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REVIEW ARTICLE

The Impact of Yoga on the Immune System of Cancer Patients: A Scoping Review of Current Evidence

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ABSTRACT

Background: Cancer is a growing problem worldwide, and new strategies for its management and treatment are required. The immune system plays a crucial role in cancer progression and the response to treatment. Recent studies have demonstrated that practicing yoga can positively affect the immune system. This review aimed to examine the impact of yoga on immune parameters in patients with cancer.

Methods: We conducted literature searches across several scientific databases for trials published from 2014 to 2023. Studies were selected based on specific criteria, including randomized controlled trials involving yoga interventions with quantitative outcome assessments.

Results: Eight studies met our inclusion criteria. These findings suggest that practicing yoga can significantly improve immune function in patients with cancer. Key findings include reductions in inflammatory cytokines, improvements in natural killer cell counts, and modulated gene expression related to immune cell survival. Specific studies have demonstrated benefits in reducing stress and fatigue, enhancing overall quality of life (QoL), and immunological benefits.

Conclusion: This review indicates that yoga interventions hold substantial promise in enhancing immune function and overall QoL in patients with cancer. Evidence supports the incorporation of yoga into cancer treatment protocols as a non-invasive, holistic approach to improving immune function. However, further research is needed to standardize yoga interventions and to explore their long-term effects.

1. INTRODUCTION

Cancer is a multifaceted disease characterized by abnormal cell growth that has the potential to invade or spread to other parts of the body. The incidence of cancer is on a rising trajectory, with the World Health Organization reporting an estimated 19.3 million new cancer cases and almost 10 million cancer-related deaths in 2020.[1] This increasing trend is anticipated to escalate, with projections suggesting 28.4 million cases by 2040, a surge of 47% from 2020. This alarming rise is partly attributed to population growth and aging, as well as changes in the prevalence and distribution of significant risk factors for cancer, many of which are associated with socioeconomic development. According to the World Health Organization, Asia has reported high cancer incidence and death rates, with statistics indicating 48.4% and 57.3%, respectively.[2]

The global burden of cancer is substantial, leading to increased economic and clinical strains in the health-care system.[3] The profound economic impact of cancer not only encompasses direct medical costs but also includes lost productivity due to illness and premature death. Globally, the financial toll of cancer was estimated to be approximately USD 1.16 trillion in 2010, a figure that has undoubtedly risen since. Beyond its economic impact, cancer imposes a significant psychological burden on patients and their families.[4] A cancer diagnosis often leads to substantial emotional distress, including anxiety, depression, and a profound fear of death. These psychological factors can further impact physical health and the overall quality of life (QoL).

The immune system plays a crucial role in the treatment and prognosis of cancer. Cancer immunoediting reflects the dual role of the immune

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system in protecting the host from cancer development and shaping the immunogenicity of the tumor. The immune system can identify and eliminate cancer cells through a process known as immune surveillance. However, cancer cells can evolve mechanisms to evade immune detection and destruction, leading to tumor progression and metastasis. Thus, immune system modulation is a critical aspect of cancer therapy and its overall management. Emerging evidence suggests that lifestyle interventions such as yoga may benefit the immune system.

1.1. Objectives

This review aims to explore the current evidence on the immune effects of yoga on cancer patients. By evaluating the impact of yoga on various immune parameters, such as cytokine levels, lymphocyte counts, and natural killer (NK) cell activity, this review sheds light on the potential of yoga as a complementary intervention in the holistic management of cancer.

2. METHODS

This systematic review aligned with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[5] Literature searches were conducted across various databases, including PubMed, Web of Science, Amed, Embase, Emcare, Cochrane Library, and CINAHL. The search utilized keywords, including yoga, cancer, inflammation, and immune response, focusing on human studies published in English from 2014 to 2023. Exclusion criteria were conference proceedings, editorials, commentaries, case reports, qualitative studies, and book-related literature. All database results were initially aggregated, and duplicates were eliminated. The remaining studies were screened, and the titles, abstracts, and full texts were examined to ascertain adherence to our inclusion criteria.

Inclusion and Exclusion Criteria and Data Analysis Methodology: The selection of studies was predicated on specific inclusion criteria: (a) randomized controlled clinical trials with human participants; (b) interventions involving "Yoga" in comparison to a non-yoga control group; and (c) the utilization of quantitative measures for outcome assessment. Publications in non-English languages were excluded from the analysis. The following data were extracted: (1). Study details, such as first author, year of publication, and country, (2). Methodological elements, including sample size and age range, were present in both the intervention and control groups, (3). Specifics of study design, such as randomization methods and duration of the study, (4) Comprehensive descriptions of the intervention and control conditions, particularly detailing the type, frequency, and duration of yoga practice. (5) Outcome measures focusing on objective laboratory parameters.

2.1. Cancer and the Immune System

The immune system is crucial for the development, progression, and treatment of cancer. It affects various stages of cancer evolution, from initiation to metastasis, through multiple factors, including systemic immunity, long noncoding RNAs, immune checkpoints, and the tumor microenvironment.

Systemic immunity contributes to the body's ability to recognize and eliminate cancer cells. The capacity of the immune system to identify cancer cells as foreign and subsequently eliminate them is the basis of immunotherapy in cancer treatment.[6] Long noncoding RNAs (lncRNAs) have been shown to play crucial roles in different phases of cancer immunity, including antigen release, antigen presentation, immune activation, immune cell migration, infiltration into cancer tissues, and killing cancer cells.[7] In addition, the immune system has been found to contribute to the effects of standard cancer risk factors, suggesting a link between immunity and cancer risk, and the interaction between the programmed cell death-1 (PD-1) receptor and its ligand PD-L1 has been identified as a vital immune checkpoint that is often adopted by cancer cells to undergo immune evasion.[8,9] These mechanisms have been shown to significantly impact the success of cancer immunotherapy, with various cancer cell-intrinsic and cancer cell-extrinsic processes regulating intrinsic or acquired resistance to cancer immunotherapy.[10]

The TME plays a critical role in shaping the immune response to cancer. Tumors create spatial and nutrient constraints that can affect immune cell function and differentiation, thereby tipping the balance between cytotoxic and regulatory immunity to facilitate tumor growth.[11,12] In addition, the metabolic plasticity displayed by innate and adaptive immune cells is influenced by tumor-derived lactate and acidity, which can restrict immunity.[13] These alterations can significantly impact immune cell behavior and function, ultimately affecting the body's ability to mount an effective anti-tumor immune response.[14] Inflammatory processes induced by cancer can also have profound effects on immunity. The activation and recruitment of immune cells during inflammation result in a cytokine- and chemokine-enriched environment that can affect cancer development and progression.[15]

2.2. The Impact of Yoga on Patients with Cancer

The impact of yoga on cancer has been extensively studied, with numerous studies exploring its potential benefits for cancer patients and survivors. Yoga has been studied in multiple intervention trials, primarily testing its impact on health-related outcomes in women with breast cancer Rock *et al*.[16] A systematic review and meta-analysis provided evidence that yoga-based interventions are associated with the improvement of depression and anxiety symptoms in people with cancer, suggesting it is a promising therapeutic modality for their management.[17]

Furthermore, yoga improves stress, inflammation, and immune function biomarkers in cancer survivors, indicating its potential to modulate immune responses.[18] Several studies have reported reliable effects of yoga interventions in managing treatment-related symptoms in patients with breast cancer.[19] In addition, yoga has shown promise for improving cancer-related symptoms, such as fatigue and stress.[20] Moreover, yoga has been associated with reduced chemotherapy-induced nausea and emesis in patients with breast cancer undergoing adjuvant radiotherapy.[21]

In addition to symptom management, yoga has been linked to improvements in cortisol rhythm and mood states in patients with early breast cancer undergoing adjuvant radiotherapy, suggesting its potential to alleviate psychological distress associated with cancer treatment.[22] Yoga interventions have also been found to reduce cancer-related fatigue and the global side-effect burden in cancer survivors, indicating their potential to enhance overall well-being.[23]

Moreover, yoga has been shown to improve sleep quality, reduce the production of pro-inflammatory cytokines, and decrease fatigue in breast cancer survivors, suggesting its potential to modulate immune and stress responses.[24] Yoga has also been associated with improved antioxidant status, immune function, and stress hormone release in young, healthy individuals, indicating its potential to positively affect immune function.[25]

Overall, evidence suggests that yoga may have a multifaceted impact on cancer, including symptom management, psychological well-being, immune function, and overall QoL. The potential benefits of yoga for cancer patients and survivors warrant further investigation to elucidate its mechanisms of action and explore its therapeutic potential in various clinical populations.

2.3. Yoga and the Immune System

Yoga has been the subject of numerous studies that have investigated its effects on immunity. These findings suggest that yoga positively affects the immune system through various mechanisms. One study has indicated that yoga reverses the negative impact of stress on the immune system by increasing the levels of immunoglobulin A and NK cells.[26] In addition, yoga was found to induce neurohormonal modulation via the HPA axis, resulting in reduced cortisol levels and a balance in the sympathetic and parasympathetic nervous systems, which can have implications for immune function.[27]

Certain yoga poses are believed to compress and rejuvenate immune organs and channels, potentially influencing immune function. Several randomized controlled trials have provided evidence that yoga may improve stress, inflammation, and immune function biomarkers, suggesting a potential immunomodulatory effect.[18] A systematic review of randomized controlled trials also suggested that yoga may exert beneficial effects by enhancing cell-mediated and mucosal immunity.[28]

Yoga is associated with improved emotional regulation, reduced pain perception, and increased pain tolerance, which may indirectly affect immune function.[29] In addition, yoga has been found to boost the immune system in oncology patients and improve immune function in individuals with type 2 diabetes.[30]

Preliminary research has demonstrated that yoga affects the immune system and may act as a more viable or suitable alternative for individuals undergoing chemotherapy, such as patients with breast cancer.[31,32] Yoga has been shown to reduce perceived stress levels, anxiety, depression, and radiation-induced DNA damage in patients with cancer undergoing radiotherapy, indicating its potential to modulate immune and stress responses.[33] In addition to its effects on immune function, yoga has been associated with reduced stress, increased well-being, and improved QoL in various populations, including nurses, individuals with chronic pancreatitis, and HIV-infected adults with cardiovascular disease risk factors.[34-36] Yoga has also been linked to reduced fatigue and improved regulation of cortisol secretion in breast cancer survivors, suggesting its potential for modulating stress-related immune responses.[37] A systematic review of 11 RCTs by Yeun *et al*. concluded that yoga might have favorable effects in reducing anti-inflammatory markers in different clinical settings.[38]

The exact mechanisms by which yoga exerts its effects are largely unknown, but are thought to include reduced inflammation, stress reduction, and relaxation, influencing the psycho-neuro-immune and endocrine axis, reductions in inflammatory cytokines, reduced stress hormone release, strengthening muscles and improving body flexibility, improving cerebral oxygenation, and balancing excitatory/inhibitory neurotransmitter equilibrium.[39-45]

3. RESULTS

Following an initial search across multiple databases, including PubMed, Web of Science, Amed, Embase, Emcare, Cochrane Library, and CINAHL, 56 potentially relevant publications were identified. After eliminating duplicates, 39 publications remained in total. A subsequent screening process based on titles and abstracts using our specific inclusion criteria further refined the selection to 29 studies. After a thorough review of the full text of these articles, 11 articles were shortlisted, but only eight of these studies met all the requirements for inclusion in our final review [Figure 1]. Herein, we present a detailed analysis of the eight selected studies and summarize their key findings in Table 1.

In their randomized trial, Kaushik *et al*. randomized 29 men with localized prostate cancer into two groups: a yoga group for 6 weeks (14 participants) and a standard-of-care group (15 participants) before radical prostatectomy.[46] The primary outcome measured was self-reported QoL, which was assessed using various tools such as the expanded prostate index composite (EPIC) and others at different time points. The secondary outcomes included changes in immune cell status and cytokine levels related to the yoga intervention. The yoga intervention in this study involved 60-minute yoga sessions twice weekly for 6 weeks, both before and after surgery. These tailored Hatha yoga sessions focused on physical postures, gentle breathing, and movement awareness to mobilize significant joints. The outcomes measured included QoL and various immune markers. The key findings indicated that the yoga group experienced significant improvements in both QoL and immune function. The yoga group showed decreased numbers of regulatory T-cell myeloid-derived suppressor cells, indicating antitumor activity and reduction in inflammatory cytokine levels (granulocyte colony-stimulating factor (0.55 [0.05–1.05], $P = 0.03$), monocyte chemoattractant protein (0.22 [0.01–0.43], $P = 0.04$), and FMS-like tyrosine kinase-3 ligand (0.91 [−0.01, 1.82], $P = 0.053$). These results suggest that yoga could be an effective adjunctive therapy for patients with prostate cancer, not only improving their QoL but also potentially enhancing their immune response against cancer.

A randomized study by Vadiraja *et al*. involved 91 patients with metastatic breast cancer divided into two groups. One group (46 patients) participated in an integrated yoga program, while the other group (45 patients) received supportive therapy and education for more than 3 months.[47] The study aimed to evaluate the impact of yoga on various health parameters, including stress, fatigue, cortisol levels, and NK cell counts, which are crucial for immune response. The intervention group received an "integrated yoga program," and the control group received "supportive counseling sessions" supportive counseling sessions, both imparted as individual sessions over 3 months. The yoga module comprised various practices, including asana (postures), pranayama (regulated nostril breathing), yogic relaxation in the supine position (Shavasana), meditation, self-appraisal, and counseling. The results showed that the yoga group experienced considerable improvements compared to the supportive therapy group. Specifically, yoga led to a notable reduction in perceived stress and various aspects of fatigue, including frequency, severity, and interference with daily life.

Furthermore, there was a significant decrease in the diurnal variation in fatigue. Notably, there was a positive correlation between a reduction in fatigue severity and salivary cortisol levels at 9 a.m. This finding is particularly relevant because cortisol is a stress hormone, and its reduction indicates decreased stress levels. In addition, NK cell counts and vital immune system components were improved. Overall, this study suggests that yoga can be a beneficial adjunct therapy for patients with metastatic breast cancer, reducing stress and fatigue, lowering cortisol levels, and enhancing immune response, as evidenced by improved NK cell counts.

In their study, Khedmati Zare *et al*. examined the combined effect of yoga and vitamin D supplementation on gene expression and psycho-physical status in BC survivors who had completed chemotherapy and radiotherapy 5 years before recruitment.[48] Thirty patients were randomly assigned into three groups: high-dose (4000 IU) vitamin D supplementation, yoga training with high-dose vitamin D, and yoga training with low-dose (2000 IU) vitamin D.

The yoga group practiced yoga twice a week for 12 weeks. The duration of the yoga program started at 60 min and progressively increased to 90 min over the course. One certified yoga teacher conducted yoga sessions. Yoga exercises were selected from the Hatha yoga style and included asana (physical posture), pranayama (breath control), and dyana (meditation). Alongside the psychological and physical assessments, blood samples were collected for gene expression analysis in leukocytes, explicitly focusing on the p53, NF-κB, Bcl2, and Bax genes. Patients in the vitamin D and yoga combined group showed significant improvements in body fat percentage, shoulder flexibility, walk tests, and anxiety compared to those taking only high-dose vitamin D. In addition, yoga combined with high-dose vitamin D significantly increased p53 expression ($P = 0.002$). In contrast, both the yoga and Vitamin D groups showed upregulated Bcl2 gene expression. Although NF-κB and Bax expression decreased in all groups, the differences were not statistically significant. The authors concluded that combining yoga training with a high dose of VD supplementation further benefits some crucial molecular markers of immune cell survival and the physical and psychological status of BC survivors.

In their randomized controlled trial, Huberty *et al*. investigated the effects of a 12-week online yoga intervention on patients with myeloproliferative neoplasm (MPN), focusing on symptom burden, QoL, and inflammatory biomarkers.[49] Patients were randomized into two groups: an online yoga group (60 min/week) and a wait-list control group (maintaining regular activity). This study used clicky, an online web analytics tool, and self-reporting to track weekly yoga participation. Inflammatory markers (interleukin [IL]-6 and tumor necrosis factor alpha [TNF-α]) were assessed using blood draws at the start and end of the intervention. The participants also completed various questionnaires to measure depression, anxiety, fatigue, pain, sleep disturbance, sexual function, total symptom burden, global health, and QoL. Of the 62 enrolled patients, 48 completed the intervention (27 and 21 in the yoga and control groups, respectively). The yoga participants showed an average engagement of approximately 40–56 min/week. The yoga group experienced minor-to-moderate improvements in sleep disturbance, pain intensity, anxiety, and depression. However, there was a significant decrease in TNF-α levels in the yoga group. This study demonstrates the potential benefits of yoga for MPN patients, not only in symptom relief but also in reducing inflammation, as evidenced by the decrease in TNF-α levels. This study demonstrates the feasibility of remote yoga intervention and blood sampling.

In their randomized study, Sohl *et al*. aimed to assess the efficacy of Yoga Skills Training (YST) in patients with gastrointestinal cancer undergoing chemotherapy.[50] The primary aim of this study was to evaluate the effectiveness of YST in reducing fatigue and treatment-related toxicities. However, a key focus was also to assess the effect of the intervention on the inflammatory markers. This was a randomized controlled pilot study involving 44 out of 77 participants (57% participation rate). The participants were randomized into two groups: the YST group (23 participants) and the attention control (AC) group (21 participants). The YST included four 30-min in-person sessions (at weeks 2, 4, 6, and 8) focused on awareness, movement, breathing practices, and meditation, supplemented by home practice with a 16-minute audio recording. Assessments were performed using patient-reported outcomes for fatigue, depressive symptoms, sleep disturbances, and psychological stress. Inflammatory cytokines (IL-6, sTNF-R1) were measured at baseline and at week 10. The YST group reported a more significant reduction in fatigue, depressive symptoms, and sleep disturbances than the AC group did. Notably, the YST group also showed a significant decrease in inflammatory cytokines (IL-6, sTNF-R1) compared to the AC group, suggesting an anti-inflammatory effect of yoga intervention.

In a large randomized controlled trial, Kiecolt-Glaser *et al*. aimed to evaluate the effectiveness of a 12-week Hatha yoga program in reducing pro-inflammatory cytokines and improving fatigue, vitality, and depression in breast cancer survivors.[51] In the study, 200 breast cancer survivors were randomized into two groups: a Hatha yoga intervention group and a wait-list control group. The yoga group participated in 90-min Hatha yoga classes twice per week for 12 weeks, involving a set of asanas and pranayama. The study assessed the production of pro-inflammatory cytokines (IL-6, TNF-α, and IL-1β) and measured fatigue, vitality, and depression using the MFSI-SF, SF-36 vitality scale, and CES-D scale. After treatment, while fatigue levels were not significantly lower, vitality was higher in the yoga group than in the control group. At 3 months post-treatment, the yoga group showed significantly lower fatigue, higher vitality, and reduced levels of IL-6, TNF-α, and IL-1β than the control group. No significant differences were found in the depression scores. Secondary analyses revealed that the frequency of yoga practice was strongly associated with reductions in fatigue and improved vitality, with more frequent practice resulting in more significant changes. Increased yoga practice also led to a decrease in IL-6 and IL-1β production. These findings are relevant in the context of cancer survivorship. The reduction in pro-inflammatory cytokines such as IL-6 and IL-1β in the yoga group suggests that yoga may have an immunomodulatory effect, which is potentially beneficial for breast cancer survivors who often experience chronic inflammation post-treatment. Inflammation contributes to physical decline, frailty, and disability. This study also highlights the importance of regular and frequent yoga practices for maximizing these benefits.

In their randomized controlled trial, Bower *et al*. investigated whether a 12-week Iyengar yoga intervention could decrease inflammation-related gene expression and circulating markers of pro-inflammatory cytokine activity in breast cancer survivors with persistent cancer-related fatigue, which is a common and debilitating long-term effect of cancer and its treatment.[52] Participants were randomized into two groups: an Iyengar yoga intervention group (16 participants) and a health education control group (15 participants). The yoga intervention emphasized passive inversions and backbends, which are characteristic of the Iyengar system. Blood samples were collected for genome-wide transcriptional profiling, bioinformatic analyses, plasma inflammatory markers, and salivary cortisol assessment at baseline, post-intervention, and at the 3-month follow-up. The yoga group demonstrated reduced activity of the pro-inflammatory transcription factor NF-κB, increased activity of the anti-inflammatory glucocorticoid receptor, and reduced activity of the CREB family transcription factors. There was a significant intervention effect on sTNF-RII, indicating stable TNF activity levels in the yoga group, whereas levels increased in the control group. However, no significant changes were observed in the CRP, IL-6, or diurnal cortisol levels. The reduction in inflammation-related gene expression and stabilization of sTNF-RII levels in the yoga group suggests that Iyengar yoga may modulate critical aspects of the inflammatory process. This is particularly relevant, given the role of inflammation in cancer progression and the impact of persistent fatigue on the QoL of breast cancer survivors. The lack of significant changes in some inflammatory markers, such as CRP and IL-6, indicated that the effects of yoga on inflammation might be specific to certain pathways or markers. These findings highlight the complexity of the inflammatory response in cancer survivors and the need for targeted intervention.

Jain *et al*. conducted a randomized clinical trial to examine the impact of yoga on immunity in patients with cancer.[53] The study aimed to assess the effects of long-term yogic intervention on the levels of inflammatory cytokines and oxidative stress markers, along with symptomatic scales and QoL, in stage II/III breast cancer patients undergoing chemotherapy and radiotherapy. Ninety-six participants were divided into two groups: a non-yoga group (Group I) and a yoga group (Group II). The group practiced various techniques 5 days a week for 48 weeks. Measurements included the European Organization for Research and Treatment of Cancer QoL Questionnaire (EORTC-QLQ30) for QoL and symptomatic scale and serum levels of pro-inflammatory cytokines (TNF-α, IFN-γ, GM-CSF) and oxidative stress markers (SOD, CAT, MDA, and NO) at baseline, 16, 32, and 48 weeks. The yoga intervention comprised asanas, pranayama, shavasana, meditation, om chanting, and yoga nidra. The study found significant reductions in IFN-γ, TNF-α, and MDA levels in the yoga group compared to those in the non-yoga group.

Additionally, the yoga group showed significant improvements in QoL and symptomatic scales. Interestingly, NO levels were upregulated in the non-yoga group but remained stable in the yoga group. Reducing pro-inflammatory cytokines (IFN-γ and TNF-α) and oxidative stress markers (MDA) in the yoga group suggests a potential anti-inflammatory and antioxidative effect of long-term yoga practice. This is particularly relevant, as inflammation and oxidative stress are linked to tumor proliferation, metastasis, and treatment-related side effects in breast cancer. In contrast to the stability of NO levels in the non-yoga group, the stability of NO levels in the yoga group may also indicate a regulatory effect of yoga on specific biochemical pathways. This study provides valuable evidence supporting the integration of yoga as a complementary therapy in cancer treatment, particularly for its potential to reduce inflammation and oxidative stress while improving the overall QoL.

4. DISCUSSION

We have found two systematic reviews that investigate the impact of yoga on immunity that have already been published. In 2018, Falkenberg *et al*. conducted a systematic review of randomized controlled trials to evaluate the effects of yoga on immune function.[28] The review covered various demographic and clinical populations and examined various immune parameters. The study concluded that yoga positively affected immune function, particularly by reducing pro-inflammatory markers. Similarly, Yeun *et al*. conducted a systematic review of randomized controlled trials in 2021 to assess the effects of yoga on immune function.[38] This study also examined different types of yoga practice, including healthy individuals and those with inflammatory diseases. The study concluded that yoga positively affects specific immune parameters, indicating its potential as a beneficial practice for enhancing immune function across different health contexts.

Our study, which specifically focused on cancer patients, supports the findings of the Falkenberg and Yeun reviews and adds to the multidimensional understanding of yoga's potential benefits by providing targeted insights into yoga's role in oncology. The randomized controlled trials analyzed in this review provide a comprehensive understanding of the effects of yoga on immunity in patients with cancer. These results consistently suggest that yoga interventions can significantly improve the immune function and QoL of this population. This review demonstrates that yoga benefits cancer patients by reducing regulatory T-cells, inflammatory cytokines, and stress, while enhancing NK cell counts and reducing pro-inflammatory markers in various cancer types. The integration of yoga with vitamin D supplementation also improved the expression of immune cell genes.

These findings highlight yoga's potential as a complementary therapy in cancer care, emphasizing its role in enhancing immune function and overall well-being. Yoga can be recommended as part of a holistic treatment approach to improve QoL, reduce treatment-related side effects, and possibly enhance antitumor immunity. However, these studies have limitations such as variations in yoga interventions, small sample sizes, and short intervention durations. The differences in yoga style and dosage make it challenging to generalize the findings. Additionally, some studies relied on self-reported measures, which may introduce bias. Future research should address these limitations by standardizing yoga interventions and using objective measures over longer durations.

One study that deserves attention is the large-scale, multicenter phase III RCT conducted by Lin *et al*. The study is yet to be fully published but was presented at the 2023 American Society of Clinical Oncology Annual Meeting.[54] This study adds significant depth to our understanding of yoga's impact on cancer survivors. The trial randomized 502 patients and compared a specific yoga program, Yoga for Cancer Survivors (YOCAS), which comprised gentle hatha and restorative yoga, against a control group receiving survivorship health education. The primary focus on inflammation, measuring pro-inflammatory and anti-inflammatory markers, addresses a critical aspect of cancer progression and survival.

The results were significant, as participants in the YOCAS group showed a marked reduction in pro-inflammatory markers (IL-1β, TNF-α, and IFN-γ) and a trend towards lower anti-inflammatory markers (IL-4, IL-10, and sTNFRI). These findings were reinforced by statistical analyses, including ANCOVA and structural equation modeling, which demonstrated a reduction in the overall inflammatory status in the YOCAS group compared to the control group.

The study findings are crucial for clinicians and healthcare providers, suggesting that yoga could be a viable non-pharmaceutical therapy to reduce inflammation in cancer survivors. This is particularly important, as inflammation is linked to a higher risk of cancer progression, recurrence, and the development of secondary cancers. This study provides strong evidence supporting the prescription of YOCAS, highlighting its potential role in reducing chronic toxicity burden and improving overall survivorship care. It broadens the scope of our understanding of yoga's benefits beyond immediate symptom management to include long-term impacts on inflammation. In addition, it opens avenues for research into yoga's effects on other aspects of cancer survivorship, such as recurrence rates and secondary cancer development.

5. CONCLUSION

In conclusion, our review suggests that yoga has numerous benefits in enhancing immune function and the overall QoL in patients with cancer. Yoga interventions significantly improve immune responses in patients with cancer by reducing inflammatory cytokines, enhancing NK cell counts, and modulating gene expression. Incorporating yoga into cancer treatment protocols can provide a non-invasive, holistic approach to improve the immune function and QoL of cancer patients. Future research should explore the long-term effects, standardize interventions, and understand the mechanisms behind yoga's impact on cancer and survivorship.

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7. AUTHORS' CONTRIBUTIONS

All the authors contributed equally to the design and execution of the article.

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9. ETHICAL APPROVALS

This study does not require ethical clearance as it is a review study.

10. CONFLICTS OF INTEREST

Nil.

11. DATA AVAIBALITY

This is an original manuscript, and all data are available for only review purposes from the principal investigators.

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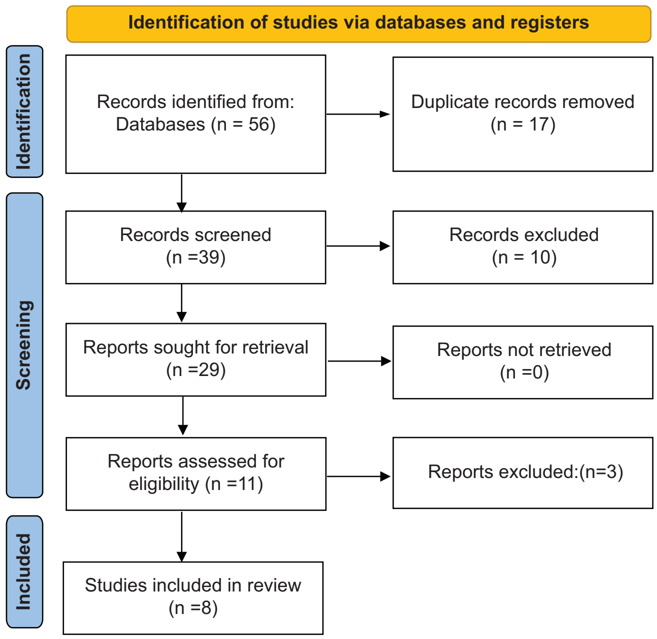

Figure 1: Summarized search strategy (Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram)

Table 1: Summary of Study Characteristics

Author and Year	Sample Size	Study Aim and Method	Conclusion
Kaushik *et al*. 2022[46]	29	Men with localized prostate cancer randomized into yoga and standard-of-care groups; 60-min Hatha yoga sessions twice weekly for 6 weeks pre- and post-surgery. Primary outcome: Quality of life via EPIC. Secondary outcomes: immune cell status and cytokine levels.	Yoga group showed significant improvements in quality of life and immune function, with decreased numbers of regulatory T-cells and myeloid-derived suppressor cells, and reduction in inflammatory cytokines.
Vadiraja *et al*. 2017[47]	91	Patients with metastatic breast cancer divided into yoga and supportive therapy groups. Integrated yoga program versus supportive counselling sessions over 3 months. Focused on stress, fatigue, cortisol levels, and NK cell counts.	Yoga led to reduced stress and fatigue, lower cortisol levels, and improved NK cell counts.
Khedmati Zare *et al*. 2021[48]	30	BC survivors post-chemotherapy/radiotherapy, randomized into three groups: High dose Vitamin D, yoga with high dose Vitamin D, and yoga with low dose Vitamin D. 12-week yoga training with Hatha yoga elements. Gene expression analysis for immune markers.	Yoga combined with high-dose Vitamin D showed significant improvements in physical and psychological status, and upregulation of certain immune-related genes.
Huberty *et al*. 2019[49]	62	Myeloproliferative Neoplasm patients randomized into an online yoga group and a wait-list control group. 12-week intervention with weekly yoga sessions, measuring inflammatory markers and various health aspects.	Yoga participants experienced improvements in sleep, pain, anxiety, depression, and significant decrease in TNF-α levels, suggesting reduced inflammation.
Sohl *et al*. 2022[50]	44	GI cancer patients undergoing chemotherapy randomized into Yoga Skills Training (YST) group and attention control group. YST included in-person sessions focused on awareness, movement, breathing, and meditation. Evaluation of fatigue, depressive symptoms, sleep disturbances, psychological stress, and inflammatory cytokines.	YST group reported greater reduction in fatigue, depressive symptoms, sleep disturbances, and larger reductions in inflammatory cytokines than control group.
Kiecolt-Glaser *et al*. 2014[51]	200	Breast cancer survivors randomized into a hatha yoga group and wait-list control group. 12-week program assessing pro-inflammatory cytokines, fatigue, vitality, and depression.	Post-treatment, yoga group showed higher vitality, reduced levels of pro-inflammatory cytokines, and lower fatigue at 3 months. No significant differences in depression scores. Frequency of practice correlated with improvements.
Bower *et al*. 2014[52]	31	Breast cancer survivors with fatigue randomized into Iyengar yoga and health education control groups. 12-week intervention focusing on inflammation-related gene expression and pro-inflammatory cytokine activity.	Yoga group showed reduced activity of pro-inflammatory transcription factors, stable TNF activity levels, and reduced inflammation-related gene expression.
Jain *et al*. 2023.[53]	96	Stage II/III breast cancer patients undergoing chemotherapy/radiotherapy randomized into a yoga and a non-yoga group. 48-week yoga intervention assessing inflammatory cytokines, oxidative stress markers, QoL, and symptomatic scale.	Yoga group experienced significant reductions in pro-inflammatory cytokines and oxidative stress markers, and improvements in QoL and symptomatic scale.