Narrative Review

Yoga as an Adjunctive Treatment for Chronic Low Back Pain: A Narrative Review

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Background: Yoga has been recognized for its many mental and physical health benefits. A growing body of literature supports yoga's indication in chronic low back pain (CLBP) management. CLBP is a major public health concern, given its high rates of associated disabilities and large healthcare costs. A biopsychosocial approach has been deemed the most effective and appropriate management strategy for this condition. When alternative and comprehensive approaches for managing the complexity of CLBP are considered, yoga poses a safe, accessible adjunctive treatment option.

Objectives: The goal of this review is to demonstrate, by highlighting yoga's benefits on mental and physical health and the pathophysiology associated with CLBP, that yoga is an effective form of CLBP management. Our other goal is to establish that yoga encompasses a biopsychosocial approach to managing CLBP.

Study Design and Methods: After thorough examination of the available published literature, this narrative review evaluated 24 articles examining yoga's benefits to CLBP patients.

Results: CLBP is associated with high rates of anxiety, depression, chronic stress, and pain catastrophizing. Numerous studies support yoga as an effective intervention for depression, anxiety, chronic stress, and pain catastrophizing, given yoga's effects on the sympathetic nervous system, endocrine system, and various neurotransmitters and brain regions, and improvements in these areas may ameliorate the clinical symptoms experienced by CLBP patients. Physically, symptoms experienced by those with CLBP include pain, impaired function and mobility, disability, fatigue, and medication dependence, all of which, according to the literature, yoga has been shown to improve. Additionally, the chronicity and persistence of low back pain are related to central and peripheral sensitization, and yoga may intervene in these pathways to minimize symptom propagation.

Limitations: This review is not without limitations. The current literature lacks standardization regarding which yoga poses are safe, appropriate, and effective for CLBP patients, which limits the generalizability of yoga therapy. Additionally, few existing prospective trials study yoga in the management of CLBP. Though numerous randomized controlled trials (RCTs) are included in this review, most of the current literature details other reviews or analyses of RCTs, includes smaller sample sizes, and lacks long-term follow-up data. Furthermore, many of these studies include patients who have volunteered or self-selected to trial yoga therapy for their back pain, indicating inherent selection bias.

Conclusion: Overall, the current management strategies for CLBP do not encompass an effective biopsychosocial approach, and an intervention such as yoga is a promising adjunctive treatment for the condition.

Key words: Yoga, chronic low back pain, back pain, chronic pain, pain management, biopsychosocial approach, mental health, physical health, central sensitization

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Yoga is a practice that originated in India over 4,000 years ago (1). Traditionally, 8 components or "limbs" comprise yoga: yama (ethics), niyama (personal behavior), asana (posture), pranayama (breath regulation), pratyahara (sensory inhibition), dharana (concentration), dhyana (meditation), and samadhi (integration). Through these core limbs, yoga is thought to lead to higher states of healing, resilience, ethics, and spirituality (2). In the Western hemisphere, a specific style of yoga known as hatha yoga is most common. Hatha yoga focuses primarily on the 3 limbs of asana (posture), pranayama (breath regulation), and dhyana (meditation), and the collaboration of these components is thought to play a role in the mind-body connection. Recently, there has been increasing evidence to support an association between hatha yoga and various physical and mental health benefits (3). More specifically, yoga has been utilized in the management of chronic low back pain (CLBP) (4).

According to the National Institute of Health Pain Consortium, CLBP is defined as back pain that lasts 3 or more months and has affected an individual on half or more of the days of the preceding 6 months (5). CLBP is the leading cause of disability in the United States (US), affecting anywhere from 13% to 20% of adults (1,6). CLBP contributes more than any other health condition to health care costs, societal costs, and morbidity, costing billions of dollars in healthcare expenditures annually (6,7).

CLBP is closely associated with sensitization, both central and peripheral. These terms are poorly delineated in the literature and clinical practice and are often used synonymously. Critical features of CLBP with sensitization include chronicity, altered sensory information processing, and altered sensory/motor interactions that impair cortical plasticity. Resultant physiological changes include chronic inflammation and inappropriate activation of multiple body systems, including the autonomic, immune, somatosensory, circulatory, and neuronal systems. Both peripheral and central sensitization contribute to these changes in patients with CLBP.

As for peripheral sensitization, chronic pain that results in chronic inflammation causes the sensitization of nociceptors from nearby inflammatory mediators, such as pro-inflammatory cytokines and prostaglandins (5). Additional mechanisms of peripheral sensitization suggest inappropriate expression of genes and their receptors involved in pain perception, implying that CLBP has a molecular component (7).

Chronic pain that leads to central sensitization is associated with alterations in neuroplasticity and neurotransmitter concentrations in the nociceptive system (5). Impaired descending inhibition affects pain-modulatory neurotransmitters such as gamma-aminobutyric acid (GABA), and GABA plays a role in transmitting nociceptive information between the peripheral and central nervous systems (5,8). Another important change is dorsal horn sensitization, which is associated with altered neuronal firing that results in exaggerated responses to noxious (hyperalgesia) and non-noxious (allodynia) stimuli, in addition to the extension of areas of pain reception (or heightened pain sensitivity over a larger area) (5).

CLBP has numerous adverse mental and physical effects on patients. Common mental effects include depression, anxiety, chronic stress, poor relationships, financial difficulties, decreased quality of life, pain catastrophizing, fear of movement, and poor self-efficacy. Significant physical effects include hyperarousal of the autonomic nervous system (ANS), altered breathing patterns, hormone imbalance (such as GABA and cortisol), avoidance behaviors (limiting physical activity), pain-related disability, increased muscle tension, poor flexibility, low energy, poor sleep, and medication dependence (1,5,7,9,10). Clinically, however, patients' presentations of these symptoms are often mixed.

By examining yoga's effects on mental health, physical health, and physiology, this review aims to illustrate yoga as a comprehensive yet individualized treatment in CLBP management. The goal of this review is to highlight how yoga encompasses a biopsychosocial approach to CLBP management and is a promising adjunctive treatment.

Methods

The primary aim of this review was to evaluate the available literature examining yoga as a CLBP treatment and the efficacy of said treatment. On February 27, 2023, a review of the literature was performed on the databases PubMed and Google Scholar. The search terms used were: "chronic low back pain" OR "low back pain" OR "chronic back pain" OR "chronic pain" OR "musculoskeletal pain" OR "pain" OR "chronic stress" OR "stress" AND "yoga." An initial search revealed a total of 313 results between the databases. Inclusion criteria consisted of publication in peer-reviewed English-language journals, evaluation of adult patients who underwent a hatha yoga intervention, examination of yoga's effects of on low back pain, and inclusion of the

terms "yoga" and "chronic low back pain," "low back pain," "back pain," "chronic pain," or "pain" in the title and analyses. Studies were excluded if they were unavailable in English or were conference abstracts, research proposals, or editorials. Any study that did not implement a hatha yoga intervention (focusing on posture, breath, and meditation) or did not discuss CLBP or low back pain in its assessment was also excluded. One reviewer evaluated all 313 study titles and abstracts for duplicates and eligibility, and abstracts that met the above criteria were reviewed in full. In total, 24 articles met inclusion and exclusion criteria for which data extraction was performed. A schematic regarding the article selection process can be seen in Fig. 1. Information extracted from the included studies comprised study design, patient characteristics, characteristics regarding the yoga intervention and standard/placebo treatment (if applicable), and outcomes related to low back pain, and this methodology ensured consistency in the data collection process. The quality of each article's evidence was assessed using the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) system, which was designed to appraise articles based on consistency, directness, precision, risk of bias, and publication bias. Overall article quality was rated as either very low, low, moderate, or high. These ratings were determined by 2 authors after independent review. Articles were synthesized for a narrative review, emphasizing common themes in study outcomes and their associated statistical and clinical significance. Study limitations were considered during the synthesis of this narrative review and are discussed throughout the manuscript.

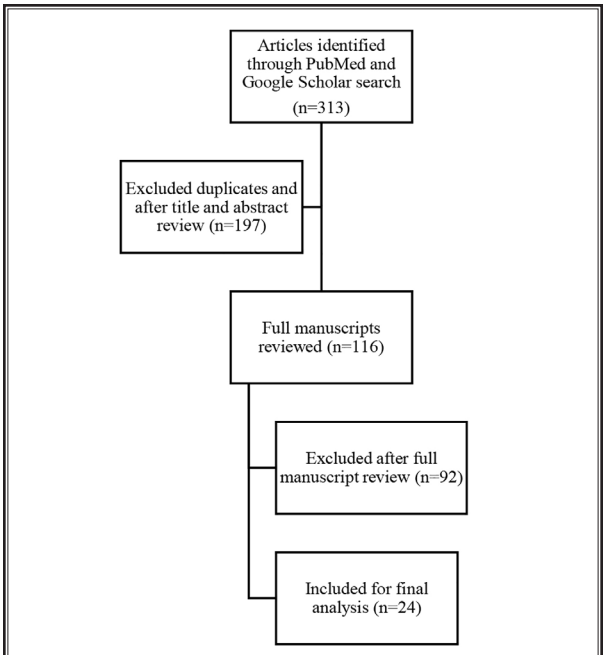

Fig. 1. *Flow diagram of article selection.*

Results

A total of 24 articles were included for analysis. Table 1 highlights study purpose, study characteristics, study findings, limitations, and quality of the article's evidence. Common themes noted were yoga's effects on depression and anxiety, chronic stress, pain catastrophizing, pain, function, disability, spinal strength and mobility, fatigue, and medication dependence, in relation to CLBP. Yoga's effects on central and peripheral sensitization are also highlighted. Additionally, comparisons of yoga to other standard therapies used in CLBP management were well studied.

Depression and Anxiety

Patients with CLBP have a greater-than-average prevalence of co-morbid depression and anxiety. Therefore, it is important to understand the relationship depression and anxiety have with yoga (10,11). Recent practice recommendations from the American Family Physician note the benefits of using yoga to treat depression and anxiety. Studies have shown that yoga is indeed effective in treating depression, much like exercise and meditation, with some studies suggesting long-term benefits. For anxiety, yoga is most beneficial when used adjunctively to other anti-anxiety treatments (12). Many studies on the relationship between yoga and mental health evaluate yoga's relationship with anxiety and depression.

Depression, anxiety, and other physiological conditions that indicate stress, such as chronic pain, are associated with autonomic imbalance and low GABAergic activity, and yoga-based interventions can improve these states. The benefits of yoga are associated closely with the "yoga breath." In the yoga breath, respiration is slowed to the point that 3 to 6 breaths per minute are completed, and the movement of the air is emphasized, causing the abdomen to rise and fall. This deep breathing activates stretch receptors and vagal afferents, which increase parasympathetic tone, improve GABA underactivity, and reduce overactivity in the sympathetic nervous system. Improvements in depression, anxiety, and chronic pain are associated with increased GABAergic

Table 1. *Description of study characteristics included in narrative review.*

Reference	Purpose of Study	Study Characteristics	Study Findings	Limitations	Quality of Evidence (GRADE)
Arya et al, 2022 (5)	Effects of medical yoga therapy on pain and quality of life in patients with chronic low back pain (CLBP)	Design: Single-center randomized controlled trial (RCT) over 8 weeks Patients: Medical yoga therapy (MYT) (n = 58) versus standard care therapy (SCT) (n = 50) Yoga Protocol: 4 weeks supervised practice (2 hours/day, 5 days/week with 6-8 patients per instructor) followed by 4 weeks of at-home practice (with the same yoga protocol)	Significantly greater reductions in pain scores and pain experience in MYT group than in SCT group Significant increase in threshold for noxious stimuli in MYT group Improvement in descending pain modulation in MYT group Improved quality of life in MYT group	Small sample size, selection bias, single-center study, limited generalizability, reporting bias	Low
Adhikari et al, 2022 (7)	Yoga effects on psychological and neuropsychological function in CLBP patients	Design: Single-center, prospective, single-arm study over 12 weeks Patients: Yoga intervention group (n = 11), no control group Yoga Protocol: Instructor-led hatha yoga intervention consisting of 23 poses over 55 minutes, supplemental online videos, and booklets for home practice	Decreased pain severity, pain interference, and pain sensitivity Improved self-efficacy and emotional regulation Changes in gene expression involved in pain and inflammation	Very small sample size, single-center study, selection bias, reporting bias, limited validity, limited generalizability, unable to prove cause and effect because the study used no control group	Very low
Saeed et al, 2019 (12)	Benefits of yoga, exercise, and meditation as adjunctive therapies for mood disorders	Design: Secondary analysis reviewing RCTs, systematic reviews, and other meta-analyses, inconsistent study durations but most commonly 3 to 24 weeks Patients: 16 studies included, most commonly yoga versus exercise or yoga versus medication Yoga Protocol: Inconsistent protocols, most commonly hatha yoga, frequency ranging from one to 7 days per week for 40 to 100 minutes	Monotherapy or adjunctive yoga improves depression, anxiety disorders, and panic disorders Adjunctive exercise has benefits on patients with depression or post-traumatic stress disorder Monotherapy or adjunctive mindfulness-based meditation improves depression and anxiety	Retrospective analysis, lack of information and inconsistency regarding specific yoga protocol, control group, and study duration	Moderate
Streeter et al, 2020 (14)	Yoga effects on gamma aminobutyric acid (GABA) levels and depression	Design: Single-center RCT over 12 weeks Patients: High-dose group (HDG, n = 15) of 3 yoga interventions/week versus low-dose group (LDG, n = 15) of 2 yoga interventions/week Yoga Protocol: Instructor-led Iyengar (form of hatha) yoga session with breath work (5 breaths/minute) for 90 minutes	Improved depression scores in both groups Significantly increased GABA levels in LDG, increased trend in both groups Increased GABA levels noted when time between yoga interventions was 3-4 days +/- 2-3 days	Small sample size, single-center study, selection bias, lack of true control, limited validity	Very low

activity (13). As part of a further study of the relationship that yoga and depression had with GABA activity, a randomized controlled trial (RCT) found that patients who underwent a 12-week yoga intervention had higher thalamic GABA levels ($P < 0.05$) and improved depression (based on the Beck Depression Inventory-II) ($P < 0.05$). It was also found that increased GABA levels were no longer observed after 8 days between yoga interventions. These findings suggest that practicing yoga once per week is needed to preserve GABA elevations (14).

Table 1 cont. *Description of study characteristics included in narrative review.*

Reference	Purpose of Study	Study Characteristics	Study Findings	Limitations	Quality of Evidence (GRADE)
Thirthalli et al, 2013 (16)	Role of yoga in depression management and lowering cortisol levels	Design: Non-randomized prospective study over 3 months, self-assigned to groups Patients: Yoga alone (n = 19), yoga with antidepressant medication (n = 19), and antidepressant medication alone (n = 16) versus health controls (n = 18) Yoga Protocol: Instructor-led one-hour yoga practice every day for 2 weeks, then once weekly at weeks 3, 4, 5, and 9, patients encouraged to practice daily at home	Decrease in serum cortisol across all interventions compared to control group More patients had cortisol decreases in yoga groups than in drug-only group In yoga-only group, cortisol decrease correlated with improved depression scores	Small sample size, single-center study, selection bias, patient self-assignment to treatment groups, reporting bias	Very low
Field et al, 2013 (17)	Effects of yoga versus social support on pre-partum and post-partum depression	Design: Single-center RCT over 12 weeks Patients: Women at 22 weeks gestation assigned to yoga (n = 46) versus social support groups (n = 46) Yoga Protocol: Instructor-led 20-minute group yoga session designed for women in second and third trimesters, once per week for 12 weeks	Greater decreases in anger, depression, anxiety, and back and leg pain in yoga group than in social support group Both groups had improved depression, anxiety, anger, and relationship scores and decreased cortisol levels	Small sample size, single-center study, limited generalizability, reporting bias	Low
van Aalst et al, 2020 (18)	Review of neuroimaging in yoga practitioners	Design: Secondary analysis of peer-reviewed imaging studies of magnetic resonance imaging (MRI), positron emission tomography (PET) or single-photon emission computed tomography (SPECT), inconsistent study durations Patients: 34 studies of the cerebral changes in yoga using MRI, PET, and SPECT Yoga Protocol: Inconsistent but most commonly including hatha yoga and its variants/subtypes, variable frequency	Greater increases in gray matter volume or density in yoga practitioners than in controls, most consistently in hippocampus and insula Greater activation of prefrontal cortex and associated region Decreases in amygdala volume Influence on brain connectivity and perfusion Improved alterations in neurotransmitter levels {AU: Do all of these results apply to the yoga practitioners?}	Retrospective analysis, lack of information and inconsistency regarding specific yoga protocol, control group, and study duration	Moderate
Tilbrook et al, 2011 (20)	Assess treatment efficacy of yoga for low back pain	Design: Multi-center RCT over 12 months Patients: Yoga (n = 156) versus usual care (n = 157) Yoga Protocol: Instructor-led 12-class Iyengar yoga program over 3 months, patients encouraged to practice for 30 minutes at home daily or at least 2 times per week	Improved back function in yoga group compared to control at months 3, 6, and 12 Decreased disability scores in yoga group at months 3, 6, and 12 Improved pain self-efficacy scores in yoga group at months 3 and 6 Similar back pain and general health scores among both groups at all time points	Selection bias, reporting bias, ~30% missing data for primary outcomes	Moderate

Table 1 cont. *Description of study characteristics included in narrative review.*

Reference	Purpose of Study	Study Characteristics	Study Findings	Limitations	Quality of Evidence (GRADE)
Highland et al, 2018 (21)	Evaluate efficacy and feasibility of yoga as a CLBP treatment	Design: Single-center RCT over 6 months Participants: Restorative Exercise and Strength Training for Operational Resilience and Excellence (RESTORE) yoga program (n = 34) versus usual care/ control (n = 34) Yoga Protocol: Instructor-led RESTORE program consisting of therapeutic yoga targeting muscles affected by CLBP, 60-minute classes twice weekly in weeks one-4 and once weekly in weeks 5-8	Greater improvements in pain in RESTORE yoga group than in control group Greater clinically significant improvements in pain, disability, physical functioning, and symptom burden at 3-month follow-up in RESTORE group Greater clinically significant improvements in symptom burden at 6-month follow-up in RESTORE group	Small sample size, selection bias, single-center study, limited generalizability, reporting bias	Low
Schmid et al, 2019 (22)	Effects of yoga on occupational performance, activity participation, and depression	Design: Single-center RCT over 8 weeks Patients: Yoga group (n = 44) versus usual care/control (n = 39) Yoga Protocol: Instructor-led one-hour yoga sessions twice weekly for 8 weeks	Significant improvements in occupational performance and occupational performance satisfaction scores in yoga group Significant increase in activity participation and engagement in yoga group Significant decrease in depression in yoga group	Small sample size, selection bias, single-center study, limited generalizability, reporting bias	Low
Chuang et al, 2012 (23)	Assess cost-effectiveness of yoga in treating CLBP	Design: Multi-center RCT over 12 months Participants: Yoga plus usual care (n = 156) versus usual care alone/ control (n = 157) Yoga Protocol: Instructor-led Iyengar yoga class once weekly for 75 minutes for 12 weeks, in addition to a relaxation compact disc, yoga manual, and education regarding back pain plus usual care	Cost-effectiveness ratio of 13,606 euros per quality-adjusted life-year (QALY) for yoga intervention 70-90% probability of yoga treatment being cost-effective with willingness to pay for additional QALY	Selection bias, reporting bias, limited generalizability given association with socioeconomic status	Moderate
Groessl et al, 2020 (24)	Evaluate cost-effectiveness of yoga compared to that of usual care in veterans with CLBP	Design: Single-center RCT over 12 months Patients: Yoga group (n = 75) versus delayed treatment (n = 75) Yoga Protocol: Instructor-led 60-minute yoga class designed by physicians and yoga experts for patients with CLBP, conducted twice weekly for 12 weeks	QALYs increased 0.043 for yoga group over 12 months Cost-effectiveness ratio of $4488 per QALY for yoga intervention 89% probability of yoga treatment being cost-effective with willingness to pay $50,000 {AU: Is the use of this currency intentional?} Comparison to physical therapy suggests that yoga is likely less costly and yields similar outcomes	Selection bias, reporting bias, limited generalizability given association with socioeconomic status and veteran population	Moderate

Chronic Stress

Chronic stress states, such as CLBP, cause overactivation in the hypothalamic-pituitary-adrenal (HPA) axis. HPA overactivity leads to prolonged cortisol elevation, creating hippocampal atrophy and amygdala hypertrophy, thus altering the feedback that the HPA axis receives. The hippocampus is relevant to CLBP because this component of the brian is involved in pain process-

Table 1 cont. *Description of study characteristics included in narrative review.*

Reference	Purpose of Study	Study Characteristics	Study Findings	Limitations	Quality of Evidence (GRADE)
Liu et al, 2021 (25)	Study changes in lumbodorsal muscles from locust yoga pose	Design: Single-center, prospective, single-arm study Patients: 52 healthy volunteers trained to perform locust pose during a single visit Yoga Protocol: Locust pose entails lying prone with hands pronated, shoulders retracted, gaze down and forward, elbows extended, spine elongated, lower abdomen contacting the below surface, and feet in plantarflexion to obtain an angle of 30 degrees between the lower limbs and bed and trunk and bed	Greater thickness of the longissimus, then multifidi and iliocostalis, then quadratus lumborum in contracted state (locust pose) than in resting state (C/R ratio), viewed under ultrasound C/R ratio can be used to indicate muscle ability to contract and used for lumbar stabilization in CLBP patients	Small sample size, single-center study, single-day study duration, selection bias, limited generalizability given health study subjects, unable to prove cause and effect because the study used no control group	Very low
Singphow et al, 2022 (26)	Analyze yoga's effect on anxiety, stress, depression, and spinal mobility in computer users with CLBP	Design: Single-center RCT over 16 weeks Patients: Yoga group (n = 40) versus physical exercises/control group (n = 40) Yoga Protocol: Yoga practice combining yoga poses with mindfulness meditation for one hour per day, 3 days per week, for 16 weeks (supervised sessions for first 8 weeks and home practice with guided videos for the last 8 weeks)	Significant decreases in anxiety, stress, and depression in computer users with CLBP after yoga intervention, compared to control group, at 16 weeks Significant increases in spinal mobility in computer users with CLBP after yoga intervention, compared to control group, at 16 weeks	Small sample size, selection bias, single-center study, limited generalizability, reporting bias	Low
Tekur et al, 2012 (27)	Assess effects of yoga versus exercise on pain, mood, and spinal mobility in residents with CLBP at a holistic health center	Design: Single-center RCT over 7 days Patients: Yoga group (n = 40) versus physical exercise/control group (n = 40) Yoga Protocol: Instructor-led yoga program (2 sessions of 60 minutes each day) with specific poses for back pain, in addition to meditation and education on yoga philosophy	Significant reductions in pain, depression, and spinal mobility in both groups, though greater reductions in yoga group Significant reductions in anxiety in yoga group	Small sample size, single-center study, short study duration, selection bias, reporting bias, limited generalizability	Very low
Metri et al, 2023 (28)	Study the changes on pain, mood, sleep, and quality of life from yoga intervention in female teachers with chronic musculoskeletal pain	Design: Single-center RCT over 6 weeks Participants: Yoga group (n = 25) versus control/no intervention (n = 25) Yoga Protocol: Instructor-led 60-minute yoga session 4 days per week for 6 weeks, with sessions including poses focusing on spinal mobility, deep stretching, meditation, and breathing/relaxation techniques	Significant decrease in pain intensity and disability in yoga group after 6 -eek intervention Improvements in depression, anxiety, stress, fatigue, and sleep scores in yoga group after 6 weeks	Small sample size, selection bias, single-center study, limited generalizability, reporting bias	Very low

Table 1 cont. *Description of study characteristics included in narrative review.*

Reference	Purpose of Study	Study Characteristics	Study Findings	Limitations	Quality of Evidence (GRADE)
Roseen et al, 2020 (29)	Assess effects of yoga and physical therapy (PT) on sleep quality in adults of low socioeconomic status with CLBP	Design: Secondary analysis of a single-center RCT over 52 weeks Participants: Yoga group (n = 127) versus PT group (n = 129) versus education (n = 64) Yoga Protocol: Instructor-led yoga classes designed to target back pain conducted for 75 minutes once weekly for 12 weeks, in addition to meditation and breathing/relaxation techniques	Sleep improvements noted in both yoga and PT groups after 12 weeks, with larger changes in yoga group Improvements in pain and physical function at 6 weeks were associated with improvements in sleep quality at 12 and 52 weeks	Secondary analysis, single-center study, selection bias, reporting bias, 20% loss to follow-up at 52 weeks in original study	Moderate
McCarthy et al, 2022 (30)	Study mechanisms by which yoga affects disability in veterans with CLBP	Design: Secondary analysis of a single-center RCT over 6 months Patients: Yoga group (n = 52) versus delayed-treatment group (n = 51) Yoga Protocol: Instructor-led yoga classes designed by physicians and yoga experts specifically targeting CLBP conducted for 60 minutes twice weekly for 12 weeks, and patients encouraged to practice at home on days without classes	Yoga significantly impacts disability directly Yoga significantly impacts disability indirectly, mediated by pain and fatigue, which accounts for 38% of disability in CLBP	Secondary analysis, single-center study, selection bias, reporting bias, limited generalizability given veteran population	Low
Williams et al, 2005 (31)	Evaluate effects of yoga on disability and pain in patients with CLBP	Design: Single-center RCT over 7 months Patients: Yoga group (n = 20) versus educational control group (n = 22) Yoga Protocol: Instructor-led Iyengar yoga classes addressing spinal imbalance, alignment, and posture conducted for 90 minutes once weekly for 16 weeks, and patients encouraged to practice at home 5 days per week	Significant differences between yoga versus control groups in medical and functional outcomes Significant reductions in functional disability (77%), pain intensity (64%), and pain medication usage (88%) in yoga group after treatment and at 3-month follow-up	Small sample size, selection bias, single-center study, reporting bias	Low
Williams et al, 2009 (32)	Evaluate the effects of Iyengar yoga in CLBP	Design: Single-center RCT over 6 months Patients: Yoga group (n = 43) versus standard treatment/control (n = 47) Yoga Protocol: Instructor-led Iyengar yoga classes for 90 minutes twice weekly for 24 weeks, and patients instructed to practice at home for 30 minutes on non-class days	Greater reductions in functional disability and pain intensity in yoga group than in control group after 24 weeks of yoga intervention Significant reduction in depression in yoga group Pain medication usage was decreased in both groups, but reduction was greater in yoga group Significant reductions in functional disability, pain, and depression at 6-month follow-up {AU: Does this finding apply to both groups?}	Small sample size, selection bias, single-center study, reporting bias	Low

ing and helps modulate pain signals. In contrast, the amygdala is involved in the pain response, including the emotional-affective aspect of pain. Hippocampal atrophy can allow for amygdala hyperactivity, which is associated with maladaptive responses such as increased fear and pain catastrophizing (15).

Table 1 cont. *Description of study characteristics included in narrative review.*

Reference	Purpose of Study	Study Characteristics	Study Findings	Limitations	Quality of Evidence (GRADE)
Whitehead, 2018 (33)	Analyze effects of yoga on CLBP compared to those of no treatment and other treatments	Design: Systematic review, study durations range but up to 6 months Patients: 12 trials that include 1,080 patients and compare yoga to exercise intervention, a non-exercise intervention like education, no intervention, or exercise and non-exercise interventions Yoga Protocol: Inconsistent protocols, commonly used Iyengar or Viniyoga styles	Yoga, compared to non-exercise, produces improvements in CLBP patients' functioning {AU: Please see that this edit retains your intended meaning.} and may be more effective in alleviating pain at 3 and 6 months Yoga is as efficacious with similar risk of adverse events to exercise	Retrospective analysis, lack of information and inconsistency regarding specific yoga protocol, control group, and study duration	Moderate
Sherman et al, 2011 (34)	Compare the effects of yoga, stretching, and education with those of a self-care book in patients with CLBP	Design: Single-center RCT over 26 weeks Patients: Yoga group (n = 92) versus a group that practiced conventional stretching exercises (n = 91) versus a group that read a self-care book (n = 45) Yoga Protocol: Instructor-led Viniyoga classes designed for patients with CLBP conducted for 75 minutes once weekly for 12 weeks, and patients asked to practice at home on non-class days	Greater improvements in functional status and pain bothersomeness {AU: Do you perhaps mean "intensity" instead"?} in yoga group than in self-care group at 12 weeks Significant improvement in function in yoga group at 26 weeks Yoga was not more beneficial than stretching at follow-up	Selection bias, single-center study, reporting bias	Moderate
Saper et al, 2017 (35)	Assess effects of yoga and PT on patients with CLBP	Design: Single-center RCT over 52 weeks Patients: Yoga group (n = 127) versus PT (n = 129) versus education (n = 64) Yoga Protocol: Instructor-led yoga classes focusing on spinal mobility and stabilization, conducted for 75 minutes once weekly for 12 weeks, and patients encouraged to practice daily at home	Yoga was not inferior to PT Yoga and PT groups were less likely to use pain medication at 12 weeks than were patients in education group Improvements in yoga and PT groups continued at 52 weeks Similar frequency of adverse events among yoga and PT groups	Selection bias, single-center study, reporting bias, disproportionate loss to follow-up of PT group	Moderate
Marshall et al, 2022 (36)	Study effects of exercise interventions and yoga on CLBP management	Design: Secondary analysis of Back to Health Trial (Saper et al, 2017), conducted over 52 weeks Patients: Yoga group (n = 127) versus PT (n = 129) versus education (n = 64) Yoga Protocol: Instructor-led yoga classes focusing on spinal mobility and stabilization, conducted for 75 minutes once weekly for 12 weeks, and patients encouraged to practice daily at home	Improvements in pain self-efficacy in all 3 groups at 12 weeks and sustained at 52 weeks, with changes from yoga and PT groups being clinically meaningful Improvements in catastrophizing in yoga and PT groups at 12 weeks and sustained at 52 weeks Small changes in fear-avoidance beliefs	Secondary analysis, single-center study, selection bias, reporting bias	Moderate

Yoga may play a role in mitigating the adverse effects of this HPA dysregulation. One factor may be yoga's beneficial influence on cortisol levels. In one study of 54 patients with depression, those who underwent a yoga intervention were found to have significantly decreased cortisol levels ($P = 0.006$), and this

cortisol change was correlated with reduced depression (based on the Hamilton Depression Rating Scale) (P = 0.001) (16). An RCT similarly found that yoga was associated with decreases in cortisol levels and depression (P < 0.001). Patients in this study also noted less anxiety and back pain as well as improved affect and personal relationships (P < 0.05) (17). Additionally, in a review of 34 studies assessing neuroimaging findings from yoga practitioners, multiple studies found that yoga increased the gray matter volume of the hippocampus and decreased the volume of the amygdala, thus providing protection against the negative changes seen in chronic stress states such as CLBP (18).

Pain Catastrophizing

Pain catastrophizing is a maladaptive, negative response to a painful or potentially painful stimulus. The 3 main components of pain catastrophizing are magnification of pain, feelings of helplessness, and persistence of that pain magnification and helplessness. Pain catastrophizing is associated with altered activation of various gray matter brain regions. The regions involved in attention to and processing of pain and cognitive and emotional regulation include the left posterior cingulate cortex (PCC), supplementary motor area (SMA), and medial frontal gyrus (MFG) (19).

In a study examining the brain imaging of patients who had CLBP after failed lumbar disc surgery, a positive correlation was noted between pain catastrophizing and depression (P = 0.01), suggesting that depression may further complicate CLBP management for patients who exhibit pain catastrophizing. This study also found a negative correlation between pain magnification and gray matter volume (GMV) in the PCC (P < 0.05). The PCC has a role in the ability to pay attention, particularly to noxious stimuli, and this association suggests that those with lower PCC GMV may be overattentive to their pain or have trouble being distracted from it. Additionally, a positive correlation was noted between helplessness and GMV in the MFG or SMA (P < 0.05). The MFG is associated with fear processing and shame, and SMA activity is increased during controlled movement with simultaneous pain processing, helping explain this correlation (19). When assessing yoga's effects on various cortical regions, a review that included magnetic resonance imaging (MRI), positron emission tomography (PET), and single-photon emission computerized tomography (SPECT) brain imaging found that patients who practiced yoga had a higher density of gray matter in the cingulate and superior gyri as well as the MFG, suggesting that yoga may offer some protection from pain catastrophizing (18).

Pain, Function, and Disability

As previously discussed, CLBP is associated with poor function, increased pain, and disability, which is burdensome personally, professionally, and financially. In an RCT of 313 CLBP patients that compared those who underwent a yoga intervention to those who received usual care, the patients in the yoga group showed improved back function and disability at 3, 6, and 12 months after the study (P < 0.05 at 3 months). These patients also had higher pain self-efficacy scores at 3 and 6 months (P < 0.05) (20). An additional study, which evaluated a total of 68 CLBP patients, randomized some of those patients into a yoga intervention group and others into a usual-care group. The study found that patients in the yoga group had improved pain at 4 and 8 weeks (P = 0.001, P = 0.02). These patients had clinically significant improvements in disability (adjusted P = 0.44), function (adjusted P = 0.33), and symptom burden (adjusted P = 1.00) at the 3-month assessment and improved symptom burdens (adjusted P = 0.03) at the 6-month assessment (21).

Yoga has also been shown to improve occupational outcomes. An 8-week yoga intervention revealed that patients with chronic pain had a 27% improvement in occupational performance and a 78% increase in occupational satisfaction (P < 0.001) over those who received standard treatment. These patients were also found to have increased engagement with their occupations and decreased depression (P = 0.024, P = 0.041) (22). Additional research reiterates yoga's associations with improvements in overall function and suggests this phenomenon may be tied to the financial benefits of using yoga in CLBP management. Studies have shown that yoga is a cost-effective option for patients with CLBP, particularly when quality-adjusted life years (QALY) are considered, and is associated with improved pain and disability (23,24).

Spinal Strength and Mobility

Other common characteristics in CLBP patients are weak or degenerative lumbar musculature, increased muscle tension, and poor flexibility. Yoga is reputed to improve lumbar muscle engagement and stability. Yoga's effect on lumbodorsal muscles was assessed in a group of 52 healthy volunteers performing the locust pose while under live ultrasonography imaging. The

muscles studied included the multifidus, longissimus, iliocostalis, and quadratus lumborum. Ultrasound examinations were performed on patients in the contracted (locust pose) and in the relaxed (lying prone) states. The outcomes studied were a contracted-to-relaxed ratio (C/R) and a change in individual muscle thickness in each state. This study found that all muscles were thicker in the locust pose ($P < 0.05$). The highest C/R was noted in the longissimus, followed by the multifidus and iliocostalis, which were subsequently followed by the quadratus lumborum, suggesting that muscles with higher C/R were more involved in spinal stabilization. These findings emphasize how yoga poses, like the locust pose, affect lumbar muscle engagement and imply that improving lumbodorsal muscle strength can mitigate muscular degeneration, which occurs in CLBP and is closely linked to pain, lower physical activity levels, and fear of movement (25).

Furthermore, when studying spinal mobility in 80 patients with CLBP, one RCT found that at 16 weeks after treatment, those who underwent a yoga intervention exhibited increased spinal flexion ($P < 0.001$), extension ($P < 0.001$), and lateral flexion (right, $P = 0.001$, and left, $P = 0.007$) over patients who had undergone physical exercise, as measured by a dial-type goniometer (26). Similarly, an additional RCT studied 80 patients over 7 days who were undergoing a yoga intervention and compared them to those who engaged in physical exercise. Spinal mobility was assessed with a "sit and reach" tool. The RCT found that both groups had improved spinal mobility. However, there was a greater increase in the yoga (49.5%) group than in the physical exercise (34.6%) group ($P < 0.001$) (27). These findings indicate that yoga's beneficial influence on spinal mobility is superior to that experienced from physical exercise alone, and this improved range of motion can minimize the myofascial pain, muscle tension, and inflexibility felt by those with CLBP.

Fatigue

Yoga's therapeutic effects on CLBP patients may be linked to its ability to improve sleep and fatigue reduction. One RCT of 50 teachers undergoing 6 weeks of yoga therapy noted statistically significant improvements in sleep scores and fatigue at the end of treatment, in addition to improved pain, stress, and disability, which were not observed in the control, or standard-treatment, group ($P < 0.05$) (28). Similarly, a study of 320 CLBP patients randomized some of the individuals into a yoga group and others into a physical therapy group, and the study outcomes were sleep quality and its effects on pain and physical function. Both groups showed statistically significant improvements in sleep quality, and this finding was associated with decreased pain and improved function ($P < 0.05$) (29). McCarthy et al performed a mediational analysis of a prior RCT to examine the relationship between yoga and disability and found that fatigue was a unique intermediary. Yoga has significant, direct effects on disability, and pain and fatigue have a significant, indirect effect, accounting for 38% of yoga's beneficial influence on disability in CLBP patients ($P < 0.05$). This finding suggests that yoga decreases pain and fatigue in patients with CLBP, which may reduce disability. The conclusion that pain plays a role in the relationship between yoga and disability is expected; however, the discovery of fatigue's role as a mediator in this relationship is novel (30).

Medication Dependence

Medication dependence negatively affects the functioning and quality of life of patients with CLBP. Yoga's capacity to reduce pain reduction, improve mood, and decrease disability can help explain the association between yoga and decreased medication use. In a study comparing CLBP patients who were randomized to receive either a yoga intervention or education to manage their condition, those who underwent yoga therapy were found to experience an 88% decrease in pain medication use, which was a statistically significant finding after the 16-week intervention and 3-month follow-up ($P < 0.05$). The pain medications studied were nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, muscle relaxants, and opioids. These patients were also noted to experience a 64% reduction in pain intensity and a 77% decrease in functional disability (31). Another study compared yoga to standard treatment and similarly noted reduced use of NSAIDs, acetaminophen, muscle relaxants, and opioids in both groups, with greater reductions noted in the yoga group after 24 weeks ($P > 0.05$). The yoga group was also noted to have significant reductions in pain intensity, depression, and functional disability ($P < 0.05$) (32). Overall, yoga's ability to decrease dependence on and use of pain medication is promising for the development of the complex management of CLBP.

Yoga's Effects on Sensitization

The characteristics described in patients suffering from CLBP may be further exacerbated by the sensiti-

zation of their pain. Therefore, to better understand yoga's role in the management of CLBP, it is important to comprehend how yoga influences central and peripheral sensitization.

Central Sensitization

Central sensitization, a component in the propagation of CLBP, may be mitigated by practicing yoga. One RCT of 108 patients evaluated CLBP and its effects on quality of life, pain thresholds, and pain modulation (as measurements of central sensitization) during and after an 8-week yoga intervention. Patients' pain was assessed on a visual analog scale (VAS) and McGill Pain Questionnaire, and quality of life was monitored on the World Health Organization Quality of Life (WHO-QOL-BREF) questionnaire. The pain threshold was evaluated by observing the nociceptive flexion reflex (NFR) response. The NFR is a spinally organized reflex that allows for withdrawal from noxious stimuli and is modulated by endogenous pain control mechanisms. To observe the NFR, the sural nerve was electrically stimulated at the skin, and electromyography was used to record the withdrawal reflex of the biceps femoris (short head). To evaluate pain modulation, endogenous pain control was assessed through the diffuse noxious inhibitory control (DNIC) test, which measured descending inhibition. A test stimulus (NFR) and conditioned stimulus (immersing the opposite hand in cold water) were required for DNIC testing. Electrical impulses were administered during and after cold water immersion, and the values were averaged to create an NFR threshold (5).

The results of this study included reductions in pain scores and improved quality of life following the 8-week yoga intervention ($P < 0.001$). Patients with CLBP were found to have hyperalgesia and low NFR thresholds at the baseline. After an 8-week yoga intervention, these patients had increased NFR thresholds that were not observed in the control group, suggesting pain reduction and improved pain tolerance ($P < 0.001$). Additionally, CLBP patients were noted to have poor descending inhibition and poor pain modulation at the baseline, and DNIC values improved after the yoga intervention (as suggested by increased NFR thresholds), another change that was not observed in the control group ($P < 0.001$). Improvements in DNIC values suggest that yoga's role in decreasing physiological stress, hyperalgesia, and hyperarousal is linked to decreases in central sensitization. Therefore, this novel study highlights yoga as a promising therapy in CLBP management, given the illustration of yoga's ability to reduce central sensitization by improving pain thresholds and pain modulation (5).

Peripheral Sensitization

Yoga may uniquely influence peripheral sensitization in patients with CLBP, specifically through yoga's potential effects on gene expression. In their study of 11 patients undergoing a 12-week yoga intervention, Adhikari et al assessed the individuals' subjective pain and sensory alterations and performed blood analysis to study gene expression and CpG methylation. Measures of pain included the Brief Pain Inventory (BPI), pain self-efficacy items, and the Emotion Regulation Questionnaire (ERQ). Sensation was assessed with quantitative sensory testing, which involved administering standardized physical stimuli and monitoring responses in pain-processing and non-pain-processing systems. Molecular measures were collected by isolating genomic DNA from white blood cells (7).

Because of the study's small sample size, statistical significance was limited. However, patients were noted to show clinical improvements in pain severity and sensitivity, self-efficacy, and emotion regulation after the 12-week yoga intervention ($P > 0.05$). As for molecular findings, specific antisense genes had increased expression in these patients after the yoga intervention ($P < 0.1$). The gene responders included KLRK1, KPNB1, LAPTM5, ICAM-3, and RPL23A, which have greater expression in individuals with CLBP, spondyloarthritis, and neuropathic pain, and increases in antisense transcripts are associated with pain reduction. Therefore, antisense transcripts form a potential area of study for future research on and development of CLBP management. Additionally, differential hypomethylation of CpG was noted in certain genes, particularly those involved in NIK/NF-kB signaling ($P < 0.1$). This signaling is sensed by glutamatergic neurons, which comprise the dorsal root ganglion, and thus a direct connection to pain modulation is feasible. The improved pain responses that followed the yoga intervention suggested this effect on pain processing. Irrespective of study quality, these data highlight domains of further study in the modulation and treatment of CLBP (7).

Yoga Versus Standard Therapies

Given yoga's numerous aforementioned benefits, it is important to compare the efficacy and safety of yoga to those of other standard therapies used in CLBP management. A systematic review of yoga practiced

by CLBP patients found that yoga was as efficacious as standard exercise and no more harmful (33). Similarly, Sherman et al conducted an RCT comparing yoga to traditional stretching and concluded that yoga was as efficacious as stretching for pain and function (34).

Numerous studies comparing yoga to physical therapy highlight that the 2 modes of treatment have similar efficacy. One RCT noted that patients who tried yoga and those who tried physical therapy had comparable improvements in pain and activity limitation as well as reduced medication use (35). In a secondary analysis of a prior trial, patients were noted to show similar improvements in pain self-efficacy and pain catastrophizing after both yoga and physical therapy interventions (36). As previously mentioned by Roseen et al, an RCT that compared yoga to physical therapy found patients showed similar improvements in sleep quality, with associated improvements in pain and function (29). However, a separate RCT studying 2 groups of patients, one who underwent yoga and one who underwent physical therapy, found that both groups exhibited improvements in pain, spinal mobility, and depression, though those improvements were greater in the yoga group. The study also found that those in the yoga group had decreased anxiety, which was not noted in the physical therapy group (27). Therefore, the benefits of yoga do not appear to stop at the physical but also seem to affect the mental symptoms experienced by CLBP patients. Traditional exercise, stretching, and physical therapy do not address these issues as well as yoga does, which is likely attributable to yoga's unique components, particularly the triad of poses, breath, and meditation.

Limitations

Yoga as a form of therapy for CLBP is not without its limitations. The current literature is varied, as evidenced by the article quality in this review, with GRADE rankings ranging from very low to moderate. While many of the articles assessed were RCTs with longer study durations, common limitations were that many were single-center studies or studied a specific population (pregnant women, veterans, etc.), which limited generalizability. Generalizability was further limited by the variation in yoga protocols that were studied. Currently, there exist no standardized and validated protocols for a yoga therapy practice schedule and the poses to perform for CLBP. Additionally, certain conditions may require medical clearance, and some low back pain conditions may necessitate avoiding certain yoga poses. For example, an unstable condition like spondylolisthesis would require neutral-based poses and avoiding excessive flexion and extension. As mentioned, CLBP is also associated with pain catastrophizing and avoidance behaviors such as fear of movement, so these patients may be apprehensive about trialing a therapy such as yoga. Other barriers include time (duration of a yoga class, time until perceived benefit, etc.), cost (cost of equipment, paying for a class/membership, etc.), access or social determinants of health, and stigma surrounding yoga.

Additional limitations include the inherent risk of the placebo effect and selection bias in the articles reviewed, since study participants were those who volunteered or selected to partake in a yoga intervention. Furthermore, most outcome measures were self-reported, which might have meant the influence of the placebo effect and a risk of reporting bias were involved. While the current body of literature is informative, more research is needed in this domain. Future studies should ensure prospective trials, random selection of study subjects, larger sample sizes, lengthy study durations, a standardized yoga protocol for CLBP, and the use of objective or validated outcome measures. Though blinding is not possible when studying yoga therapy, the above measures would minimize bias and further strengthen the current body of evidence supporting yoga as a form of CLBP management. Nonetheless, like any treatment for CLBP, patient participation, compliance, consistency, and commitment to treatment are required to promote positive outcomes.

Conclusion

As evidenced by the ongoing personal and societal burdens caused by CLBP, the current management of CLBP is insufficient, and adjunctive treatments like yoga should be seriously considered. A growing body of evidence supports yoga's role in CLBP management, since yoga addresses the mental and physical components that afflict these patients, which other treatments do not encompass as broadly and collectively. The psychological and physical benefits of yoga are vast and include improvements in mood, stress, pain catastrophizing, self-efficacy, quality of life, function, disability, sleep, and medication dependence. Yoga may also promote positive coping, which is possibly related to its associated improvements in pain catastrophizing and self-efficacy. These developments are necessary for those chronically suffering from low back pain. Additionally, reduced medication use, improve-

ments in disability, and conservative management allow yoga to be a more cost-effective option than other currently proposed treatments for CLBP, and implementing such a management strategy is vital, given the billions of dollars spent annually on CLBP treatment. To an extent, yoga's profound benefits may be attributed to its involvement in mitigating central and peripheral sensitization, which may help halt or minimize the propagation of CLBP. Furthermore, it has been demonstrated that yoga exhibits equal or greater efficacy in improving patients' mental and physical health when compared to other standard therapies that are currently recommended in CLBP management.

Overall, this review highlights yoga's safety and benefits on mental and physical health and sensitization in CLBP patients. Therefore, yoga is a personalized, comprehensive, and effective adjunctive CLBP

References

1. Holtzman S, Beggs RT. Yoga for chronic low back pain: A meta-analysis of randomized controlled trials. *Pain Res Manag* 2013; 18:267-272.
2. Freeman H, Vladagina N, Razmjou E, Brems C. Yoga in print media: Missing the heart of the practice. *Int J Yoga* 2017; 10:160-166.
3. Luu K, Hall PA. Hatha yoga and executive function: A systematic review. *J Altern Complement Med* 2016; 22:125-133.
4. Dowell D, Ragan KR, Jones CM, Grant BT, Chou R. CDC Clinical Practice Guideline for Prescribing Opioids for Pain - United States, 2022. *MMWR Recomm Rep* 2022; 71:1-95.
5. Arya S, Yadav RK, Venkataraman S, Deepak KK, Bhatia R. Objective evidence for chronic back pain relief by Medical Yoga therapy. *Front Pain Res* 2022; 3:1060685.
6. Stevans JM, Delitto A, Khoja SS, et al. Risk factors associated with transition from acute to chronic low back pain in US patients seeking primary care. *JAMA Netw Open* 2021; 4:e2037371.
7. Adhikari B, Starkweather A, Xu W, et al. A feasibility study on yoga's mechanism of action for chronic low back pain: Psychological and neurophysiological changes, including global gene expression and DNA methylation, following a yoga intervention for chronic low back pain. *Pilot Feasibility Stud* 2022; 8:142.
8. Wang C, Hao H, He K, et al. Neuropathic injury-induced plasticity of GABAergic system in peripheral sensory ganglia. *Front Pharmacol* 2021; 12:702218.
9. Combs MA, Thorn BE. Yoga attitudes in chronic low back pain: Roles of catastrophizing and fear of movement. *Complement Ther Clin Pract* 2015; 21:160-165.
10. Sullivan MJL, Reesor K, Mikail S, Fisher R. The treatment of depression in chronic low back pain: Review and recommendations. *Pain* 1992; 50:5-13.
11. Hu Y, Yang Z, Li Y, Xu Y, Zhou X, Guo N. Anxiety symptoms and associated factors among chronic low back pain patients in China: A cross-sectional study. *Front Public Health* 2022; 10:878865.
12. Saeed SA, Cunningham K, Bloch RM. Depression and anxiety disorders: Benefits of exercise, yoga, and meditation. *Am Fam Physician* 2019; 99:620-627.
13. Streeter CC, Gerbarg PL, Saper RB, Ciraulo DA, Brown RP. Effects of yoga on the autonomic nervous system, gamma-aminobutyric-acid, and allostasis in epilepsy, depression, and post-traumatic stress disorder. *Med Hypotheses* 2012; 78:571-579.
14. Streeter CC, Gerbarg PL, Brown RP, et al. Thalamic gamma aminobutyric acid level changes in major depressive disorder after a 12-week Iyengar yoga and coherent breathing intervention. *J Altern Complement Med* 2020; 26:190-197.
15. Hannibal KE, Bishop MD. Chronic stress, cortisol dysfunction, and pain: A psychoneuroendocrine rationale for stress management in pain rehabilitation. *Phys Ther* 2014; 94:1816-1825.
16. Thirthalli J, Naveen GH, Rao MG, Varambally S, Christopher R, Gangadhar BN. Cortisol and antidepressant effects of yoga. *Indian J Psychiatry* 2013; 55:S405-408.
17. Field T, Diego M, Delgado J, Medina L. Yoga and social support reduce prenatal depression, anxiety and cortisol. *J Bodyw Mov Ther* 2013; 17:397-403.
18. van Aalst J, Ceccarini J, Demyttenaere K, Sunaert S, Van Laere K. What has neuroimaging taught us on the neurobiology of yoga? A review. *Front Integr Neurosci* 2020; 14:34.
19. Chehadi O, Suchan B, Konietzny K, Köster O, Schmidt-Wilcke T, Hasenbring MI. Gray matter alteration associated with pain catastrophizing in patients 6 months after lumbar disk surgery: A voxel-based morphometry study. *Pain Rep* 2017; 2:e617.
20. Tilbrook HE, Cox H, Hewitt CE, et al. Yoga for chronic low back pain: A randomized trial. *Ann Intern Med* 2011; 155:569-578.
21. Highland KB, Schoomaker A, Rojas W, et al. Benefits of the restorative exercise and strength training for operational resilience and excellence yoga program for chronic low back pain in service members: A pilot randomized controlled trial. *Arch Phys Med Rehabil* 2018; 99:91-98.
22. Schmid AA, Van Puymbroeck M, Fruhauf CA, Bair MJ, Portz JD. Yoga improves occupational performance, depression, and daily activities for people with chronic pain. *Work Read Mass* 2019; 63:181-189.
23. Chuang LH, Soares MO, Tilbrook H, et al. A pragmatic multicentered randomized controlled trial of yoga for chronic low back pain: Economic evaluation. *Spine* 2012; 37:1593-1601.
24. Groessl EJ, Liu L, Richard EL, Tally SR. Cost-effectiveness of yoga for chronic low back pain in veterans. *Med Care* 2020; 58:S142-S148.
25. Liu W, Li J, Zhou X, et al. Dynamic evaluation of the contractile function of lumbodorsal muscles during locust pose in yoga by real-time ultrasound. *BMC Sports Sci Med Rehabil* 2021; 13:87.
26. Singphow C, Purohit S, Tekur P, et al. Effect of yoga on stress, anxiety, depression, and spinal mobility in computer users with chronic low back pain. *Int J Yoga* 2022; 15:114-121.
27. Tekur P, Nagarathna R, Chametcha

S, Hankey A, Nagendra HR. A comprehensive yoga programs improves pain, anxiety and depression in chronic low back pain patients more than exercise: An RCT. *Complement Ther Med* 2012; 20:107-118.

28. Metri KG, Raghuram N, Narayan M, et al. Impact of workplace yoga on pain measures, mental health, sleep quality, and quality of life in female teachers with chronic musculoskeletal pain: A randomized controlled study. *Work* 2023; 76:521-531.
29. Roseen EJ, Gerlovin H, Femia A, et al. Yoga, physical therapy, and back pain education for sleep quality in low-income racially diverse adults with chronic low back pain: A secondary analysis of a randomized controlled trial. *J Gen Intern Med* 2020; 35:167-176.
30. McCarthy A, Liu L, Groessl E. Mediational analysis of yoga's effect on chronic low-back pain in veterans: What factors really matter? *Int J Yoga Ther* 2022; 32:Article 9.
31. Williams KA, Petronis J, Smith D, et al. Effect of Iyengar yoga therapy for chronic low back pain. *Pain* 2005; 115:107-117.
32. Williams K, Abildso C, Steinberg L, et al. Evaluation of the effectiveness and efficacy of Iyengar yoga therapy on chronic low back pain. *Spine (Phila Pa 1976)* 2009; 34:2066-2076.
33. Whitehead PB. The effect of yoga on chronic nonspecific low back pain. *Am J Nurs* 2018; 118:64.
34. Sherman KJ, Cherkin DC, Wellman RD, et al. A randomized trial comparing yoga, stretching, and a self-care book for chronic low back pain. *Arch Intern Med* 2011; 171:2019-2026.
35. Saper RB, Lemaster C, Delitto A, et al. Yoga, physical therapy, or education for chronic low back pain: A randomized noninferiority trial. *Ann Intern Med* 2017; 167:85-94.
36. Marshall A, Joyce CT, Tseng B, et al. Changes in pain self-efficacy, coping skills, and fear-avoidance beliefs in a randomized controlled trial of yoga, physical therapy, and education for chronic low back pain. *Pain Med* 2022; 23:834-843.