

Review article

Effect of Yoga on inflammatory markers and its impact on cardiovascular health and rehabilitation: A systematic review

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ABSTRACT

One of the main mechanisms in cardiovascular disease (CVD) development is inflammation. Increased risk of CVD has been linked to elevated levels of inflammatory markers such as C-reactive protein (CRP), interleukin-6 (IL-6), and tumour necrosis factor-alpha (TNF- α). According to recent estimates, CVD, which includes ischemic heart disease and stroke, accounted for 19.8 million fatalities globally, or around 32% of all deaths, with an age-standardized death rate of 235 per 100,000. Over 523 million individuals worldwide are affected by prevalence, which is fuelled by risk factors like diabetes and hypertension as well as aging populations. According to the Global Burden of Disease report, low- and middle-income areas continue to have significant burdens.

In the management of CVD, yoga, a mind-body intervention, has been proven to have anti-inflammatory effects. This review intends to investigate the association between heart health and inflammatory indicators, as well as the function of yoga in treating CVD. Atherosclerosis development and cardiovascular disease (CVD) events are driven by chronic inflammation, and severe unfavourable cardiac outcomes in patients with coronary artery disease (CAD) are independently predicted by higher levels of C-reactive protein (CRP), interleukin-6 (IL-6), and tumour necrosis factor-alpha (TNF- α). Even though there are more than 200 million cases of CAD worldwide, traditional cardiac rehabilitation results in poor adherence and a chronic inflammatory burden following percutaneous coronary intervention (PCI). This highlights the need for supplemental, non-pharmacological therapies like yoga that alter autonomic regulation and cytokine networks and its role in rehabilitation.

This systematic review synthesizes unique evidence on yoga's effects on inflammatory markers and their mechanistic links to cardiovascular health improvements in adults with or at risk for CVD.

Comprehensive searches across PubMed, Cochrane Library, Web of Science, Scopus, and Embase (2000-2026) employed MeSH terms and keywords including ("yoga" OR "hatha yoga" OR pranayama OR "yoga therapy") AND ("inflammatory markers" OR CRP OR "hs-CRP" OR IL-6 OR TNF- α OR cytokine*) AND ("cardiovascular diseases" OR CAD OR "myocardial infarction" OR "endothelial function" OR "cardiac rehabilitation"), restricted to randomised controlled trials (RCTs), humans, and English-language publications. PRISMA guidelines directed study selection, data extraction (mean differences, standardized mean differences for biomarkers like CRP, IL-6, TNF- α , adiponectin), and risk-of-bias assessment via Cochrane RoB 2 tool.

Yoga interventions consistently and reproducibly attenuate systemic inflammation in CVD populations, offering mechanistic support for enhanced cardiovascular risk reduction beyond standard care. These findings advocate standardized yoga protocols relevant for secondary prevention guidelines, warranting large-scale trials to establish dose-response relationships and long-term clinical outcomes.

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1. Introduction

Cardiovascular disorders are a primary cause of global mortality. It continues to be the leading cause of death worldwide, taking the lives of about 19.8 million people each year and affecting over 523 million people [1]. Due to early onset caused by diabetes, urbanization, and lifestyle factors, India bears a disproportionate burden of 28–32% of its mortality (age-standardized rate 272 per 100,000) [2]. Cardiac rehabilitation (CR) participation among CVD patients is extremely low, at 20–30% worldwide and less than 10% in India [3]. This is due to a number of obstacles, including a lack of facilities, high expenses, poor referrals, transportation problems, and low awareness, especially in rural and post-PCI settings. In high-burden areas like India, this gap calls for alternate CR methods like yoga-based or tele-rehabilitation programs, which provide scalable, culturally relevant, affordable solutions to improve adherence, lower recurrence, and solve resource restrictions (see Table 1).

Inflammation has recently garnered attention as a potential risk factor for cardiovascular disease (CVD). Research indicates that chronic inflammation may have a role in the initiation and advancement of atherosclerosis, characterized by the accumulation of lipid deposits within arterial walls. The presence of inflammatory markers, such as C-reactive protein (CRP) and interleukin-6 (IL-6), has been linked to a higher risk of cardiovascular events, like heart attacks and strokes [4]. Some risk factors of CVD include high blood pressure, high cholesterol, smoking, and obesity. Many studies have looked into how yoga might assist lower the inflammation and improve cardiovascular health [5]. Yoga is best practice for the mind and body that combines meditation, breathing exercises, and synergised breath based physical movements. It has been shown to offer several health benefits, such as lowering blood pressure and cholesterol levels, improving flexibility and balance, and lowering stress and anxiety. Studies indicate that consistent yoga practitioners exhibit diminished levels of inflammatory markers such as CRP and IL-6, prompting researchers to propose that yoga may possess anti-inflammatory effects [6].

Cardiovascular problems develop and deteriorate in advanced stages as a result of inflammation. Numerous inflammatory markers have been found as potential predictors of cardiovascular disease (CVD) events; chronic low-grade inflammation is commonly acknowledged as a hallmark of CVD [7]. Globally, the number of people who have heart illnesses caused by inflammatory indicators is going up. Chronic inflammation fosters the advancement and exacerbation of vascular injury and dysfunction, subsequently leading to the emergence of ischaemic heart disease, myocardial infarction (MI), heart failure, and stroke [5]. Chronic inflammation is a major risk factor in the development of atherosclerosis and cardiovascular disorders. A number of inflammatory markers, such as CRP, IL-6, TNF- α , and others, have been shown to be connected to a higher risk of heart disease [8]. There are several important inflammatory markers connected to CVD and how they affect the disease's pathophysiology such as Interleukin-6 (IL-6) and other pro-inflammatory cytokines induce the synthesis of C-reactive protein (CRP), a non-specific indicator of inflammation. High levels of CRP have been associated to a higher risk of cardiovascular events such MI, stroke, and sudden cardiac death (SCD) [9,10]. RP has also been shown to predict future CVD events in persons who seem to be healthy [11].

Interleukin-6 (IL-6) is a pro-inflammatory cytokine that is released when there is an injury, stress, or an infection. It has been shown to have a role in the origins of CVD and atherosclerosis. Elevated IL-6 levels have been associated with an increased risk of cardiovascular disease events [11]. Additionally, it has been shown that IL-6 is a predictor of mortality in individuals with heart failure [12].

Scientists have been looking on how Yoga controls regulation of IL-6. One such mechanism is the modulation of the autonomic nerve system (ANS) (Fig. 1). When the sympathetic nervous system (SNS) is active, inflammation goes up. When the parasympathetic nervous system (PNS)

Table 1

Randomised control trials showing reduction in pro-inflammatory markers in CVD.

Sr no.	Authors	Type of study	Markers targeted	Type of Intervention and its duration	Results
1.	Pullen et al., 2008 (Georgia)	RCT	Interleukin-6 (IL-6), high-sensitivity C-reactive protein (hsCRP),	8-week regimen of yoga therapy and standard medical therapy (MT)	IL-6, hsCRP, show significant improvement after 8week of Yoga intervention.
2.	Ganesan et al., 2020	RCT	Interleukin-1 α (IL-1 α), IL-6, tumour necrosis factor- α (TNF- α),	Yoga therapy for 12 weeks (30 min, 3 times/week),	IL-1 α , IL-6, TNF- α , and decreased after 12 weeks of Yoga intervention in participants, most significantly decrease in IL-1 α levels.
3.	Fathollahi et al., 2020	RCT	Interleukin-6 (IL-6) and high sensitivity C-reaction protein (hs-CRP)	8 Weeks of Yoga intervention	Interleukin-6 (IL-6) and high sensitivity C-reaction protein (hs-CRP) levels decrease significantly after Yoga intervention
4.	Jain et al., 2022 (India)	RCT	C-reactive protein (CRP) &NTproBNP	Yoga intervention 1hr/daily for 3 months	HF patients significantly improve NTproBNP and reduces CRP level
5.	Patil et al., 2024 (India)	RCT	hs-CRP& TNF-alpha	more than 3 h of yoga per week,12-week assessment	reduction in hs-CRP
6.	Stephan et al., 2003	RCT	IL-6, IL-1 β and TNF-alpha	4-6 times daily for 10 min on a bicycle ergometer, follow up of 6months	Training reduces the IL-6, IL-1 β and TNF-alpha expressions.
7.	Hammet et al., 2006	RCT	white blood cell (WBC) count, fibrinogen, high-sensitivity C-reactive protein (CRP), soluble intercellular adhesion molecule 1 (sICAM-1), and soluble CD40 ligand (sCD40L)	effects of 6 weeks of regular exercise training with follow up of 12 weeks of exercise training	Exercise training improved cardiorespiratory fitness and the anti-inflammatory effect of training is associated with BMI.
8.	Silva et al., 2017	RCT	interleukin-6 and tumour necrosis factor-alpha	exercise training for 12weeks	exercise on functional capacity improves the IL-6 and TNF-alpha expressions.
9.	Pedersen et al. (2019)	RCT	TNF-alpha and CRP	12-weeks supervised (AIT and LED + AIT) three times weekly followed by 40 weeks AIT twice weekly.	decrease in CRP and TNF-alpha

(continued on next page)

Table 1 (continued)

Sr no.	Authors	Type of study	Markers targeted	Type of Intervention and its duration	Results
10.	Taylor et al., 2022	RCT	TNF- α , IL-6, hsCRP, IL-8, IL-10 and (NT ProBNP)	AIT: Aerobic interval training LED: Low Energy Diet Immediately post, 6 h post, 24 h post, and 48 h post steady State (SS) or High Intensity Interval (HIIT) training	Significant correlation found in between the markers after high intensity interval training.

is active, inflammation goes down. Practicing yoga can make the PNS work harder and the SNS work less, which lowers inflammation [50]. Breast cancer survivors who engaged in Yoga for 12 weeks exhibited reduced levels of IL-6 as compared to the control group. Yoga is proven to lower stress, which also lowers IL-6 levels and inflammation. Twelve weeks of yoga also reduced IL-6 and another inflammatory marker in rheumatic arthritis (RA) [13]. The researchers argued that yoga's stress-reducing effects contributed to decreased inflammation. Yoga may decrease IL-6 levels via multiple mechanisms, including autonomic nervous system regulation, stress alleviation, and improved sleep quality. Yoga may serve as a valuable adjunct therapy for those with chronic inflammatory illnesses. Nevertheless, additional study is required to fully understand the processes by which yoga regulates IL-6 levels and to

establish the optimal duration and frequency of yoga practice.

TNF-alpha is a cytokine that causes inflammation and is involved in the development of atherosclerosis and cardiovascular disease [8]. There is a connection between high levels of TNF-alpha and a higher chance of having CVD events such MI, stroke, and SCD. TNF-alpha has also been shown to predict future cardiovascular disease events in individuals who seem to be healthy [14].

IL-1 beta is a pro-inflammatory cytokine that plays a role in the development of atherosclerosis and cardiovascular disease (CVD). High levels of IL-1 beta have been associated to an increased risk of cardiovascular disease events such heart attacks and strokes [15].

MMPs are enzymes that break down proteins in the extracellular matrix and help cause atherosclerosis and cardiovascular disease (CVD) [16]. High levels of MMPs have been associated to an increased risk of cardiovascular disease events, like MI [17]. MMPs have also been shown to predict death in people with heart failure [18].

1.1. Role of yoga in reducing inflammation

Yoga is an age-old Indian discipline that has been utilised to enhance mental, physical, and spiritual well-being. Recent studies suggest that yoga may have anti-inflammatory qualities, which could make it a useful treatment for chronic inflammation and associated conditions. Chronic inflammation is a major factor in cardiovascular illnesses, including atherosclerosis, heart disease, and stroke [19]. Since inflammation is a normal reaction to injury or illness, it aids the body in fending off infections and accelerating healing in the short duration. On the other hand, persistent inflammation can harm tissue and contribute to the development of long-term conditions like diabetes, cancer, heart disease, and autoimmune diseases. Many times, chronic inflammation is linked to high levels of pro-inflammatory cytokines such TNF- α , CRP, and IL-6. These indicators are linked to a higher risk of cardiovascular

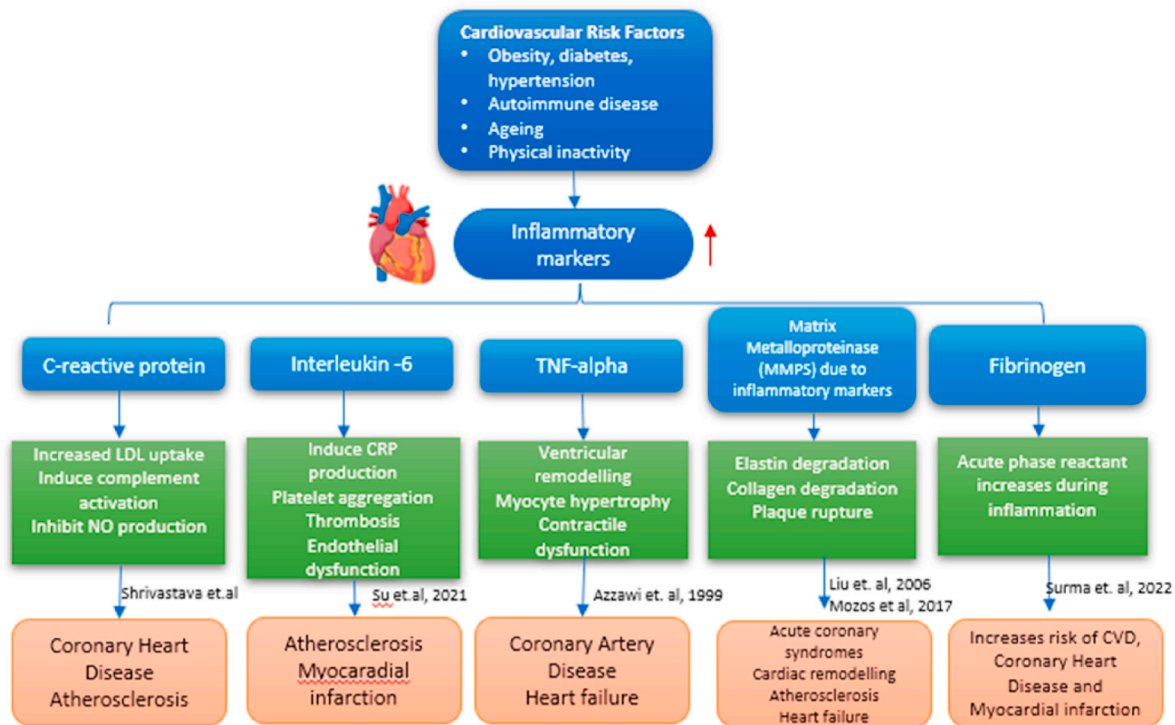


Fig. 1. CVD risk markers and their association with inflammatory markers. This figure illustrates the association between various cardiovascular risk factors (obesity, diabetes, hypertension, ageing, physical inactivity, autoimmune disease) and inflammatory markers (C-reactive protein [CRP], Interleukin-6 [IL-6], Tumour Necrosis Factor-alpha [TNF-alpha], Matrix metalloproteinases [MMPs], Fibrinogen). These markers contribute to the progression of heart-related diseases. CRP: Increases LDL uptake into macrophages and causes endothelial dysfunction. IL-6: Induces platelet aggregation and endothelial dysfunction [12]. TNF-alpha: Associated with ventricular remodelling and recovery dysfunction [14]. MMPs: Contribute to collagen degradation and elastic fibre fragmentation. Fibrinogen: Increases acute phase reactants, causing inflammation [18].

disease and are frequently employed in clinical settings to measure inflammation levels [20].

A recent analysis by Kiecolt-Glaser and colleagues highlighted the ways in which yoga may reduce inflammation, including stress reduction, improved immune function, and changed gene expression. The authors noted that studies have shown yoga can increase interleukin-10 (IL-10) levels while lowering pro-inflammatory cytokine levels such as TNF- α , CRP, and IL-6. During these changes, it is anticipated that the sympathetic nervous system will be downregulated and the parasympathetic nervous system will be elevated, leading to less stress and improved immune function [21]. In a randomised controlled trial, Dusek and colleagues found that a 12-week yoga program significantly reduced the blood levels of CRP and IL-6 in heart failure patients [22]. Accordingly, a 2018 study by Rao and associates found that individuals with coronary artery disease who took part in a 12-week yoga program experienced a significant drop in TNF- and IL-6 levels [23]. A 12-week yoga program significantly reduced the levels of CRP and IL-6 in patients with depression and heart disease, according to another randomised controlled experiment conducted by Innes and colleagues (2015) [24]. Additionally, researchers have examined the impact of yoga on inflammation in healthy individuals (Fig. 2). A 3-month yoga program significantly reduced the levels of CRP and IL-6 in middle-aged and older participants, according to a study by Kiecolt et al. [25]. In breast cancer survivors who had persistent fatigue, a 12-week yoga program was associated with significantly decreased levels of TNF and IL-6 [26]. Cardiovascular disease prevention and management may be greatly impacted by yoga's anti-inflammatory qualities. Yoga may be a useful adjunctive treatment for cardiovascular disease, with possible benefits for blood pressure, lipid profiles, and glucose management, according to a review by Cramer and colleagues. According to the authors, more investigation is required to completely comprehend how yoga's cardiovascular advantages are influenced by its anti-inflammatory qualities.

1.2. Yoga as a cardiac rehabilitation tool

The underlying pathophysiology of CVD includes atherosclerosis, vascular remodelling, oxidative stress, and endothelial dysfunction. This figure shows how different pathways interact as CVD progresses and emphasizes the positive pleiotropic effects of yoga as a treatment. Yoga has been demonstrated to enhance cardiovascular health by regulating autonomic function, oxidative stress, and inflammatory responses. This study explores these connections and offers corroborating scientific evidence. Atherosclerosis and other CVDs are preceded by endothelial dysfunction. It is marked by elevated expression of inflammatory cytokines as PTX3, TNF- α , IL-1 β , and IL-6, as well as decreased nitric oxide

(NO) bioavailability. Vascular inflammation and dysfunction are caused by elevated adhesion molecules, including monocyte chemoattractant protein-1 (MCP-1), intercellular adhesion molecule-1 (ICAM-1), and vascular cell adhesion molecule-1 (VCAM-1). Studies show that by boosting NO generation and reducing oxidative stress, yoga significantly reduces circulating inflammatory markers and enhances endothelial function [27].

Improved endothelial function and decreased systemic inflammation are two of yoga's many benefits. It has been shown that regular practice of asana, pranayama, and meditation can improve flow-mediated dilation and change endothelial progenitor cells [28].

Frequent yoga practice has been associated with improvements in a number of important cardiovascular risk factors, such as metabolic syndrome, obesity, dyslipidaemia, and hypertension. By encouraging relaxation and enhancing vascular function, yoga lowers both systolic and diastolic blood pressure. Studies show that yoga increases HDL cholesterol while lowering LDL and triglyceride levels [29]. Additionally, yoga improves insulin sensitivity and helps control weight, which lowers the risk of metabolic syndrome and diabetes. Yoga boosts antioxidant defences while lowering inflammatory markers like TNF- α , CRP, and IL-6 [30].

2. Methods

2.1. Search strategy

A thorough search was performed across many databases, including the Cochrane Library, PubMed, Science Direct, and Google Scholar, from January 2005 to December 2025.

Databases were queried with the 'Keywords in title, abstract, and keyword' methodology. The selected search technique incorporated terms related to yoga practice and its impact on Cardiovascular disease, inflammatory markers within the title, abstract, or keywords. The PubMed electronic search strategy was formulated as follows: "([yoga][MeSH Terms] OR "meditation"[MeSH Terms] OR "yoga*" [Title/Abstract] OR "Yogic"[Title/Abstract] OR "yogi*" [Title/Abstract] OR "pranayam*" [Title/Abstract] OR "Sudarshan Kriya" [Title/Abstract] OR "kriya yog*" [Title/Abstract] OR "mindfulness" [MeSH Terms]) AND ("inflammation" [Title/Abstract] OR "inflammatory" [Title/Abstract] OR "CRP" [Title/Abstract] OR "C-reactive protein" [Title/Abstract] OR "hs-CRP" [Title/Abstract] OR "IL-6" [Title/Abstract] OR "interleukin-6" [Title/Abstract] OR "tnf" [Title/Abstract] OR "tumour necrosis factor" [Title/Abstract] OR "TNF-alpha" [Title/Abstract] OR "cytokine*" [Title/Abstract] OR "IL-1beta" [Title/Abstract] OR "interleukin 1 beta" [Title/Abstract] OR "BDNF" [Title/Abstract] OR "brain-derived neurotrophic factor" [Title/Abstract] OR "adiponectin" [Title/Abstract] OR "leptin" [Title/Abstract]) AND ("Cardiovascular disease" [Title/Abstract] OR "CVD" [Title/Abstract] OR "heart disease" [Title/Abstract] OR "coronary artery disease" [Title/Abstract] OR "CAD" [Title/Abstract] OR "coronary heart disease" [Title/Abstract] OR "myocardial infarction" [Title/Abstract] OR "atherosclerosis" [Title/Abstract] OR "endothelial function" [Title/Abstract] OR "cardiac rehabilitation" [Title/Abstract] OR "vascular health" [Title/Abstract])". The Cochrane Library and ScienceDirect were searched in a comparable manner. The initial 19 results were selected according to their relevancy for all search engines. Only randomised controlled studies involving human participants and published in English were considered in the search. The PRISMA recommendations were adhered to, and all potential studies that satisfied the inclusion criteria were evaluated for analysis.

2.2. Study selection

A two-step methodology was employed to find the studies: title/abstract screening followed by full-text review. To ascertain potentially eligible searches, two independent reviewers (S.K. and S.S.) examined the titles and abstracts of the retrieved publications. According to

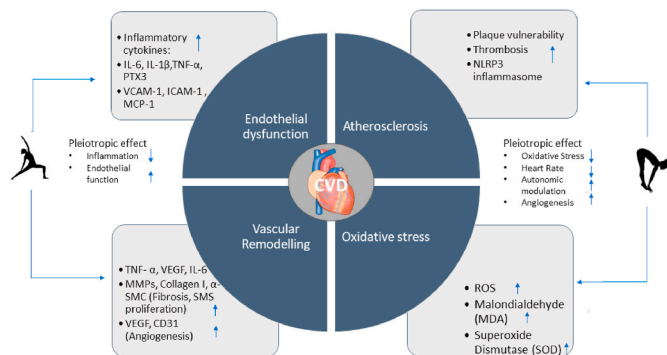


Fig. 2. The pleiotropic effects of yoga on cardiovascular disease (CVD) by modulating key pathological mechanisms: Reducing inflammatory cytokines and improving endothelial function, decreasing plaque vulnerability and thrombosis, reducing ROS and enhancing NO bioavailability, and promoting angiogenesis. Yoga interventions are a holistic approach to mitigating these processes and improving cardiovascular health.

established criteria.

The whole texts of these possibly relevant papers were subsequently assessed for inclusion based on the eligibility criteria. A third reviewer (J.S.) was engaged to resolve any disagreements between the initial two reviewers.

2.3. Search strategy

A specified set of eligibility criteria was established to identify relevant studies for inclusion in the systematic review.

The population, intervention, comparison, outcomes, and study design. The target population comprised patients diagnosed with chronic or acute medical illnesses impacting cardiovascular functions, including CAD (Coronary Artery Disease), MI (Myocardial Infarction), AF (Atrial Fibrillation), Ischemic Heart Disease or any kind of cardiovascular diseases. The focus was on yoga therapy, utilised either independently or in conjunction with other treatments, including pharmacological interventions, lifestyle modifications, or further complementary and alternative approaches.

Comparison: Any controlled intervention, including no treatment, standard care, placebo interventions, and alternative active interventions, was permitted to assess the comparative efficacy of yoga therapy. Studies lacking a clearly identified control group were removed. The study design mandated that inclusion criteria be confined to randomised controlled trials (RCTs) published as full-text journals. Observational studies, case reports, conference abstracts, and editorials were omitted. Publications in languages other than English were excluded.

2.4. Data extraction

The data extraction was conducted autonomously utilising a pre-determined data extraction form. The gathered data encompassed study characteristics. Authors, year of publication, study design, Jadad score, sample size, participant characteristics (age, diagnosis), intervention specifics (kind of yoga, frequency, duration), comparator group details, and outcomes. Any discrepancies in data extraction were resolved through discussion or contact with a third reviewer.

2.5. Evaluation of quality and assessment of risk of bias

The Jadad scale allocates a score between 0 and 5 based on the criteria of randomisation, blinding, and the reporting of withdrawals and dropouts employed for assessing the methodological quality of the included research [31]. Studies with a score of ≤ 2 were deemed low quality, whilst those with a score of ≥ 3 were classified as good quality [32]. The potential for bias in the included studies was evaluated according to the criteria outlined in the "Cochrane Handbook for Systematic Reviews of Interventions". The researchers performed a subjective evaluation of each study and categorised the risk levels as "High," "Low," or "Unclear" across various bias domains, including selection bias (randomised sequence generation, allocation concealment), performance and detection bias (blinding of participants, staff, and outcomes), attrition bias (management of incomplete outcome data), reporting bias (selective outcome reporting), and other possible sources of bias. The findings of the risk-of-bias evaluation were summarised in Fig. 4(a) and (b), respectively.

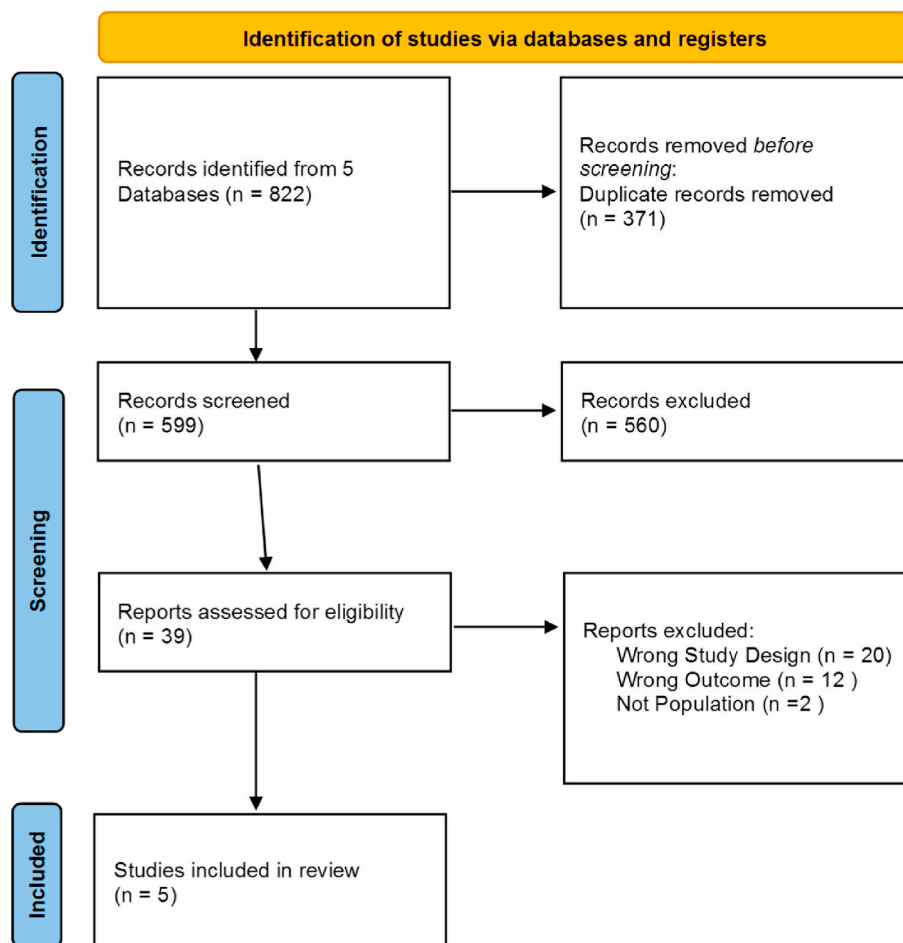


Fig. 3. PRISMA flow Chart.

3. Results

3.1. Study selection

Study selection Fig. 3 shows the PRISMA flow diagram of the entire search procedure and the methodology used in the selection of the studies. After a preliminary database search, studies were selected for screening. Seven studies met the inclusion criteria for the systematic review and quality evaluation.

3.2. Quality assessment

Present the risk of bias evaluation for each study.
Out of 9 randomised controlled trials (RCTs), 4 exhibited a significant risk of bias related to random sequence creation, allocation concealment, and other biases, while the other studies presented some

ambiguous biases.
Primarily with the blinding of participants and evaluation. All studies exhibiting insufficient outcome data and selective reporting demonstrated a low degree of bias.
The evaluation of the quality of clinical trials included in the study was conducted utilising the Jadad score, as illustrated in Fig. 3. The Jadad score evaluates multiple dimensions of trial quality, encompassing randomisation, blinding, reporting of withdrawals and dropouts, inclusion and exclusion criteria, evaluation of adverse effects, and delineation of statistical analysis. Among the three studies covered the highest scores.

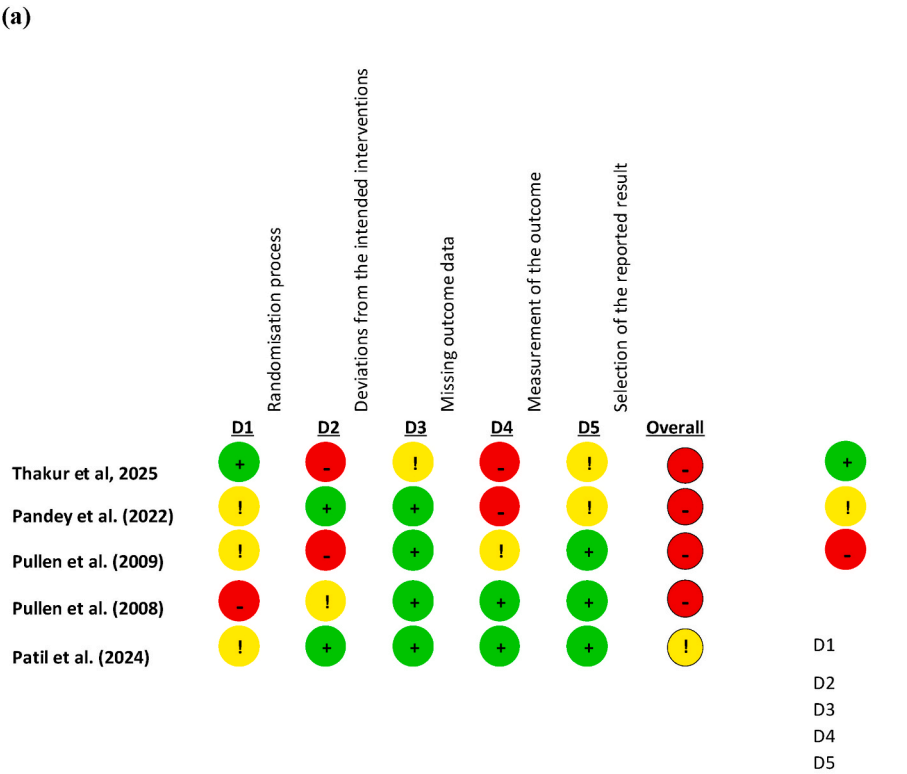
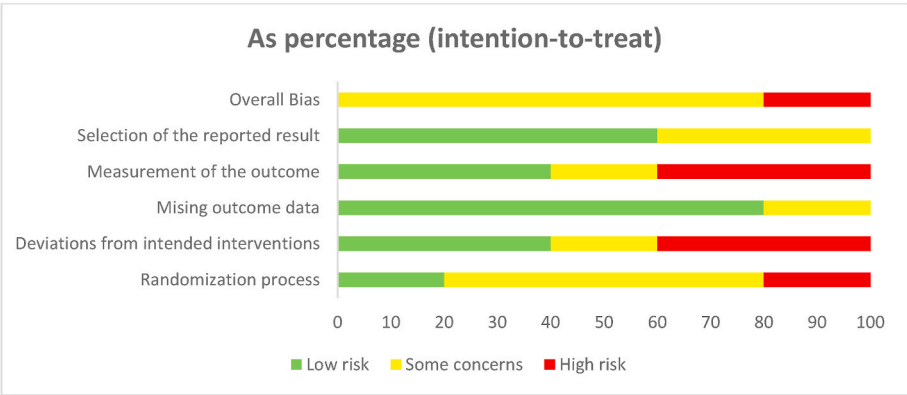


Fig. 4. (a) Risk of bias summary: the review authors' evaluations of each risk of bias item for each included study. (b) Risk of bias graph: the review authors' assessments of each risk of bias item depicted as percentages across all included studies.

4. Results

4.1. Role of yoga in CVD mediated by neural growth factors

Neuroprotection is a mechanism that preserves the structural and functional integrity of neurons. Numerous neuroprotective moieties exist, including Brain-derived neurotrophic factor (BDNF), Ciliary neurotrophic factor (CNTF), Fibroblast growth factor (FGF), Epidermal growth factor (EGF), and Insulin-like growth factor (IGF) [33]. Among them.

Brain-Derived Neurotrophic Factor (BDNF) is a neurotrophic protein that significantly contributes to cerebral health and development. Physical exercise, such as Yoga, serves a neuroprotective function by increasing BDNF levels in the blood following three months of CYP treatment [34]. Yogic intervention administered to veterans with post-traumatic stress disorder over a duration of three weeks resulted in an increase in BDNF levels in the bloodstream. This may enhance symptoms of PTSD [35]. BDNF exists in two forms: pro BDNF and mature BDNF. Pro-BDNF is transformed into mature BDNF, however, in patients with depression, levels of mature BDNF are diminished. Nonetheless, yogic intervention results in the augmentation of mature BDNF [36]. Yogic intervention enhances BDNF, which also contributes to cardiac health. Zhasem et al. shown that a decrease in BDNF results in diminished heart function [37]. Brain-derived neurotrophic factor (BDNF) and its receptors are located on the surface of epithelial cells in coronary arteries, contributing to the maintenance of vascular integrity [38]. Brain-derived neurotrophic factor (BDNF) is a cardioprotective protein that contributes to the survival and maintenance of cardiomyocytes and vascular endothelial cells [39]. Consequently, yoga may influence cardiac health by stimulating the neuroprotective chemical BDNF.

CNTF is a neurotrophic factor that promotes the survival of both neuronal and non-neuronal cells [40]. An earlier investigation by Angouti et al. demonstrated that six weeks of aerobic exercise increases CNTF levels in the hippocampus of diabetic rats [41]. Consequently, physical activity such as Yoga may positively influence CNTF levels. CNTF additionally serves a cardioprotective function by promoting the development of cardiomyocytes [42]. The relationship between Yoga and CNTF in relation to cardiac health has yet to be elucidated.

4.2. Role of yoga in angiogenesis-

Angiogenesis is the process that leads to new vessel formation and the sprouting of existing vessels. Several proteins and factors induce the process of angiogenesis, including vascular endothelial Growth Factor (VEGF), Angiopoietin, Matrix Metalloproteinase (MMP), Class 3 semaphorins (SEMA3s) [43], which can be affected by Yoga.

4.3. VEGF

Vascular Endothelial Growth Factor fosters angiogenesis and neo-vascularisation through enhanced proliferation, migration, and invasion of endothelial cells into the surrounding tissue. Therefore, VEGF also plays a similar role in promoting cardiac health. VEGF acts as a drug target in various coronary heart diseases. Zhai S et al. found that treating the in-vivo rat model of myocardial infarction and in-vitro human umbilical vein endothelial cells with medicine extract promoted angiogenesis by activating the VEGF pathway. Another study by Zhang et al. has shown that when they treated hypoxic conditions treated cardiomyocytes with salidroside, it leads to enhancement of VEGF, which promotes cardiac health [44]. Yoga may foster cardio protection by enhancing the expression of VEGF. Kaur et al. have shown that after 3 months of the Diabetes Yoga Protocol, there was a significant increase in the level of VEGF in patients with diabetes [45]. However, the link between Yoga, Cardiac health, and VEGF remains to be deciphered in a more elaborate manner.

4.4. Role of yoga in apoptosis

Apoptosis is a regulated kind of cell death that is beneficial, however it can be detrimental under pathological conditions. Apoptosis is an intrinsic cellular response to various traumas, including DNA damage, membrane disruption, mitochondrial impairment, and viral-induced injuries. Yoga can influence apoptotic factors, promoting cell survival.

4.5. Caspase-3

Caspase-3 is a mediator of apoptosis that contributes to the degeneration of cardiomyocytes in heart failure [46]. Caspase-3 has been demonstrated to augment infarct size in the transgenic mouse model [47]. In vitro treatment of cardiomyofibrils with caspase-3 results in the cleavage of many cardioprotective substances [48]. Exposure to radiation in female rats resulted in diminished heart function and increased levels of Caspase-3. A decline in cardiac function correlates with an elevation in caspase-3 levels [49]. Yoga can influence the process of apoptosis. Research conducted by Ram et al. has demonstrated that Yoga regulates cellular dysfunction and the apoptotic index in breast cancer patients [50]. Further research is necessary to examine the influence of Yogic practices on the regulation of apoptotic processes.

4.5.1. Risk of bias assesment

By using intention-to-treat analysis and the Cochrane RoB 2 tool, the figures shows risk of bias evaluations for randomised controlled trials on yoga therapies for cardiovascular health. The first bar graph displays the overall domain risks for all studies: low for the randomisation process and reported result selection; some worries about outcome measurement; and high for missing outcome data and variations from planned interventions. Per-study hazards are shown in the second chart (Thakur et al., 2025, Pandey et al., 2022, Pullen et al., 2009/2008). Green circles indicate moderate risk, yellow indicates some worries, and red indicates high risk, emphasizing persistently high risks in missing data and deviations.

5. Discussion

The ancient practice of yoga, which consists of physical postures, breathing exercises, and meditation, has garnered a lot of attention recently due to the potential benefits it may offer in the treatment of cardiovascular diseases (CVDs). Recent research in the field of science has shed light on the possibility that yoga may have cardioprotective effects. Atherosclerosis and the exacerbation of heart conditions like coronary artery disease (CAD) are largely caused by inflammation. Even in healthy individuals, blood markers like CRP, IL-6, and TNF- α can predict heart attacks. For instance, high CRP levels in middle-aged men indicate a higher chance of blocked arteries in the future, much as elevated IL-6 indicates an impending heart attack. Additionally, research indicates that these indicators are associated with the development of high blood pressure and enzymes like matrix metalloproteinases that cause arterial plaques to become unstable, which worsens the consequences following a heart attack [51]. The persistent practice of yoga has been connected to lower levels of inflammatory markers [52], which is evidence that yoga has been discovered to have anti-inflammatory benefits. Reviews of numerous studies have demonstrated that yoga lowers various detrimental indicators, including CRP, IL-6, and TNF- α in chronic conditions. For example, a brief yoga program increased good cholesterol (HDL) and improved blood vessel health following artery stents (PCI), and yoga practitioners had fewer dying immune cells than breast cancer patients. As an additional illustration, heart bypass patients who practiced yoga in addition to normal rehabilitation experienced decreases in IL-6 and hs-CRP, and yoga increased levels of brain-protective BDNF, which supports the health of the heart and nerves. Similar to how it helps worried breast cancer survivors, yoga prevents cardiac muscle cell death from enzymes like

caspase-3 by calming stress signals (like NF- κ B) through improved relaxation and vagus nerve activation [53].

Yoga is thought to have an effect on the autonomic nervous system (ANS) as well as the hypothalamic-pituitary-adrenal (HPA) axis. Nevertheless, the precise mechanism by which it brings about a reduction in inflammation is still a mystery [52]. Yoga has been shown to improve cardiovascular health and reduce the risk of cardiovascular disease (CVD) occurrences. Chronic inflammation has been identified as a causal component in the pathogenesis of cardiovascular diseases (CVDs). Systemic inflammation can be reduced through the practice of yoga, which has been shown to reduce levels of pro-inflammatory cytokines. Indicators like as IL-6 and CRP, for instance, have been proven to be dramatically reduced by yoga therapies, according to research as well. Based on these findings, it appears that yoga may be able to assist in the decrease of the inflammatory processes that are the root cause of cardiovascular disorders [50]. Another factor, such as atherosclerosis, is a result of endothelial dysfunction, which is a significant factor in vascular health. Improvements in endothelial function have been associated with yoga, which may be attributed to an increase in the availability of nitric oxide and a decrease in oxidative stress by yoga practitioners. Enhanced blood flow and vascular relaxation are both beneficial to cardiovascular health [52], and this augmentation contributes to both of these outcomes. Yoga has been proven to have beneficial benefits on a wide variety of metabolic indicators that are associated with cardiovascular risk. There is a possibility that persistent practice will result in improvements in lipid profiles, such as reductions in low-density lipoprotein (LDL) cholesterol and increases in high-density lipoprotein (HDL) cholesterol. Furthermore, yoga has been associated with the improvement of glycaemic management in individuals who have type 2 diabetes, hence reducing the risk of cardiovascular disease [52]. A number of physiological and molecular mechanisms are responsible for the influence that yoga has on inflammatory pathways of the body. Yoga has been shown to improve heart rate variability (HRV) and reduce sympathetic overactivity, both of which are connected with inflammation throughout the body. In addition, yoga has an effect on the hypothalamic-pituitary-adrenal (HPA) axis, which helps to lessen the effects of chronic stress reactions that could lead to the release of pro-inflammatory cytokines. Both meditation and pranayama have the ability to enhance vagal tone, which in turn influences the signalling of NF- κ B and reduces inflammation. Additionally, yoga improves metabolic profiles such as glucose management, lipid balance, and body composition, which in turn reduces inflammation that is produced by metabolic dysfunction. These mechanisms, which are interconnected, contribute to the reduction of systemic inflammation and the improvement of cardiovascular health [53]. Yoga addresses significant gaps in real-world cardiac rehab, where only 20–30% of heart patients enroll worldwide (and even fewer in India, where CVD accounts for 28% of mortality). Unlike simple exercise regimens, it increases blood vessel growth factors (VEGF) and promotes artery cell survival via BDNF. In the same way that yoga at home helps rural high-risk women lower diabetic markers, it encourages the development of new vessels and decreases recurrent heart problems in place of costly gym visits that few can afford.

However, there are still issues: yoga methods differ, studies are brief and small, and they frequently concentrate on India, which increases the possibility of bias. In order to evaluate yoga against medications like SGLT2 inhibitors in stent patients and monitor significant outcomes like new heart attacks, future large trials will require routine checks (like Robvis tools). In order to prevent harm and increase blood stem cells (CD34⁺) in high-CRP patients, doctors should suggest yoga [54–56]. This would make heart care more accessible and efficient in countries like India.

5.1. Current gaps and future recommendations

Despite rising evidence that yoga improves inflammatory indicators

and cardiovascular health, significant study gaps remain. Notably, the variability of study designs, which includes differences in intervention length, yoga styles, and intensity, makes it difficult to draw solid results and limits cross-study comparisons. Furthermore, the under-representation of diverse demographics, particularly healthy people, older adults, and different ethnic groups, limits the generalisability of the findings. Furthermore, while markers such as C-reactive protein (CRP) and interleukin-6 (IL-6) have been extensively studied, there has been little research on other biomarkers such as fibrinogen, homocysteine, and adhesion molecules, which could provide a more comprehensive understanding of yoga's anti-inflammatory properties. Furthermore, the scarcity of detailed mechanistic studies relating yoga's physiological effects to cellular and molecular inflammation pathways emphasizes the need for more focused research. Finally, the scarcity of longitudinal research limits the ability to examine long-term anti-inflammatory effects and probable relapse patterns [57]. To address these shortcomings, standardized yoga intervention methods must be developed in order to improve study comparability and allow for meaningful meta-analysis. Expanding studies to incorporate lesser-studied biomarkers, including adiponectin, resisting, and microRNAs, could reveal new pathways behind yoga's health effects. Research should be conducted across various demographics to evaluate the broader application of yoga therapies, including adolescents, the elderly, and people with different genetic predispositions. Investigating yoga practice's ideal frequency, duration, and intensity is critical for establishing efficient dose-response relationships for inflammatory management. Furthermore, investigating the combination of yoga with traditional pharmacological therapy and lifestyle changes may increase its translational potential, providing a comprehensive approach to cardiovascular disease prevention and management [58].

6. Conclusion

As demonstrated by numerous studies, elevated markers such as CRP, IL-6, TNF- α , and matrix metalloproteinases reliably predict adverse events from healthy cohorts to post-MI patients, underscoring the critical role inflammation plays in atherosclerosis and cardiovascular disease progression. Through parasympathetic optimization and NF- κ B suppression, yoga consistently reduces pro-inflammatory cytokines, improves endothelial function, increases neuroprotective BDNF, and reduces caspase-mediated myocyte damage. These effects have been validated in RCTs involving CAD, heart failure, and surgical cohorts, including post-PCI and bypass populations, where yoga-CR hybrids outperform isolated exercise by elevating HDL, VEGF, and CD34⁺ progenitors. Yoga provides a scalable, low-cost alternative that is especially well-suited to resource-constrained settings, bridging access gaps while delivering superior adherence and culturally resonant secondary prevention over pharma-centric models like SGLT2i, despite the gloomy global CR uptake (20–30%, falling below 10% in India amid its 28% CVD mortality burden). These findings support the immediate clinical integration of standardized yoga programs (e.g., Yoga-CaRe) for high-CRP patients, shifting paradigms from damage mitigation to neurotrophic resilience and warranting guideline endorsement to curb India's escalating CAD epidemic, despite protocol heterogeneity, modest sample sizes, and regional biases requiring robus-validated multicenter trials tracking MACE and cost-effectiveness.

Author contributions

SK: Writing, Data curation, analysis; SS: Conceptualization, Resources, JS: Writing - Review and editing, Validation; RS: Visualization, Project administration, NS: Writing - Review and diting, Validation, AA: Supervision, Conceptualization, ND: Conceptualization, Analysis, GS: Supervision and Editing.

Declaration of generative AI in scientific writing

The author(s) did not use any kind of Artificial Intelligence (AI) tools during the preparation of this manuscript. The author(s) reviewed and edited the content as and when suggested and takes full responsibility for the content of the publication.

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Conflict of interest

There is no conflict of Interest among authors.

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