Mathematical Methods and Models in Biosciences
June 15–20, 2025, Sofia, Bulgaria
https://biomath.math.bas.bg/biomath/index.php/bmcs

Impact of vaccination on tuberculosis control: a mathematical modeling approach

Festus Abiodun Oguntolu[1], Olumuyiwa James Peter[2]

[1]Department of Mathematics,
Federal University of Technology Minna, Niger State, Nigeria
festus.tolu@futminna.edu.ng

[2]Department of Mathematical and Computer Sciences,
University of Medical Sciences, Ondo State, Nigeria
peterjames4real@gmail.com

Tuberculosis remains a global health concern, especially in high-transmission areas. This paper proposes a mathematical model to assess the influence of vaccination on tuberculosis control, with a focus on five demographic compartments: susceptible, vaccinated, latent, active tuberculosis, and recovered.

We use Partial Rank Correlation Coefficient (PRCC) analysis to uncover crucial parameters influencing tuberculosis dynamics, such as vaccine efficacy, coverage, and immunity duration. We use simulations to evaluate the efficacy of various vaccination tactics, such as the introduction of booster doses and targeted immunization campaigns in high-risk populations. Our findings show that high immunization coverage and efficacy can dramatically lower tuberculosis incidence and prevalence.

The PRCC analysis demonstrates that the pace of development from latent to active tuberculosis and the rate of fading immunity are critical in determining the overall success of the vaccination strategy. We advocate developing comprehensive immunization campaigns, particularly in high-burden areas, and combining these efforts with early identification and treatment options to improve control.

The findings highlights the necessity of ongoing research into creating vaccines with stronger efficiency and longer-lasting protection to further limit tuberculosis spread. This study offers useful insights for policymakers and public health authorities, underlining the importance of vaccination in complete tuberculosis control programs. By incorporating these findings into public health strategies, governments can better address the ongoing tuberculosis epidemic and improve health outcomes for afflicted communities.

Keywords: tuberculosis, vaccination, mathematical model, PRCC analysis, public health, epidemiology, vaccine efficacy, health policy

References

[1] A. Srivastava, P. K. Srivastava, A tuberculosis model incorporating the impact of information, saturated treatment and multiple reinfections, *The European Physical Journal Plus*, 138:1156, 2023.

[2] D.-P. Gao, N.-J Huang, Optimal control analysis of a tuberculosis model, *Applied Mathematical Modelling*, 58:47–64, 2018.

[3] Z.-K. Guo, H. Xiang, H.-F. Huo, Analysis of an age-structured tuberculosis model with treatment and relapse, *Journal of Mathematical Biology*, 82:45, 2021.

[4] A. O. Egonmwan, D. Okuonghae, Mathematical analysis of a tuberculosis model with imperfect vaccine, *International Journal of Biomathematics*, 12:1950073, 2019.