIV-associated mortality rate.
- $\lambda_{d=1,k=1,p}^{a,s,r}$ refers to the force of infection experienced by HIV-negative individuals.
- σ_d refers to the HIV disease progression rate.
- $\theta_{d,k=1}^{a,s,r}$ refers to the ART initiation rate
- $\gamma_{d,k=2}^{a,s,r}$ refers to the ART dropout rate
- $\phi_{d=1,k=1}^{a,s,r}$ refers to the PrEP initiation rate
- $\zeta_{d=1,k=1}^{a,s,r}$ refers to the PrEP dropout rate
- τ refers to the risk of HIV infection among PrEP users relative to those among PrEP non-users.

4 Model structure

Figure 1: Structure of dynamic deterministic model



5 Model equations

6 Behavioral risk

7 Demography

8 Interventions

9 Transmission

10 Disease progression

11 Initial conditions

12 Model fitting

13 Uncertainty analysis

14 Scenarios

15 Discussion

16 References