Sex-structured Disease Transmission Model and Control Mechanisms for Visceral Leishmaniasis (VL)

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Leishmaniasis are a group of diseases caused by more than 20 species of the protozoan that are transmitted through the bite of female sand fly. The disease is endemic to 98 countries of the world. It affects most commonly the poorest of the poor and mainly males. Several research has been conducted to propose disease control strategies. Effective medical care, vector control, environmental hygiene, and personal protection are the mainstays of the current preventative and control methods. The mathematical models for the transmission dynamics of the disease studied so far did not consider the sex-biased burden of the disease into consideration.

Unlike the previous VL works, this study introduces a new deterministic sex-structured model for understanding the transmission dynamics of visceral leishmaniasis. Basic properties of the model including basic reproduction number ($\mathcal{R}_0$), and conditions for the existence of backward bifurcation of the model are explored. Baseline parameter values were estimated after the model was fitted to Ethiopia's VL data. Sensitivity analysis of the model was performed to identify the parameters that significantly impact the disease threshold. Numerical simulations were performed using baseline parameter values, and scenario analysis is performed by changing some of these parameters as appropriate.

The analysis of the model shows that there is a possibility for a backward bifurcation for $\mathcal{R}_0 < 1$, which means bringing $\mathcal{R}_0$ merely to less than unity alone

may not be enough to eradicate the disease. Our numerical result shows that the implementation of disease-preventive strategies, as well as effectively treating the affected ones can significantly reduce the disease prevalence if applied for more proportion of the male population. Furthermore, the implementation of vector management strategies also can considerably reduce the total prevalence of the disease. However, it is demonstrated that putting more effort in treating affected reservoir animals may not have any significant effect on the overall prevalence of the disease as compared to other possible mechanisms. The numerical simulation infers that a maximum of 60% of extra preventative measures targeted to only male population considerably reduces the total prevalence of VL by 80%. It is also possible to decrease the total prevalence of VL by 69.51% when up to 50% additional infected males receive treatment with full efficacy. Moreover, applying a maximum of 15% additional effort to reduce the number of vectors, decreases the total VL prevalence by 57.71%. Therefore, in order to reduce the disease burden of visceral leishmaniasis, public health officials and concerned stakeholders need to give more emphasis to the proportion of male humans in their intervention strategies.

Keywords: Visceral Leishmaniasis, sex-structured model, dynamical systems, sex dependent interventions, sensitivity analysis, parameter estimation.

References

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