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A Data-Driven Optimal Control Model for the Dynamics of Monkeypox in a Variable Population with a Comprehensive Cost-Effectiveness Analysis

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Abstract : Introduction: In the realm of public health, the threat posed by Monkeypox continues to elicit concern, prompting rigorous studies to understand its dynamics and devise effective containment strategies. Particularly significant is its recurrence in variable populations, such as the observed outbreak in Nigeria in 2022. In light of this, our study undertakes a meticulous analysis, employing a data-driven approach to explore, validate, and propose optimized intervention strategies tailored to the distinct dynamics of Monkeypox within varying demographic structures. Utilizing a deterministic mathematical model, we delved into the intricate dynamics of Monkeypox, with a particular focus on a variable population context. Our qualitative analysis provided insights into the disease-free equilibrium, revealing its stability when R0 is less than one and discounting the possibility of backward bifurcation, as substantiated by the presence of a single stable endemic equilibrium. The model was rigorously validated using real-time data from the Nigerian 2022 recorded cases for Epi weeks 1 – 52. Transitioning from qualitative to quantitative, we augmented our deterministic model with optimal control, introducing three time-dependent interventions to scrutinize their efficacy and influence on the epidemic's trajectory. Numerical simulations unveiled a pronounced impact of the interventions, offering a data-supported blueprint for informed decision-making in containing the disease. A comprehensive cost-effectiveness analysis employing the Infection Averted Ratio (IAR), Average Cost-Effectiveness Ratio (ACER), and Incremental Cost-Effectiveness Ratio (ICER) facilitated a balanced evaluation of the interventions' economic and health impacts. In essence, our study epitomizes a holistic approach to understanding and mitigating Monkeypox, intertwining rigorous mathematical modeling, empirical validation, and economic evaluation. The insights derived not only bolster our comprehension of Monkeypox's intricate dynamics but also unveil optimized, cost-effective interventions. This integration of methodologies and findings underscores a pivotal stride towards aligning public health imperatives with economic sustainability, marking a significant contribution to global efforts in combating infectious diseases.

Keywords : monkeypox, equilibrium states, stability, bifurcation, optimal control, cost-effectiveness
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