A Novel Spatiotemporal Model for Epidemics in Dynamic Populations

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Spatiotemporal modelling is important in understanding communicable disease progression dynamics and evaluating public health intervention strategies. However, existing spatiotemporal models incorporate neither population-level migration patterns (PLMP) nor individual-level movement tendencies (ILMT). In this study, Spatiotemporal Dynamic Population SEIR (SDP-SEIR), a novel continuous compartmental model, was developed to incorporate PLMP and ILMT. Numerical experiments were conducted with finite difference methods for SDP-SEIR. Simulations were conducted on Zika, an emerging vector-borne disease, for 10 southern US states (with both human and mosquito populations) and on measles, a re-emerging disease, for 12 counties in the New York metropolitan area. SDP-SEIR predicted that, without intervention, an introduced Zika case in Florida would spread Zika across all 10 states within ~2 years and that measles cases would spread all 12 New York counties within ~3 years. Travel restrictions delay peak infection time (PIT) for both diseases. A high vaccination coverage (e.g. 10,000 per day) curtails Zika peak infections (PI), and geographically-targeted vaccination strategies can delay Zika PIT in individual states. A low vaccination coverage (e.g. 50 per day) reduces measles PI. Sensitivity analyses suggested that recovery rate and vector-host contact rate be principal effectors for Zika transmission, contrasted with contact rate and recovery rate for measles transmission. Basic reproduction numbers computed with Next Generation Matrices were consistent with those reported in literature for both diseases. In summary, SDP-SEIR provides flexible predictions of epidemic progression while considering both PLMP and ILMT, helping optimize public health intervention strategies.

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