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Perspective

# Influence of Early BCG Vaccination on Malaria-Specific Cytokine Profiles

**Adna Vanessa***

*Department of Clinical Microbiology, National Institute of Respiratory Diseases (INER), Mexico City, Mexico*

## ABOUT THE STUDY

The Bacillus Calmette-Guérin (BCG) vaccine, primarily used to prevent tuberculosis, has been observed to have non-specific effects on the immune system, influencing responses to various pathogens beyond *Mycobacterium tuberculosis*. Recent research has examined how neonatal BCG vaccination impacts in vitro cytokine responses to *Plasmodium falciparum*, the parasite responsible for malaria. This topic holds significant relevance, given the high burden of malaria and the potential for BCG vaccination to modulate immune responses to this and other infectious diseases.

The immunological landscape shaped by BCG vaccination is complex and multifaceted. One of the notable effects is the enhancement of innate immunity, a phenomenon referred to as "trained immunity." This concept describes the long-term functional reprogramming of innate immune cells, such as monocytes and macrophages, leading to an enhanced response to subsequent infections. Trained immunity is mediated through epigenetic reprogramming and metabolic changes within these cells, resulting in heightened cytokine production upon exposure to various pathogens.

In the context of *Plasmodium falciparum*, cytokines play a critical role in the immune response. The immune system's ability to produce specific cytokines can influence the outcome of the infection. For example, pro-inflammatory cytokines such as IFN-γ and TNF-α are important for controlling parasitemia, while regulatory cytokines like IL-10 help modulate inflammation to prevent tissue damage. Therefore, understanding how BCG vaccination influences these cytokine responses can provide insights into potential benefits or drawbacks of BCG in malaria-endemic regions.

Studies investigating the influence of neonatal BCG vaccination on cytokine responses to *Plasmodium falciparum* have yielded intriguing results. For instance, BCG vaccination has been associated with increased production of pro-inflammatory cytokines in response to malaria antigens. This enhanced cytokine response could potentially improve the body's ability to control and clear the parasite, reducing the severity of the infection. However, the balance of cytokine production is essential; excessive inflammation could lead to immunopathology and adverse clinical outcomes.

*In vitro* studies provide a controlled environment to assess these cytokine responses. By isolating Peripheral Blood Mononuclear Cells (PBMCs) from vaccinated and unvaccinated neonates and exposing them to *Plasmodium falciparum* antigens, researchers can measure the levels of various cytokines produced. These studies have demonstrated that BCG-vaccinated individuals often exhibit a more robust cytokine response, characterized by higher levels of IFN-γ, TNF-α, and other pro-inflammatory cytokines. This suggests that BCG vaccination primes the immune system for a more vigorous response to malaria antigens.

Moreover, the timing and context of BCG vaccination can influence the immune response. Neonatal vaccination, occurring when the immune system is still developing, might have a more pronounced impact on shaping long-term immune function compared to vaccination later in life. The neonatal immune system is characterized by a higher degree of plasticity, allowing BCG-induced trained immunity to potentially have more significant and lasting effects.

However, the relationship between BCG vaccination and malaria immunity is not straightforward. While enhanced pro-inflammatory responses can aid in controlling parasitemia, they must be carefully balanced with regulatory mechanisms to prevent excessive tissue damage. For instance, IL-10 production, which helps limit inflammation and protect tissues, must also be considered in evaluating the overall impact of BCG vaccination on malaria outcomes.

Field studies in malaria-endemic regions provide further context to these *in vitro* findings. Observational studies and randomized controlled trials have explored whether BCG vaccination correlates with reduced malaria incidence or severity. Some studies have suggested that BCG-vaccinated children experience fewer severe malaria episodes, potentially due to the enhanced trained immunity elicited by the vaccine. However, these

**Correspondence to:** Adna Vanessa, Department of Clinical Microbiology, National Institute of Respiratory Diseases (INER), Mexico City, Mexico, E-mail: adnavanessa@lumc.mx

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findings are not universal, and variability in study designs, populations, and malaria transmission intensity complicates the interpretation of results.

## CONCLUSION

In summary, the influence of neonatal BCG vaccination on *in vitro* cytokine responses to *Plasmodium falciparum* underscores the complex interplay between vaccination and immune modulation. BCG-induced trained immunity appears to enhance pro-inflammatory cytokine production, which could contribute to better control of malaria infection. However, the balance of cytokine responses is important to avoid detrimental inflammation. Further research, including longitudinal studies and more comprehensive field trials, is needed to fully understand the implications of BCG vaccination on malaria immunity and to optimize vaccination strategies in malaria-endemic regions. Understanding these dynamics can inform integrated approaches to vaccination and disease prevention, ultimately improving health outcomes in affected populations.