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YOGA AND INFLAMMATORY BIOMARKERS (CRP, IL-6, AND TNF- α) IN ADULTS WITH CHRONIC CONDITIONS: A NARRATIVE REVIEW

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ABSTRACT

Chronic low-grade inflammation contributes to the pathogenesis and progression of many chronic disorders, and inflammatory biomarkers such as C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor- α (TNF- α) are frequently used to quantify systemic inflammatory activity. Yoga, a multidimensional mind-body practice combining physical postures, breathing techniques, and meditation, has been proposed as an adjunctive strategy to modulate stress-related neuroendocrine pathways and inflammation. This narrative review summarizes and critically discusses evidence on the effects of yoga-based interventions on CRP, IL-6, and TNF- α in adults with chronic conditions. The literature was explored using targeted searches of major biomedical databases and relevant reference lists, prioritizing randomized trials and meta-analyses reporting biomarker outcomes. Across clinical contexts—including inflammatory rheumatic disease, cardiovascular risk and post-myocardial infarction rehabilitation, and inflammatory bowel disease—yoga interventions consistently improved patient-reported outcomes such as stress, anxiety, and quality of life. Biomarker findings were heterogeneous: reductions in TNF- α and IL-6 were reported in some settings and protocols, whereas CRP changes were less consistent. Differences in populations, intervention intensity and duration, comparator conditions, and biomarker assessment methods likely contribute to variability across studies. Overall, current evidence suggests yoga may have anti-inflammatory potential in selected chronic disease populations, but more standardized, adequately powered trials with longer follow-up are needed to clarify the magnitude, durability, and mechanisms of biomarker effects.

KEYWORDS

Yoga; C-Reactive Protein; Interleukin-6; Tumor Necrosis Factor-alpha; Chronic Disease; Inflammation

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1. Introduction

Chronic low-grade inflammation is a central pathophysiological mechanism underlying a broad spectrum of diseases, including autoimmune, cardiovascular, metabolic, and malignant conditions (Furman et al., 2019). Rheumatoid arthritis, as a prototypical inflammatory rheumatic disease, illustrates the clinical consequences of persistent systemic inflammation and cytokine-driven tissue injury (Smolen et al., 2016). Although contemporary pharmacological therapies targeting immune pathways have improved outcomes, long-term treatment is often limited by adverse effects, incomplete disease control, and a need for supportive strategies that address both biological and psychosocial determinants of chronic illness (Smolen et al., 2016).

In this context, complementary approaches—particularly mind-body interventions—have gained increasing attention for their potential to improve patient-reported outcomes and modulate inflammation-related pathways (Sibilia & Toussiro, 2024). Yoga is a multidimensional practice integrating physical postures, controlled breathing, and meditation, with accumulating evidence suggesting beneficial effects on stress regulation, autonomic balance, and systemic inflammatory activity (Cramer et al., 2013; Djalilova et al., 2019). Mechanistically, yoga may influence the hypothalamic-pituitary-adrenal axis, enhance parasympathetic tone, and modulate immune signaling, thereby contributing to changes in circulating inflammatory biomarkers (Venkatesh et al., 2020). Clinical studies have reported improvements in stress-related indices and cardiometabolic parameters following structured yoga interventions, alongside changes in pro-inflammatory cytokines in selected populations (Patil et al., 2024; Wolff et al., 2015; Yadav et al., 2012).

In inflammatory rheumatic diseases, yoga has been associated with reductions in IL-6 and TNF- α , as well as improvements in autonomic regulation and functional outcomes (Ye et al., 2020). Similar benefits have been explored in other chronic conditions, including chronic fatigue syndrome, where yoga-based interventions were linked to reduced fatigue and improved physiological regulation (Oka et al., 2018). At the evidence-synthesis level, meta-analytic findings suggest a potential TNF- α -lowering effect of yoga and related

practices, although heterogeneity across interventions, populations, and biomarker assessment methods remains substantial (Mishra et al., 2024; Shah et al., 2022). Moreover, biomarker responses—particularly for CRP—appear less consistent across settings, highlighting the need for cautious interpretation and clinically contextualized conclusions.

Given the growing literature and variability of reported biomarker effects, the purpose of this narrative review is to synthesize and critically discuss evidence on yoga-based interventions and key inflammatory biomarkers—C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor- α (TNF- α)—in adults with chronic conditions. We focus on patterns across disease contexts, intervention characteristics, and plausible mechanisms that may explain heterogeneity in outcomes.

2. Methodology

This narrative review was conducted to synthesize and critically examine existing evidence on the effects of yoga-based interventions on systemic inflammatory biomarkers in adults with chronic conditions. A targeted literature search was performed using major biomedical databases, including PubMed and Scopus, to identify relevant peer-reviewed studies.

Search terms combined keywords and Medical Subject Headings (MeSH) related to yoga, inflammation, and chronic disease. Core search combinations included terms such as “yoga” or “yoga therapy” paired with “inflammatory markers,” “inflammatory biomarkers,” “C-reactive protein,” “cytokines,” “interleukin,” and “tumor necrosis factor,” as well as disease-related descriptors including “chronic disease,” “autoimmune disease,” “cardiovascular disease,” “inflammatory bowel disease,” and “metabolic syndrome.” Boolean operators were adapted to database-specific indexing systems to optimize sensitivity and relevance.

The review focused on studies involving adult populations with chronic diseases characterized by low-grade systemic inflammation. Priority was given to randomized controlled trials, controlled clinical studies, and meta-analyses evaluating structured yoga interventions and reporting quantitative outcomes related to key inflammatory biomarkers, particularly C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor- α (TNF- α). When relevant to mechanistic interpretation or clinical context, selected observational and experimental studies were also considered.

Studies were evaluated for relevance based on population characteristics, intervention design, biomarker assessment, and clinical applicability. Evidence synthesis followed a narrative approach, with findings organized thematically according to disease category, intervention characteristics, and biomarker outcomes. Particular attention was given to intervention duration, delivery format (e.g., in-person vs. remote), comparator conditions, and methodological limitations that could influence biomarker responses.

Given the heterogeneity in study populations, yoga protocols, outcome measures, and laboratory methodologies, a quantitative meta-analysis was not undertaken. Instead, the available evidence was integrated descriptively to highlight patterns, inconsistencies, and emerging mechanistic insights relevant to inflammation modulation through yoga-based practices.

3. Results

The available literature indicates heterogeneous effects of yoga-based interventions on inflammatory biomarkers across diverse chronic disease populations. Evidence spans inflammatory rheumatic disorders, cardiovascular and cardiometabolic conditions, gastrointestinal inflammatory diseases, and mixed chronic disease cohorts exposed to intensive lifestyle-based yoga programs. Across studies, the most frequently evaluated biomarkers included C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor- α (TNF- α), although additional endothelial, neuroendocrine, and adhesion markers were also reported. A structured summary of key clinical studies is presented in Table 1.

Table 1. Key clinical studies evaluating yoga-based interventions and inflammatory and related biomarkers across chronic disease populations.

Author (Year)	Population / Condition	Intervention	Duration	Key Biomarkers	Main Findings
Singh et al. (2023)	Ankylosing spondylitis	Tele-yoga vs standard care	8 weeks	IL-6, TNF- α , hs-CRP	IL-6 $\downarrow$, TNF- α $\downarrow$; hs-CRP: ns. BASDAI $\downarrow$; anxiety $\downarrow$
Yadav et al. (2012)	Mixed chronic conditions (intensive program)	Yoga-based lifestyle intervention	10 days	IL-6, TNF- α , cortisol	IL-6 $\downarrow$, TNF- α $\downarrow$, cortisol $\downarrow$; β -endorphin $\uparrow$
Peerani et al. (2022)	Inflammatory bowel disease	Online multicomponent stress reduction incl. yoga	12 weeks	CRP, fecal calprotectin	CRP: ns; fecal calprotectin: ns. Stress/anxiety/QoL $\uparrow$
Shah et al. (2022)	Mixed chronic disease populations (meta-analysis)	Yoga, meditation, breathing interventions	Varied	TNF- α , IL-6, cortisol	TNF- α $\downarrow$ (pooled); IL-6: ns; cortisol: ns; heterogeneity high
Patil et al. (2024)	Post-myocardial infarction patients	Yoga-based cardiac rehabilitation	12 weeks	hs-CRP, TNF- α , endothelial markers	hs-CRP: ns; TNF- α : ns. Endothelial markers improved
Wolff et al. (2015)	Adults with cardiovascular risk	Medical yoga vs home yoga vs control	12 weeks	hs-CRP, IL-6	hs-CRP: ns; IL-6: ns. Modest metabolic changes

Abbreviations: IL-6 — Interleukin-6; TNF- α — Tumor Necrosis Factor-alpha; CRP — C-reactive protein; hs-CRP — High-sensitivity C-reactive protein; QoL — Quality of life; BASDAI — Bath Ankylosing Spondylitis Disease Activity Index; ns — Not statistically significant.

In inflammatory rheumatic disease populations, yoga interventions have demonstrated promising anti-inflammatory and clinical effects. In a randomized controlled trial involving patients with ankylosing spondylitis, an eight-week tele-yoga program produced significant improvements in disease activity (BASDAI, $p \leq 0.001$) and anxiety ($p = 0.0004$). Biomarker analysis revealed significant reductions in IL-6 and TNF- α , while decreases in hs-CRP did not reach statistical significance (Singh et al., 2023). These findings suggest that yoga may exert immunomodulatory effects in inflammatory joint disease, potentially mediated through neuroendocrine and autonomic mechanisms.

Short-duration intensive yoga-based lifestyle interventions have also demonstrated measurable biochemical effects. In a ten-day program involving adults with chronic conditions, significant reductions were observed in cortisol, IL-6, and TNF- α , accompanied by an increase in β -endorphin levels (Yadav et al., 2012). The magnitude and rapid onset of biomarker change in this setting suggest that intervention intensity and environmental immersion may influence inflammatory responsiveness.

In gastrointestinal inflammatory disease, findings appear more variable. A randomized controlled trial in patients with inflammatory bowel disease evaluated a 12-week online stress-reduction program incorporating yoga, breathing practices, and meditation. Participants experienced significant improvements in stress, anxiety, depression, and quality of life indices; however, inflammatory biomarkers, including CRP and fecal calprotectin, did not differ significantly between intervention and control groups (Peerani et al., 2022). This divergence between psychological and biochemical outcomes highlights the complexity of inflammation modulation in chronic immune-mediated gastrointestinal disorders.

Cardiovascular and cardiometabolic populations provide further mixed evidence. In a multicenter randomized controlled trial assessing yoga-based cardiac rehabilitation following myocardial infarction, significant improvements were observed in endothelial and adhesion markers, including ADMA, endothelin-1, and ICAM-1 (Patil et al., 2024). However, classical systemic inflammatory biomarkers such as hs-CRP and TNF- α did not demonstrate significant between-group changes. Similarly, in adults with elevated cardiovascular risk, a controlled clinical trial comparing medical yoga, home-based yoga, and standard care reported no significant reductions in hs-CRP or IL-6 after 12 weeks, despite modest improvements in metabolic and blood pressure parameters (Wolff et al., 2015).

Evidence synthesized at the meta-analytic level provides additional context. A systematic review and meta-analysis evaluating yoga, meditation, and breathing-based interventions reported a statistically significant overall reduction in TNF- α concentrations, while effects on IL-6 and cortisol remained

nonsignificant and highly heterogeneous (Shah et al., 2022). These findings suggest that TNF- α may represent the most consistently responsive inflammatory biomarker to yoga-based practices, although inter-study variability remains substantial.

Across clinical contexts, yoga interventions were consistently associated with improvements in psychological well-being, perceived stress, and disease-related quality of life. In contrast, biochemical outcomes demonstrated variable responsiveness. Intensive short-term interventions appeared more likely to produce measurable cytokine reductions, whereas longer-duration programs in cardiometabolic populations yielded modest or nonsignificant inflammatory changes (Patil et al., 2024; Wolff et al., 2015; Yadav et al., 2012). Collectively, these findings underscore the importance of intervention design, population characteristics, and biomarker selection in interpreting the anti-inflammatory potential of yoga-based therapies.

4. Discussion

This narrative review synthesizes current evidence on the effects of yoga-based interventions on systemic inflammatory biomarkers across diverse chronic disease populations. Overall, the literature suggests that yoga may exert modulatory effects on inflammatory processes; however, the magnitude and consistency of biomarker changes vary substantially across clinical contexts, intervention designs, and study populations.

Evidence from clinical trials indicates that yoga may complement conventional therapeutic strategies in inflammatory rheumatic, cardiovascular, and gastrointestinal diseases. In inflammatory joint disorders, including ankylosing spondylitis, structured yoga interventions have been associated with reductions in pro-inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- α), alongside improvements in disease activity and psychological outcomes (Singh et al., 2023). Similar multidimensional benefits—encompassing stress reduction, functional improvement, and enhanced coping—have been observed across chronic disease populations, reinforcing yoga's role as a mind-body therapeutic modality (Cramer et al., 2013; Yadav et al., 2012).

In contrast, findings in cardiometabolic and cardiovascular risk populations appear less consistent. While yoga-based cardiac rehabilitation programs have demonstrated favourable effects on endothelial and vascular function markers, classical systemic inflammatory biomarkers such as high-sensitivity C-reactive protein (hs-CRP) and TNF- α have not shown uniform reductions (Patil et al., 2024). Similarly, controlled trials in individuals with elevated cardiovascular risk have reported minimal or nonsignificant changes in IL-6 and hs-CRP despite modest metabolic improvements (Wolff et al., 2015). These discrepancies suggest that yoga's anti-inflammatory effects may be more pronounced in conditions characterized by active immune dysregulation than in primary cardiometabolic risk states.

Meta-analytic evidence provides additional perspective. Pooled analyses of mind-body interventions incorporating yoga, meditation, and breathing techniques have demonstrated significant reductions in TNF- α , whereas effects on IL-6 and cortisol remain heterogeneous and frequently nonsignificant (Shah et al., 2022). This pattern aligns with observations from individual trials and may indicate differential responsiveness among inflammatory biomarkers.

The biological mechanisms underlying yoga's immunomodulatory effects are likely multifactorial. Yoga practices have been associated with improved autonomic regulation, characterized by enhanced parasympathetic activation and attenuation of sympathetic overactivity (Cramer et al., 2013; Venkatesh et al., 2020). Neuroendocrine modulation, including reductions in cortisol and stress-related hormonal signaling, may further contribute to downstream cytokine regulation (Yadav et al., 2012). At the molecular level, emerging evidence suggests that yoga may influence gene expression pathways linked to inflammation and immune cell function (Venkatesh et al., 2020; Shah et al., 2022). Collectively, these adaptations support the conceptualization of yoga as an integrative intervention targeting both physiological and psychosocial determinants of chronic inflammation.

Despite encouraging findings, several limitations within the evidence base must be acknowledged. Considerable heterogeneity exists in study design, intervention duration, delivery format, and biomarker assessment methodologies (Djalilova et al., 2019; Shah et al., 2022). Many trials involve small sample sizes, short follow-up periods, or multicomponent interventions that limit attribution of effects specifically to yoga. Additionally, variability in adherence, intensity, and instructor supervision may influence outcomes and complicate cross-study comparison.

Future research should prioritize large-scale, methodologically rigorous randomized controlled trials employing standardized yoga protocols, harmonized biomarker panels, and extended follow-up. Mechanistic studies integrating molecular, autonomic, and neuroendocrine endpoints will be essential to clarify causal pathways and to identify patient populations most likely to benefit from yoga-based interventions.

5. Conclusions

This narrative review highlights the potential role of yoga-based interventions as adjunctive strategies in the modulation of systemic inflammation across chronic disease populations. Evidence from clinical trials and meta-analyses suggests that yoga may reduce selected inflammatory biomarkers—particularly TNF- α —while also improving psychological well-being, stress regulation, and functional outcomes.

However, biomarker responses remain heterogeneous, with inconsistent effects observed for CRP and IL-6, particularly in cardiometabolic populations. Variability in intervention intensity, duration, and study design limits direct comparability and generalizability of findings.

Taken together, current evidence supports yoga as a safe, accessible, and integrative therapeutic modality with potential anti-inflammatory benefits when incorporated alongside conventional medical care. Further high-quality trials with standardized methodologies and long-term follow-up are warranted to establish the durability, clinical magnitude, and mechanistic basis of these effects.

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