Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 15 [2] January 2026.24-31

Online ISSN 2277-1808
Journal's URL: http://www.bepls.com
CODEN: BEPLAD

REVIEW ARTICLE **OPEN ACCESS**

The Role of T-helper 17 and regulatory T cells Dynamics in HIV Pathogenesis and Treatment Strategies in West Africa

[a]Obaji Monday Uchenna, [b*]Emeruwa Akunna Perpetua, [c]Nwankwo Ezinne Janefrances
[a]Department of Pharmaceutical Microbiology and Biotechnology, Faculty of Pharmaceutical Sciences, Nnamdi Azikiwe University, Agulu, Nigeria.
[b]Department of Microbiology and Parasitology, Faculty of Allied Health Sciences, David Umahi Federal University of Health Sciences, Uburu, Nigeria.
[c]Department of Pharmaceutical Microbiology and Biotechnology, University of Port Harcourt, Nigeria.
Corresponding author: Emeruwa Akunna Perpetua, Department of Microbiology and Parasitology, Faculty of Allied Health Sciences, David Umahi Federal University of Health Sciences, P.M.B. 211, Uburu, Ebonyi, Nigeria E-mail: perpetuanwigwe@gmail.com

ABSTRACT
The interplay between T-helper 17 (Th17) and regulatory T (Treg) cells plays a crucial role in immune homeostasis, particularly in chronic viral infections such as HIV. Th17 cells are essential for mucosal immunity and pathogen clearance, while Treg cells suppress excessive immune activation to prevent immunopathology. However, an imbalance in Th17/Treg dynamics contributes to chronic inflammation and poor immune reconstitution in HIV-infected individuals. This review aims to examine the role of Th17/Treg balance in HIV pathogenesis with a focus on its implications for HIV management in West Africa. A comprehensive literature review was conducted using peer-reviewed articles from PubMed, Scopus, and Web of Science databases. Studies investigating Th17/Treg dynamics in HIV, particularly in African populations, were included. The review explored cytokine signaling pathways, genetic and environmental influences, and emerging immunomodulatory strategies targeting Th17/Treg equilibrium. Additionally, clinical data on the impact of Th17/Treg balance on antiretroviral therapy (ART) response and immune recovery were analyzed. Findings indicate that HIV infection disrupts Th17/Treg homeostasis, which leads to Th17 depletion and increased Treg-mediated immunosuppression. This imbalance contributes to immune dysfunction, which is associated with poor ART responses. In West African populations, high prevalence of coinfections and nutritional factors further modulate Th17/Treg responses. While ART partially restores Th17 function, residual immune activation persists, necessitating additional immunomodulatory interventions. The Th17/Treg axis plays a pivotal role in HIV pathogenesis and treatment responses. Given the unique immunological landscape in West Africa, targeted immunotherapeutic strategies could enhance ART efficacy.
Keywords: Th17/Treg balance, HIV immunopathogenesis, Immune regulation, West Africa, Cytokine signaling, Therapeutic immunomodulation

Received 05.12.2025 Revised 21.12.2025 Accepted 25.01.2026

INTRODUCTION

HIV remains a major public health concern in West Africa, a region with diverse epidemiological patterns and unique socio-economic and genetic influences on disease progression. While West Africa has lower HIV prevalence rates compared to Eastern and Southern Africa, countries such as Nigeria, Ivory Coast, and Ghana still experience significant disease burdens [1, 2]. The predominant strain in the region is HIV-1 group O and HIV-2, with HIV-2 known for its slower disease progression and lower transmission rates. However, despite advancements in antiretroviral therapy (ART), challenges such as late diagnosis, limited healthcare infrastructure, and high rates of coinfections continue to hinder effective disease control [3, 4]. HIV pathogenesis is characterized by a progressive loss of immune function, primarily due to CD4+ T cell depletion and chronic immune activation [5]. Beyond direct viral-mediated cytotoxicity, HIV disrupts immune homeostasis by altering key regulatory pathways, which leads to persistent inflammation [6]. The immune system attempts to balance pro-inflammatory and anti-inflammatory responses to prevent excessive tissue damage while maintaining effective antiviral immunity. Dysregulation of this balance exacerbates disease severity, increasing susceptibility to opportunistic infections and non-AIDS-related

complications. Thus, immune regulatory mechanisms play a pivotal role in determining the pace of HIV progression and the effectiveness of ART in restoring immune function [7, 8).

Among the various immune regulatory components, the interplay between T-helper 17 (Th17) and regulatory T (Treg) cells is critical for maintaining immune equilibrium. Th17 cells play a protective role in mucosal immunity by enhancing antimicrobial responses through maintaining gut barrier integrity and preventing microbial translocation—a key driver of chronic immune activation in HIV [9]. Conversely, Treg cells suppress excessive immune responses to prevent autoimmunity and tissue damage [10]. However, in HIV infection, this balance is disrupted; Th17 cells are selectively depleted, which leads to increased gut permeability and systemic inflammation, while Treg cells expand, contributing to immune suppression and viral persistence. The resulting Th17/Treg imbalance not only accelerates HIV disease progression but also influences ART responses and the likelihood of immune reconstitution [9, 11]. Given the distinct immunological landscape in West African populations, shaped by genetic variations and environmental factors, further investigation into Th17/Treg dynamics is essential for optimizing HIV treatment strategies tailored to the region's needs.

IMMUNOLOGICAL BASIS OF Th17/Treg DYNAMICS IN HIV

Th17 and Treg cells play critical yet opposing roles in maintaining immune homeostasis. Th17 cells, a subset of $CD4^+$ T cells, primarily defend mucosal barriers against bacterial and fungal infections through the production of pro-inflammatory cytokines such as interleukin-17 (IL-17) and IL-22. They promote neutrophil recruitment and antimicrobial peptide production, which ensures pathogen clearance [12, 13]. Conversely, Treg cells, characterized by the expression of the transcription factor FoxP3, exert immunosuppressive functions essential for controlling excessive immune activation. These cells prevent autoimmunity and maintain tolerance by secreting anti-inflammatory cytokines such as IL-10 and transforming growth factor-beta (TGF-β) [14]. The balance between Th17 and Treg cells is vital for immune homeostasis, as dysregulation can result in chronic inflammation or immune suppression, both of which are pivotal in HIV pathogenesis.

Distinct cytokine networks tightly regulate the differentiation and function of Th17 and Treg cells. Th17 cell development is driven by the presence of IL-6, IL-1β, and TGF-β, with IL-23 playing a crucial role in their expansion and stabilization [15]. IL-17, the hallmark cytokine of Th17 cells, induces inflammatory responses essential for pathogen clearance but can also contribute to tissue damage in chronic infections [16]. Additionally, IL-22 enhances epithelial barrier integrity, further supporting mucosal immunity [17]. In contrast, Treg cells require TGF-β for differentiation, while IL-10 reinforces their immunosuppressive activity by dampening excessive immune activation [18]. The interplay between these cytokines determines the balance between protective immunity and immune tolerance. An optimal Th17/Treg equilibrium ensures effective pathogen control while preventing harmful inflammation. However, perturbations in these cytokine pathways can lead to immune dysfunction, as seen in HIV infection.

HIV profoundly disrupts the Th17/Treg balance, which leads to immune dysregulation and disease progression. One of the earliest immunological consequences of HIV infection is the preferential depletion of Th17 cells in the gut-associated lymphoid tissue (GALT). This depletion compromises mucosal integrity and causes chronic inflammation [19]. The loss of IL-17 and IL-22 production weakens mucosal defenses, which facilitates opportunistic infections and disease progression. Conversely, Treg cells are relatively preserved or even expanded in HIV-infected individuals, which contributes to immune suppression and impaired antiviral responses [20]. The increased presence of IL-10 and TGF-β further inhibits effective immune activation, which creates an environment that favors viral persistence. This imbalance between inflammatory Th17 cells and immunosuppressive Treg cells is a hallmark of HIV pathogenesis.

Th17/Treg IMBALANCE IN HIV PROGRESSION AND IMMUNE DYSFUNCTION

One of the earliest and most detrimental consequences of HIV infection is the selective depletion of Th17 cells, particularly in the GALT. Th17 cells play a crucial role in maintaining mucosal barrier integrity by promoting epithelial repair, antimicrobial peptide production, and neutrophil recruitment [21]. Their loss leads to increased gut permeability, which allows the leakage of bacterial products such as lipopolysaccharides (LPS) into the bloodstream. This translocation triggers systemic immune activation [22]. The decline in IL-17 and IL-22 further exacerbates mucosal damage, which impairs the host's ability to control opportunistic infections. Consequently, the gut becomes a major site of chronic immune activation, making it more susceptible to co-infections [23].

While Th17 cells are depleted during HIV infection, Treg cells are often preserved or even expanded to contribute to an immunosuppressive environment. This expansion is driven by increased levels of IL-10 and TGF-β, which promote Treg differentiation and suppress effector T-cell responses [11, 24]. The accumulation of Treg cells dampens immune activation, thereby reducing the effectiveness of antiviral

responses. High Treg activity also inhibits antigen-presenting cells and cytotoxic T lymphocytes (CTLs), which further impairs viral clearance [25]. This situation, where excessive immune suppression coexists with chronic inflammation, creates an immune environment that favors HIV replication while limiting effective immune control. The imbalance between Th17 loss and Treg expansion fuels chronic inflammation, which is a key driver of immune exhaustion in HIV. Persistent immune activation, triggered by microbial translocation and viral replication, leads to sustained production of pro-inflammatory cytokines such as IL-6, TNF-α, and IFN-γ [26, 27]. This prolonged immune stimulation results in T-cell dysfunction, characterized by the upregulation of inhibitory receptors such as PD-1, CTLA-4, and TIM-3. As a result, $CD4^+$ and $CD8^+$ T cells progressively lose their proliferative and cytotoxic capacities [28]. Additionally, chronic inflammation contributes to non-AIDS-related comorbidities, including cardiovascular diseases and metabolic disorders, which further complicates HIV management. Table 1 describes the consequences of Th17/Treg imbalance in HIV progression and immune dysfunction.

GENETIC AND ENVIRONMENTAL INFLUENCES ON Th17/Treg BALANCE IN WEST AFRICAN POPULATIONS

Genetic variations play a crucial role in shaping immune responses, including the regulation of Th17 and Treg cell dynamics. In West African populations, polymorphisms in cytokine genes such as IL-17A, IL-10, and TGF-β have been linked to variations in immune activation, inflammation, and disease progression in HIV-infected individuals [35, 36]. Certain single nucleotide polymorphisms (SNPs) in the IL-17 gene may influence Th17 differentiation and cytokine production, potentially affecting mucosal immunity and microbial translocation. Similarly, polymorphisms in IL-10 and TGF-β genes could alter Treg-mediated immune suppression, thereby impacting the ability to control chronic inflammation and immune exhaustion [37].

The high burden of coinfections such as tuberculosis (TB) and malaria in West Africa significantly influences Th17/Treg balance in HIV-infected individuals. TB, a common opportunistic infection in people living with HIV, induces strong Th1 and Th17 responses, which may initially aid in pathogen clearance. However, chronic TB infection can lead to Th17 depletion and an increase in Treg cells, which contributes to immune suppression and increased susceptibility to further infections [38, 39]. Similarly, malaria, caused by ***Plasmodium*** species, triggers immune modulation that skews the Th17/Treg ratio. Studies suggest that severe malaria promotes Treg expansion and IL-10 production, dampening immune responses and potentially exacerbating HIV-related immune dysfunction [40, 41]. These coinfections create a complex immunological landscape, where Th17 cell depletion and excessive Treg activity may accelerate HIV disease progression.

Malnutrition remains a significant public health challenge in many parts of West Africa, with profound effects on immune function and cytokine signaling [42]. Deficiencies in key micronutrients such as vitamin A, vitamin D, and zinc have been shown to disrupt Th17/Treg balance, leading to impaired mucosal immunity and increased inflammation [43]. For instance, vitamin D deficiency is associated with reduced IL-17 production and enhanced Treg activity. Additionally, exposure to environmental pollutants, chronic parasitic infections, and poor sanitation conditions can exacerbate immune dysregulation, further shifting the Th17/Treg balance toward immune suppression and chronic inflammation [44]. These environmental stressors not only influence HIV progression but also affect responses to ART and immunotherapy. Table 2 shows the impacts of genetic and environmental influences on Th17/Treg balance.

CLINICAL IMPLICATIONS OF Th17/Treg IMBALANCE IN HIV MANAGEMENT

The balance between Th17 and Treg cells plays a pivotal role in determining the trajectory of HIV progression and treatment response. A decline in Th17 cells is associated with increased microbial translocation, systemic inflammation, and a higher risk of opportunistic infections, all of which contribute to rapid disease progression [49]. Conversely, an expansion of Treg cells may suppress protective immune responses, leading to inadequate viral control and immune exhaustion. Studies have shown that individuals with a preserved Th17 compartment tend to have slower HIV progression and better responses to ART [50, 51]. Therefore, monitoring Th17/Treg ratios could provide valuable insights into disease severity, ART efficacy, and the likelihood of immune reconstitution following treatment initiation.

Given the central role of Th17/Treg dynamics in HIV immunopathogenesis, these cell subsets have emerged as potential biomarkers for disease monitoring and therapeutic decision-making. Quantifying Th17 and Treg populations, along with their associated cytokines (e.g., IL-17, IL-10, TGF-β), could offer a more precise evaluation of immune status beyond traditional CD4+ T-cell counts [52]. Elevated Treg frequencies, for instance, may indicate persistent immune suppression, while diminished Th17 levels could serve as an early marker of gut mucosal damage and systemic inflammation. These biomarkers may also help predict ART treatment failure and individuals at higher risk of comorbidities such as tuberculosis and chronic

inflammation-related disorders [53]. Therefore, integrating Th17/Treg profiling into routine immune monitoring could enhance patient stratification.

Effective HIV vaccines rely on the induction of robust and durable immune responses [54]. However, Th17/Treg imbalance may impair vaccine efficacy by modulating immune activation and memory cell formation. Excessive Treg activity can dampen vaccine-induced immune responses, which reduces the ability to generate long-lasting protective immunity [55]. Conversely, a compromised Th17 compartment may limit mucosal immunity, which is critical for preventing HIV transmission and early viral replication [56]. Furthermore, the extent of Th17 depletion and Treg expansion may influence immune reconstitution following ART initiation, with some individuals failing to achieve optimal CD4+ T-cell recovery despite viral suppression [57]. Strategies aimed at restoring Th17/Treg balance, such as cytokine-based adjuvants or immune checkpoint modulators, could enhance vaccine efficacy and improve immune reconstitution in HIV-infected individuals.

THERAPEUTIC STRATEGIES TARGETING Th17/Treg BALANCE

ART remains the cornerstone of HIV treatment, significantly reducing viral replication and restoring immune function [58]. However, its impact on Th17/Treg dynamics is variable. While ART helps in partial recovery of Th17 cells, particularly in individuals who initiate treatment early, complete restoration of Th17 function is often limited, especially in those with advanced disease [59]. Persistent immune activation and microbial translocation may continue to drive inflammation despite viral suppression. Additionally, Treg expansion persists in some individuals, potentially contributing to immune suppression and incomplete CD4+ T-cell recovery [60]. These findings highlight the need for adjunctive strategies to enhance Th17 reconstitution while preventing excessive Treg-mediated immune suppression.

Given the critical role of cytokines in regulating Th17 and Treg differentiation, targeted immunomodulatory therapies have been explored to restore balance [61]. IL-17 inhibitors, which have been widely used in autoimmune diseases, may hold potential for modulating excessive Th17 responses in the context of chronic immune activation. However, their use in HIV requires careful evaluation to avoid further compromising mucosal immunity [62]. On the other hand, TGF-β modulators aim to regulate excessive Treg activity, thereby preventing immunosuppression and enhancing antiviral immunity. Therapies that selectively modulate these pathways could help fine-tune Th17/Treg dynamics without disrupting overall immune homeostasis.

Recent evidence suggests that gut microbiome composition significantly influences Th17/Treg balance, given the role of microbial-derived metabolites in immune regulation. Probiotic supplementation with beneficial bacteria such as ***Lactobacillus*** and ***Bifidobacterium*** has been shown to enhance Th17 cell recovery and reduce systemic inflammation in HIV-infected individuals [63, 64]. Additionally, microbiome-based interventions, including fecal microbiota transplantation (FMT), are being investigated for their potential to restore gut homeostasis and improve mucosal immunity [65]. Cytokine-based therapies represent another promising avenue. IL-7 and IL-22 have been explored for their capacity to enhance Th17 cell survival and promote mucosal healing, while IL-2 therapy may help modulate Treg expansion to prevent excessive immune suppression [66, 67, 68]. These approaches, either alone or in combination with ART, could provide novel strategies to optimize immune reconstitution in HIV-infected individuals. Table 3 shows the implications of therapeutic strategies targeting Th17/Treg balance in HIV.

FUTURE DIRECTIONS AND RESEARCH GAPS

Despite growing evidence on Th17/Treg dynamics in HIV, most studies have been conducted in Western or Asian populations, with limited data from West Africa. Given the distinct genetic background, environmental exposures, and prevalence of coinfections in this region, there is a pressing need for region-specific research to understand how these factors influence Th17/Treg balance. Large-scale cohort studies investigating cytokine profiles, immune cell distribution, and microbiome composition in West African HIV-infected individuals will provide crucial insights into disease progression and treatment responses [74, 75, 76]. These studies will also help refine immunotherapeutic strategies tailored to the unique immune landscape of West African populations.

The growing understanding of Th17/Treg dysregulation opens new avenues for personalized immunotherapy in HIV care. Targeted interventions, such as cytokine-based therapies, microbiome modulation, and immune checkpoint inhibitors, could be tailored based on an individual's immune profile. For instance, patients with persistent Treg expansion and immune suppression may benefit from TGF-β modulation, while those with severe Th17 depletion and mucosal dysfunction may require IL-22 or IL-7 therapy [77]. The integration of multi-omics approaches, including transcriptomics and proteomics, could further refine patient stratification and optimize treatment strategies [78]. However, translating these

personalized approaches into clinical practice requires rigorous validation through clinical trials and cost-effective implementation strategies.

While targeting Th17/Treg imbalance presents a promising adjunct to ART, several challenges hinder its clinical translation. First, the complexity of immune regulation necessitates precise modulation to avoid unintended consequences, such as exacerbating inflammation or further suppressing antiviral immunity [79]. Second, the high cost of immunotherapies and advanced diagnostic tools may limit accessibility in resource-constrained settings, particularly in West Africa. Additionally, ethical considerations regarding patient stratification based on immune profiling must be addressed to ensure equitable healthcare access [80]. Overcoming these challenges requires interdisciplinary collaboration, policy-driven funding for immunological research, and the development of scalable, cost-effective interventions that can be integrated into routine HIV management.

CONCLUSION

Th17/Treg imbalance plays pivotal role in HIV pathogenesis, particularly in West African populations where genetic, environmental, and infectious factors further modulate immune responses. Addressing this dysregulation through targeted biomarkers, personalized therapies, and optimized ART could enhance disease treatments. Continued region-specific research and collaboration are essential to translate these findings into practical strategies for improving HIV care in West Africa.

Competing interests: The authors declare that they have no competing interests.

Author's Contribution: OMU wrote the manuscript; EAP supplied the data and reviewed the manuscript while NEJ also reviewed the final copy.

Funding: The authors did not benefit from any funding during the course of this research and the writing of this manuscript.

Data Availability: All data are included in the manuscript.

REFERENCES

1. Parker E, Judge MA, Macete E, Nhampossa T, Dorward J, Langa DC, Schacht C, Couto A, Vaz P, Vitoria M, Molfino L, Idowu RT, Bhatt N, Naniche D, Le Souëf PN. (2021). HIV infection in Eastern and Southern Africa: Highest burden, largest challenges, greatest potential. South Afr J HIV Med. 28;22(1):1237. https://doi.org/10.4102/sajhivmed.v22i1.1237
2. Ford N, Ball A, Baggaley R, et al. (2018). The WHO public health approach to HIV treatment and care: Looking back and looking ahead. Lancet Infect Dis. 18(3):e76–e86.10.1016/S1473-3099(17)30482-6
3. Telisinghe L, Charalambous S, Topp SM, et al. (2016). HIV and tuberculosis in prisons in sub-Saharan Africa. Lancet (London, England). 388(10050):1215–1227. 10.1016/S0140-6736(16)30578-5
4. Peterson K, Jallow S, Rowland-Jones SL, de Silva TI. (2011). Antiretroviral Therapy for HIV-2 Infection: Recommendations for Management in Low-Resource Settings. AIDS Res Treat. 463704. https://doi.org/10.1155/2011/463704
5. Moretti S, Schietroma I, Sberna G, Maggiorella MT, Sernicola L, Farcomeni S, Giovanetti M, Ciccozzi M, Borsetti A. (2023). HIV-1–Host Interaction in Gut-Associated Lymphoid Tissue (GALT): Effects on Local Environment and Comorbidities. International Journal of Molecular Sciences. 24(15):12193. https://doi.org/ 10.3390/ijms241512193
6. Rutstein SE, Ananworanich J, Fidler S, et al. (2017). Clinical and public health implications of acute and early HIV detection and treatment: A scoping review. J Int AIDS Soc. 20(1):21579.
7. Megha KB, Joseph X, Akhil V, Mohanan PV. (2021). Cascade of immune mechanism and consequences of inflammatory disorders. Phytomedicine. ;91:153712.
8. Ezeuko AY, Nduka SO, Ezeuko CC, Oli AN, Ekwunife OI. (2024). Protocol for the development and validation of a trigger tool for antiretroviral ADE detection among adult HIV/AIDS patients: A short communication. 28(02), 052–058 https://doi.org/10.30574/gscbps.2024.28.2.0280
9. Knochelmann HM, Dwyer CJ, Bailey SR, Amaya SM, Elston DM, Mazza-McCrann JM, Paulos CM. (2028). When worlds collide: Th17 and Treg cells in cancer and autoimmunity. Cell Mol Immunol.;15(5):458-469. https://doi.org/10.1038/s41423-018-0004-4
10. Oparaugo NC, Ouyang K, Nguyen NPN, Nelson AM, Agak GW. (2023). Human Regulatory T Cells: Understanding the Role of Tregs in Select Autoimmune Skin Diseases and Post-Transplant Nonmelanoma Skin Cancers. Int J Mol Sci.12;24(2):1527.
11. Valverde-Villegas JM, Matte MC, de Medeiros RM, Chies JA. (2015). New Insights about Treg and Th17 Cells in HIV Infection and Disease Progression. J Immunol Res. 2015:647916.
12. Obaji MU, Oli AN, Ugwu MC. (2025). The Roles of IL-6, IL-8, and TNF-α in Pediatric Immune Defense and Infection Severity. *OBM Genetics* ; 9(2): 293; https://doi:10.21926/obm.genet.2502293

13. Ma R, Su H, Jiao K, Liu J. (2023). Role of Th17 cells, Treg cells, and Th17/Treg imbalance in immune homeostasis disorders in patients with chronic obstructive pulmonary disease. Immun Inflamm Dis.;11(2):e784. https://doi.org/10.1002/iid3.784
14. Goswami TK, Singh M, Dhawan M, Mitra S, Emran TB, Rabaan AA, Mutair AA, Alawi ZA, Alhumaid S, Dhama K. (2022). Regulatory T cells (Tregs) and their therapeutic potential against autoimmune disorders - Advances and challenges. Hum Vaccin Immunother.31;18(1):2035117.
15. Zheng SG. (2013). Regulatory T cells vs Th17: differentiation of Th17 versus Treg, are mutually exclusive? Am J Clin Exp Immunol. 27;2(1):94-106. https://doi.org/10.1007/978-3-0348-0522-3_6
16. Sun L, Wang L, Moore BB, Zhang S, Xiao P, Decker AM, Wang HL. (2023). IL-17: Balancing Protective Immunity and Pathogenesis. J Immunol Res. 12;2023:3360310. https://doi.org/10.1155/2023/3360310
17. Fuka Yamazaki, Kyosuke Kobayashi, Junko Mochizuki, Toshihiro Sashihara, (2024). Interleukin-22 enhanced the mucosal barrier and inhibited the invasion of *Salmonella enterica* in human-induced pluripotent stem cell-derived small intestinal epithelial cells, *FEMS Microbiology Letters*, Volume 371, 2024, fnae006, https://doi.org/10.1093/femsle/fnae006
18. Sanjabi S, Zenewicz LA, Kamanaka M, Flavell RA. (2009). Anti-inflammatory and pro-inflammatory roles of TGF-beta, IL-10, and IL-22 in immunity and autoimmunity. Curr Opin Pharmacol. ;9(4):447-53. https://doi.org /10.1016 / j.coph.2009.04.008
19. Kim CJ, McKinnon LR, Kovacs C, Kandel G, Huibner S, Chege D, Shahabi K, Benko E, Loutfy M, Ostrowski M, Kaul R. (2013). Mucosal Th17 cell function is altered during HIV infection and is an independent predictor of systemic immune activation. J Immunol. 1;191(5):2164-73. https://doi.org/10.4049/jimmunol.1300829
20. Ryan ES, Micci L, Fromentin R, Paganini S, McGary CS, Easley K, Chomont N, Paiardini M. (2016). Loss of Function of Intestinal IL-17 and IL-22 Producing Cells Contributes to Inflammation and Viral Persistence in SIV-Infected Rhesus Macaques. PLoS Pathog. 1;12(2):e1005412. https://doi.org/10.1371/journal.ppat.1005412
21. Tomas Raul Wiche Salinas, Annie Gosselin, Laurence Raymond Marchand, Etiene Moreira Gabriel, Olivier Tastet, Jean-Philippe Goulet, Yuwei Zhang, Dragos Vlad, et al. (2021). IL-17A reprograms intestinal epithelial cells to facilitate HIV-1 replication and outgrowth in CD4+ T cell. iScience. 24 (11): 10322 https://doi.org/ 10.1016/j.isci. 2021.103225
22. Di Vincenzo F, Del Gaudio A, Petito V, Lopetuso LR, Scaldaferri F. (2024). Gut microbiota, intestinal permeability, and systemic inflammation: a narrative review. Intern Emerg Med.;19(2):275-293. https://doi.org/ 10.1007/s11739-023-03374-w
23. Cai CW, Sereti I. (2021). Residual immune dysfunction under antiretroviral therapy. Semin Immunol. 51:101471 https://doi.org/10.1016/j.smim.2021.101471
24. Zayas, J. P., & Mamede, J. I. (2022). HIV Infection and Spread between Th_{17} Cells. **Viruses**, ***14***(2), 404. https://doi.org/10.3390/v14020404
25. Sun, L., Su, Y., Jiao, A. *et al.* (2023). T cells in health and disease. Sig Transduct Target Ther 8, 235. https://doi.org/10.1038/s41392-023-01471-y
26. Paiardini M, Müller-Trutwin M. (2013). HIV-associated chronic immune activation. Immunol Rev.254(1):78-101. https://doi.org/10.1111/imr.12079
27. Mollie AA Boyd, David van Bockel, Cynthia Mee Ling Munier, Anthony D Kelleher. (2022). Navigating the complexity of chronic HIV-1 associated immune dysregulation. Current Opinion in Immunology. (76):102186. https://doi.org/10.1016/j.coi.2022.102186
28. [28] Shukla S, Kumari S, Bal SK, Monaco DC, Ribeiro SP, Sekaly RP, Sharma AA. (2021). "Go", "No Go," or "Where to Go"; does microbiota dictate T cell exhaustion, programming, and HIV persistence? Curr Opin HIV AIDS. 1;16(4):215-222. https://doi.org/10.1097/coh.0000000000000692
29. Bixler SL, Mattapallil JJ. (2013). Loss and dysregulation of Th17 cells during HIV infection. Clin Dev Immunol.:852418. https://doi.org/10.1155/2013/852418
30. Tanes C, Walker EM, Slisarenko N, Gerrets GL, Grasperge BF, Qin X, Jazwinski SM, Bushman FD, Bittinger K, Rout N. Gut Microbiome Changes Associated with Epithelial Barrier Damage and Systemic Inflammation during Antiretroviral Therapy of Chronic SIV Infection, Viruses, 2021: 10.3390/v13081567, 13, 8, (1567). https://doi.org/10.3390/v13081567
31. Alexis Yero, Tao Shi, Omar Farnos, Jean-Pierre Routy, Cécile Tremblay, Madeleine Durand, Christos Tsoukas, Cecilia T. Costiniuk, Mohammad-Ali Jenabian, Dynamics and epigenetic signature of regulatory T-cells following antiretroviral therapy initiation in acute HIV infection, eBioMedicine, 2021: 10.1016.
32. Zhikai W, Zhifeng Z, Yao L, Yuhan L, Yuan L, Xiaoping P, Wei Z. Regulatory T cells and T helper 17 cells in viral infection. 2020; 91(5): e12873 https://doi.org/10.1111/sji.12873
33. Trickey A, Sabin CA, Burkholder G, Crane H, d'Arminio Monforte A, Egger M, Gill MJ, Grabar S, Guest JL, Jarrin I, et al. Life expectancy after 2015 of adults with HIV on long-term antiretroviral therapy in Europe and North America: A collaborative analysis of cohort studies. Lancet HIV. 2023;10:e295–e307. https://doi.org/10.1016/s2352-3018(23)00028-0
34. Hileman CO, Funderburg NT. Inflammation, Immune Activation, and Antiretroviral Therapy in HIV. Curr. HIV/AIDS Rep. 2017;14:93–100. https://doi.org/10.1007/s11904-017-0356-x
35. Ismail AM, Higazi AM, Nomeir HM, Farag NM. IL-23/Th17 pathway and IL-17A gene polymorphism in Egyptian children with immune thrombocbytopenic purpura. Ital J Pediatr. 2021 Aug 26;47(1):178. https://doi.org/10.1186/s13052-021-01131-3

36. Tang C, Chen S, Qian H, Huang W. (2012). Interleukin-23: as a drug target for autoimmune inflammatory diseases. Immunology. 135(2):112–124. https://doi.org/10.1111/j.1365-2567.2011.03522.x
37. Thiam F, Diop G, Coulonges C, Derbois C, Thiam A, Diouara AAM, Mbaye MN, Diop M, Nguer CM, Dieye Y, Mbengue B, Zagury JF, Deleuze JF, Dieye A. (2024). An elevated level of interleukin-17A in a Senegalese malaria cohort is associated with rs8193038 IL-17A genetic variant. BMC Infect Dis. 4;24(1):275. https://doi.org/10.1186/s12879-024-09149-8
38. Wen L, Shi L, Wan SS, Xu T, Zhang L, Zhou ZG. (2023). Changes in the balance of Th17/Treg cells and oxidative stress markers in patients with HIV-associated pulmonary tuberculosis who develop IRIS. Exp Ther Med. 21;25(6):271 https://doi.org/10.3892/etm.2023.11970
39. Tesfaye B, Alebel A, Gebrie A, Zegeye A, Tesema C, Kassie B. (2018). The twin epidemics: Prevalence of TB/HIV co-infection and its associated factors in Ethiopia; A systematic review and meta-analysis. PLoS One.;13(e0203986) https://doi.org/10.1371/journal.pone.0203986
40. Su XZ, Xu F, Stadler RV, Teklemichael AA, Wu J. Malaria: Factors affecting disease severity, immune evasion mechanisms, and reversal of immune inhibition to enhance vaccine efficacy. PLoS Pathog. 2025 Jan 23;21(1):e1012853. https://doi.org/10.1371/journal.ppat.1012853
41. Frosch AE, John CC. Immunomodulation in Plasmodium falciparum malaria: experiments in nature and their conflicting implications for potential therapeutic agents. Expert Rev Anti Infect Ther. 2012 Nov;10(11):1343-56. https://doi.org/10.1586/eri.12.118
42. Morales F, Montserrat-de la Paz S, Leon MJ, Rivero-Pino F. Effects of Malnutrition on the Immune System and Infection and the Role of Nutritional Strategies Regarding Improvements in Children's Health Status: A Literature Review. Nutrients. 2023 Dec 19;16(1):1. https://doi.org/10.3390/nu16010001
43. Gombart AF, Pierre A, Maggini S. A Review of Micronutrients and the Immune System-Working in Harmony to Reduce the Risk of Infection. Nutrients. 2020 Jan 16;12(1):236. https://doi.org/10.3390/nu1 2010236
44. Reda R, Abbas AA, Mohammed M, El Fedawy SF, Ghareeb H, El Kabarity RH, Abo-Shady RA, Zakaria D. The Interplay between Zinc, Vitamin D and, IL-17 in Patients with Chronic Hepatitis C Liver Disease. J Immunol Res. 2015:846348.https://doi.org/10.1155/2015/846348
45. Adel Abdel-Moneim, Heba H. Bakery, Gamal Allam. The potential pathogenic role of IL-17/Th17 cells in both type 1 and type 2 diabetes mellitus. Biomedicine & Pharmacotherapy. 2018 (101): 287-292 https://doi.org/10.1016/j.biopha.2018.02.103
46. Bijker EM, Deshpande S, Salgame P, Song R. Malaria and tuberculosis co-infection-a review. Oxf Open Immunol. 2023 Nov 15;4(1):iqad008 https://doi.org/10.1093/oxfimm/iqad008
47. Maizels RM, Smith KA. Regulatory T cells in infection. Adv Immunol. 2011;112:73-136. https//doi.org/10.1016/B978-0-12-387827-4.00003-6
48. Ross AG, Papier K, Luceres-Catubig R, Chau TN, Inobaya MT, Ng SK. Poverty, Dietary Intake, Intestinal Parasites, and Nutritional Status among School-Age Children in the Rural Philippines. Trop Med Infect Dis. 2017 Sep 21;2(4):49. https://doi.org/10.3390/tropicalmed2040049
49. Jacqueline María Valverde-Villegas, Maria Cristina Cotta Matte, Rúbia Marília de Medeiros, José Artur Bogo Chies. New Insights about Treg and Th17 Cells in HIV Infection and Disease Progression. Journal of Immunology Research. 2015. https://doi.org/10.1155/2015/647916
50. Su, J.; Zhang, J.; Wang, Q.; Liu, X.; Wang, S.; Ruan, Y.; Li, D. Multiparametric Immune Profiles and Their Potential Role in HIV-1 Disease Progression and Treatment. **Pathogens** 2025, ***14***, 347. https://doi.org/10.3390/pathogens14040347
51. Bekker, L.G.; Beyrer, C.; Mgodi, N.; Lewin, S.R.; Delany-Moretlwe, S.; Taiwo, B.; Masters, M.C.; Lazarus, J.V. HIV infection. Nat. Rev. Dis. Primers 2023, 9, 42 https://doi.org/10.1038/s41572-023-00452-3
52. Ip B, Cilfone NA, Belkina AC, DeFuria J, Jagannathan-Bogdan M, Zhu M, et al. Th17 Cytokines Differentiate Obesity From Obesity-Associated Type 2 Diabetes and Promote Tnfα Production. Obes (Silver Spring Md) 2016, 24(1):102–112
https://doi.org/10.1002/oby.21243
53. Caruso, M.P., Falivene, J., Holgado, M.P. et al. Impact of HIV-ART on the restoration of Th17 and Treg cells in blood and female genital mucosa. Sci Rep 9, 1978 (2019). https://doi.org/10.1038/s41598-019-38547-1
54. Adepoju VA, Udah DC, Onyezue OI, Adnani QES, Jamil S, Bin Ali MN. Navigating the Complexities of HIV Vaccine Development: Lessons from the Mosaico Trial and Next-Generation Development Strategies. Vaccines (Basel). 2025 Mar 5;13(3):274. https://doi.org/10.3390/vaccines13030274
55. Stepkowski S, Bekbolsynov D, Oenick J, Brar S, Mierzejewska B, Rees MA, Ekwenna O. The Major Role of T Regulatory Cells in the Efficiency of Vaccination in General and Immunocompromised Populations: A Review. Vaccines (Basel). 2024 Aug 30;12(9):992. https://doi.org/10.3390/vaccines12090992
56. Hartigan-O'Connor DJ, Hirao LA, McCune JM, Dandekar S. Th17 cells and regulatory T cells in elite control over HIV and SIV. Curr Opin HIV AIDS. 2011 May;6(3):221-7. https://doi.org/10.1097/coh.0b013e32834577b3
57. Yang X, Su B, Zhang X, Liu Y, Wu H, Zhang T. Incomplete immune reconstitution in HIV/AIDS patients on antiretroviral therapy: Challenges of immunological non-responders. J Leukoc Biol. 2020 Apr;107(4):597-612. https://doi.org/10.1002/jlb.4mr1019-189r
58. [58] Tseng A, Seet J, Phillips EJ. The evolution of three decades of antiretroviral therapy: challenges, triumphs and the promise of the future. Br J Clin Pharmacol. 2015 Feb;79(2):182-94. https://doi.org/10.1111/bcp.12403
59. Yero A, Goulet JP, Shi T, Costiniuk CT, Routy JP, Tremblay C, Mboumba Bouassa RS, Alexandrova Y, Pagliuzza A, Chomont N, Ancuta P, Jenabian MA. (2024). Altered memory CCR6+ Th17-polarised T-cell function and biology in

people with HIV under successful antiretroviral therapy and HIV elite controllers. EBioMedicine.107:105274 https://doi.org/10.1016/j.ebiom.2024.105274
60. Klatt NR, Chomont N, Douek DC, Deeks SG. (2023). Immune activation and HIV persistence: implications for curative approaches to HIV infection. Immunol Rev. 254(1):326-42. https://doi.org/10.1111/imr.12065
61. Wang X, Sun B, Wang Y, Gao P, Song J, Chang W, Xiao Z, Xi Y, Li Z, An F, Yan C. (2024). Research progress of targeted therapy regulating Th17/Treg balance in bone immune diseases. Front Immunol. 30;15:1333993. https://doi.org/10.3389/fimmu.2024.1333993
62. Huangfu L, Li R, Huang Y, Wang S. (2023). The IL-17 family in diseases: from bench to bedside. Signal Transduct Target Ther. 11;8(1):402. https://doi.org/10.1038/s41392-023-01620-3
63. Liu Y, Yan D, Chen R, Zhang Y, Wang C, Qian G. (2025). Recent insights and advances in gut microbiota's influence on host antiviral immunity. Front Microbiol.27;16:1536778. https://doi.org/10.3389/fmicb.2025.1536778
64. Alwin A., Karst S. M. (2021). The influence of microbiota-derived metabolites on viral infections. Curr. Opin. Virol. 49, 151–156. https://doi.org/10.1016/j.coviro.2021.05.006
65. [65] Sahle Z, Engidaye G, Shenkute Gebreyes D, Adenew B, Abebe TA. (2024). Fecal microbiota transplantation and next-generation therapies: A review on targeting dysbiosis in metabolic disorders and beyond. SAGE Open Med. 31;12:20503121241257486.
66. Al-Qahtani AA, Alhamlan FS, Al-Qahtani AA. (2024). Pro-Inflammatory and Anti-Inflammatory Interleukins in Infectious Diseases: A Comprehensive Review. Trop Med Infect Dis.4;9(1):13. https://doi.org/10.3390/tropicalmed9010013
67. Yazdi A.S., Ghoreschi K. (2026). The Interleukin-1 Family. Adv. Exp. Med. Biol. 941:21–29.
68. Kaneko N., Kurata M., Yamamoto T., Morikawa S., Masumoto J. (2029). The role of interleukin-1 in general pathology. Inflamm. Regen.39:12. https://doi.org/10.1186/s41232-019-0101-5
69. Caruso MP, Falivene J, Holgado MP, Zurita DH, Laufer N, Castro C, Nico Á, Maeto C, Salido J, Pérez H, Salomón H, Cahn P, Sued O, Fink V, Turk G, Gherardi MM. (2029). Impact of HIV-ART on the restoration of Th17 and Treg cells in blood and female genital mucosa. Sci Rep. 13;9(1):1978. https://doi.org/10.1038/s41598-019-38547-1
70. Arneth, B. (2025). Molecular Mechanisms of Immune Regulation: A Review. Cells, 14, 283
71. Cooper MD, Miller JF. (2019). Discovery of 2 distinctive lineages of lymphocytes, T cells and B cells, as the basis of the adaptive immune system and immunologic function: 2019 Albert Lasker Basic Medical Research Award. JAMA 322, 1247–1248. https://doi.org/10.1001/jama.2019.13815
72. Airola C, Severino A, Porcari S, Fusco W, Mullish BH, Gasbarrini A, Cammarota G, Ponziani FR, Ianiro G. (2032). Future Modulation of Gut Microbiota: From Eubiotics to FMT, Engineered Bacteria, and Phage Therapy. Antibiotics (Basel). 8;12(5):868 https://doi.org/10.3390/antibiotics12050868
73. Gomaa E.Z. (2020). Human gut microbiota/microbiome in health and diseases: A review. Antonie Van Leeuwenhoek Int. J. Gen. Mol. Microbiol.113:2019–2040. https://doi.org/10.1007/s10482-020-01474-7
74. Mills, K.H.G. (2023). IL-17 and IL-17-producing cells in protection versus pathology. Nat Rev Immunol 23, 38–54. https://doi.org/10.1038/s41577-022-00746-9
75. Elizabeth H. Mann, Leona Gabryšová, Paul E. Pfeffer, Anne O'Garra, Catherine M. Hawrylowicz; (2019). High-Dose IL-2 Skews a Glucocorticoid-Driven IL-17+IL-10+ Memory CD4+ T Cell Response towards a Single IL-10–Producing Phenotype. J Immunol 1. 202 (3): 684–693 https://doi.org/10.4049/jimmunol.1800697
76. Svetlana Zamorina, Valeria Timganova, Maria Bochkova, Kseniya Shardina, Sofya Uzhviyuk, Pavel Khramtsov, Darya Usanina, Mikhail Rayev, (2023). The Effect of PEGylated Graphene Oxide Nanoparticles on the Th17-Polarization of Activated T Helpers, Materials, 10.3390/ma16020877, 16, 2, (877). https://doi.org/10.3390/ma16020877
77. Chang Y, Zhai L, Peng J, Wu H, Bian Z, Xiao H. (2021). Phytochemicals as regulators of Th17/Treg balance in inflammatory bowel diseases. Biomedicine & Pharmacotherapy. (141): 111931..
78. Subramanian I, Verma S, Kumar S, Jere A, Anamika K. (2020). Multi-omics Data Integration, Interpretation, and Its Application. Bioinform Biol Insights.31;14:1177932219899051.
79. Thomas R, Qiao S, Yang X. (2023). Th17/Treg Imbalance: Implications in Lung Inflammatory Diseases. Int J Mol Sci. 2;24(5):4865. https://doi.org/10.3390/ijms24054865
80. Adeniji AA, Dulal S, Martin MG. (2021). Personalized Medicine in Oncology in the Developing World: Barriers and Concepts to Improve Status Quo. World J Oncol.12(2-3):50-60. https://doi.org/10.14740/wjon1345

CITATION OF THIS ARTICLE

Obaji M U, Emeruwa A P, Nwankwo E J. The Role of T-helper 17 and regulatory T cells Dynamics in HIV Pathogenesis and Treatment Strategies in West Africa. Bull. Env. Pharmacol. Life Sci., Vol 15 [2] January 2026. 24-31