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Navigating the Nexus of HIV/AIDS Care: Leveraging Statistical Insight to Transform Clinical Practice and Patient Outcomes

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Abstract : The management of HIV/AIDS is a global challenge, demanding precise tools to predict disease progression and guide tailored treatment. CD4 cell count dynamics, a crucial immune function indicator, play an essential role in understanding HIV/AIDS progression and enhancing patient care through effective modeling. While several models assess disease progression, existing methods often fall short in capturing the complex, non-linear nature of HIV/AIDS, especially across diverse demographics. A need exists for models that balance predictive accuracy with clinical applicability, enabling individualized care strategies based on patient-specific progression rates. This study utilizes patient data from Kenyatta National Hospital (2003–2014) to model HIV/AIDS progression across six CD4-defined states. The Exponential, 2-Parameter Weibull, and 3-Parameter Weibull models are employed to analyze failure rates and explore progression patterns by age and gender. Model selection is based on Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) to identify models best representing disease progression variability across demographic groups. The 3-Parameter Weibull model emerges as the most effective, accurately capturing HIV/AIDS progression dynamics, particularly by incorporating delayed progression effects. This model reflects age and gender-specific variations, offering refined insights into patient trajectories and facilitating targeted interventions. One key finding is that older patients progress more slowly through CD4-defined stages, with a delayed onset of advanced stages. This suggests that older patients may benefit from extended monitoring intervals, allowing providers to optimize resources while maintaining consistent care. Recognizing slower progression in this demographic helps clinicians reduce unnecessary interventions, prioritizing care for faster-progressing groups. Gender-based analysis reveals that female patients exhibit more consistent progression, while male patients show greater variability. This highlights the need for gender-specific treatment approaches, as men may require more frequent assessments and adaptive treatment plans to address their variable progression. Tailoring treatment by gender can improve outcomes by addressing distinct risk patterns in each group. The model's ability to account for both accelerated and delayed progression equips clinicians with a robust tool for estimating the duration of each disease stage. This supports individualized treatment planning, allowing clinicians to optimize antiretroviral therapy (ART) regimens based on demographic factors and expected disease trajectories. Aligning ART timing with specific progression patterns can enhance treatment efficacy and adherence. The model also has significant implications for healthcare systems, as its predictive accuracy enables proactive patient management, reducing the frequency of advanced-stage complications. For resource limited providers, this capability facilitates strategic intervention timing, ensuring that high-risk patients receive timely care while resources are allocated efficiently. Anticipating progression stages enhances both patient care and resource management, reinforcing the model's value in supporting sustainable HIV/AIDS healthcare strategies. This study underscores the importance of models that capture the complexities of HIV/AIDS progression, offering insights to guide personalized, data-informed care. The 3-Parameter Weibull model's ability to accurately reflect delayed progression and demographic risk variations presents a valuable tool for clinicians, supporting the development of targeted interventions and resource optimization in HIV/AIDS management.

Keywords : HIV/AIDS progression, 3-parameter Weibull model, CD4 cell count stages, antiretroviral therapy, demographic-specific modeling
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