

## How Might Yoga Work? An Overview of Potential Underlying Mechanisms

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### Abstract

Research interest and participation in yoga for health-related outcomes are increasing worldwide, though the medical hypotheses and underlying mechanisms of yoga are infrequently discussed. This literature overview employs a systematic search to include articles of clinical investigation, synthesis or review that focus on potential underlying mechanisms for yoga's effect on prevention and treatment of disease. Results indicate that empirical evidence and theories for yoga mechanisms are most prevalent in areas of hormonal regulation, sympathetic activity in the nervous system and the betterment of physical health attributes such as improved balance, flexibility, strength and cardiorespiratory health. Hypothetical effects of yoga on metabolism, circulation, behaviour, oxidative stress, inflammation and psychological thought processes are also examined, while new hypotheses in immunology, nerve conduction and bioelectromagnetism are reviewed. In context of the Medical Research Council's complex intervention framework, methodological limitations and prospective research directions are discussed.

### Introduction

Popular and academic interest in yoga for treatment of health conditions are increasing at an alarming rate while over 30 million people claim to practice yoga for health benefit worldwide [1]. The practice of yoga originates from 5000 BCE in India to combine specific postures (asanas), breathing techniques (pranayama), meditative techniques (dhyana), chants (mantras) and wisdom teachings (sutras) to encourage union with body and mind [2]. Yoga therapy is the "process of empowering individuals to progress toward improved health and well-being through the application of the philosophy and practice of Yoga" [3]. Today, nearly 14 million Americans (6.1% of the population) say that a doctor or therapist has recommended yoga to them for their health condition [4]. In the United Kingdom, national healthcare services promote yoga as a safe and effective way to promote physical activity, improving strength, balance and flexibility as well as a potential benefit for people with high blood pressure, heart disease, aches and pains, depression and stress [5].

Over 2000 health and yoga-related journal articles are published online ([www.ncbi.nlm.nih.gov/pubmed](http://www.ncbi.nlm.nih.gov/pubmed)). A recent summary (2012) indicates that there is relatively strong evidence to suggest that yoga may have beneficial effects for pain-associated disability and mental health [6]. A preceding overview (2010) shows unanimously positive evidence emerged for depression and cardiovascular risk reduction with yoga, with little supporting evidence to suggest benefit for patients with epilepsy, asthma or various pain conditions [7]. A further clinical review suggests that psychological symptoms and disorders (anxiety, depression, sleep), pain syndromes, autoimmune conditions (asthma, multiple sclerosis), immune conditions (lymphoma, breast cancer), pregnancy and weight loss can all be positively affected by yoga [8]. From an evidence-based healthcare perspective, the hypothetical underlying mechanisms to explain potential effects of yoga are in the early stages of investigation. In response to the Medical Research Council's guidelines for evaluating complex interventions [9,10], a coherent theoretical basis should be established in advance of further research development.

### Purpose of this Review

As evidence suggests, yoga has a potential role in the prevention and treatment of numerous health conditions. The theoretical basis

for health effects is important to clinicians, researchers and yoga practitioners. The purpose of this literature review is to synthesize the current hypotheses and scientific evidence for underlying mechanisms of yoga intervention.

### Methodology

#### Inclusion criteria

**Type of articles:** Any clinical investigation, review or evidence synthesis that explores potential underlying mechanisms for yoga's effect in a health-related context is included. Authors must name yoga as the primary focus of their research. To improve the quality of data, only peer-reviewed articles published on-line within public medical research databases after January 1, 2006 are included. Hypotheses presented without sufficient scientific evidence are set aside and presented as emergent hypotheses.

**Type of mechanisms:** Any yoga mechanism or description that includes underlying effects of practicing yoga or explanations supported with scientific inquiry or preliminary evidence is included. Health outcomes such as blood pressure, reducing body weight or decreasing stress are insufficient for inclusion, though may be included if underlying mechanisms of these outcomes are discussed.

**Type of yoga:** Any type of yoga is included for review. A standardized definition of yoga in research is not available at this time. For the purposes of this review, a broad and conventional definition is a pragmatic choice, where the described yoga intervention must

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include one or more of the following characteristics: (breathing techniques), asana (postures) and dhyana (meditation) and/or other yoga teachings.

### Exclusion criteria

Articles that discuss interventions similar to yoga (i.e., massage, tai chi, talk therapy) are excluded. Research protocols or papers that discuss yoga mechanisms only in their introduction or study rationale are not included.

### Search strategy

**Databases:** An on-line search of three scholarly databases includes the Cochrane Library, PubMed and Scopus databases. Conferences and websites of yoga institutions and references from found articles are also searched. Hand-searches in yoga-specific journals and books also performed to ensure a comprehensive search.

**Online search terms and limitations:** A rapid systematic search employs free-text terms: [yoga] AND [(mechanism OR pathway OR effect) AND (clinic\* OR review)]. The literature search is current as of 1 December 2012.

## Results

### Description of included articles

The title-search identified 454 potential articles, 110 abstracts were screened and 24 full-text articles assessed for eligibility. Eighteen original articles are included in this literature review (Figure 1). A variety of outcome effects are presented in the literature, including treatment and prevention of cardiovascular disease (CVD), diabetes, obesity, arthritis, cancer, epilepsy and erectile dysfunction. Psychological wellbeing, relaxation, decrease in depression and anxiety, delayed aging, improved pain management and sleep quality were also discussed. Five of the articles introduce potential mechanisms that lack empirical evidence and will be discussed separately as emerging hypotheses. Table 1 lists the characteristics of included studies.

The characteristics of yoga intervention are not explicitly reported in the majority of cases, although asana practice appears most

commonly cited (17 articles). The Oswal study [11] examines the effect of pranayama and dhyana components of yoga only. Six articles were excluded after initial screening because of insufficient empirical evidence to support theories, or yoga mechanisms are not the focus of the paper, or the paper includes interventions other than yoga (Table 2).

One of the 18 included reports identifies an adverse effect of yoga [12]. In this case, a female practitioner developed thrombosis of the vertebrasilar artery due to an intimal tear and suffered a subsequent stroke. The nature of this injury is attributed to adopting an unusual neck posture [13].

### Quality of included articles

One included article is a systematic review of underlying mechanisms for yoga [14] and receives a high-quality rating (AMSTAR=9) [15]. One randomized control trial [9] (n=30) reports double blinding and shows reasonable effort to minimize bias and appears to follow the CONSORT [16] guidelines for transparency and effective reporting procedures. Three controlled trials [17-19] are included, though the quality of evidence is low due to selective recruitment and lack of randomization with no mention of blinding techniques. Furthermore, in two instances the reporting of results does not match the authors' hypotheses [18] and conclusions [17]. The remaining articles (13) are literature reviews or clinical reports and do not report on methodological considerations such as search protocols, inclusion or exclusion criteria of studies or rating the quality of evidence.

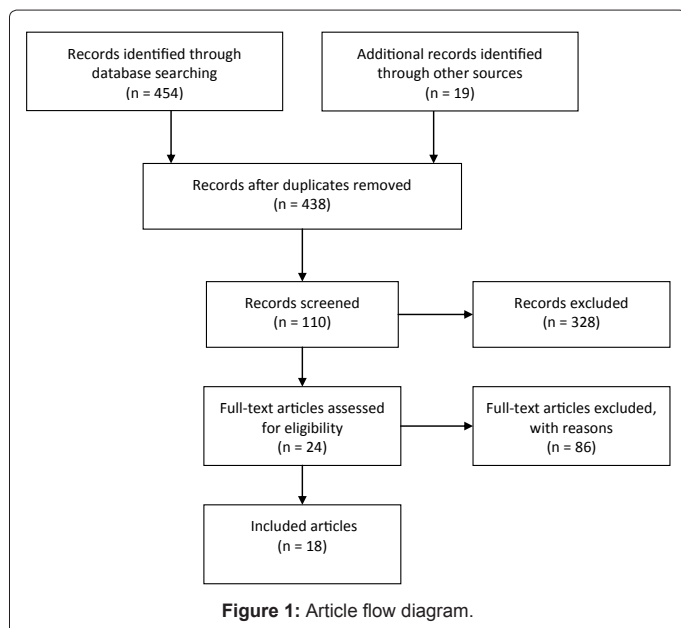
### Overview of mechanisms

The empirical evidence supporting underlying mechanisms for clinical effects of yoga is limited. A current systematic overview or review that thoroughly assesses the quality and weight of evidence to support or reject hypotheses has not been found. Research interest for mechanisms that examine pathways originating in the endocrine system, nervous system and cardiovascular, respiratory and physical parameters of health (BMI, muscular strength, psychomotor skills, etc.) are most prevalent. Mechanisms that affect metabolism, circulation (BP, atherosclerosis) and behavioural or social tendencies are frequently cited. Figure 2 depicts a summary of evidence as expressed in empirical and hypothetical findings.

### Empirical evidence

**Endocrine system:** The strongest evidence in both quality and quantity suggests yoga has a positive impact on hormone regulation. Salivary levels of cortisol have been measured and notably decreased in numerous reviews and trials [8,14,19,20]. Lowering cortisol is associated with decreasing perceived stress, decreasing anxiety, increasing feelings of well-being and improving pain management [21]. Enhanced serotonin production for erectile dysfunction [20], oxytocin released during visualization techniques to regulate bone mass [11] and higher levels of melatonin to improve immunity and sleep quality [12,22] are other potential effects of yoga practice.

**Nervous system:** An explanatory framework that attributes benefits of yoga through direct influence on the sympathetic and parasympathetic activity in the autonomic nervous system is common. Evidence suggests the respiratory effects of pranayama, visualization and calming techniques in dhyana as well as physical movement in asanas reduce sympathetic activation, increase levels of gamma-



Author	Year of Publication	Type of study	Outcomes effects	Description of Mechanism(s)
Balaji et al. [21]	2012	review	treatment and prevention of diabetes, obesity, arthritis, cancer, immune disorders	improved respiration, reduced cardiovascular risk, body mass index, blood pressure, hormone regulation, cellular metabolism.
Balk et al. [25]	2011	review	improve bone health, reducing fracture risk	improving balance, increases strength, reducing falls, reducing hyperkyphosis and inflammation.
Brotto et al. * [20]	2009	review	treats erectile dysfunction, enhanced sexuality	serotonin regulation, enhanced awareness, mental focus.
Dunn [30]	2008	review	improves mood disorders, decrease perceived stress, anxiety, increased wellbeing, relaxation prevention of chronic diseases: CVD, cancer, diabetes, Alzheimer's	improved cardiorespiration (decrease basal metabolic rate), cortisol regulation, increases feelings of satisfaction and self-control, stimulation of PNS and decrease of SNS, hypothalamic-pituitary-adrenal (HPA) axis, increases bioavailability and blood levels of nitric oxide, vasodilation of the CV system, increase levels of total antioxidant status (TAS) and decrease of other oxidate stress markers.
Field* [8]	2011	review	prevention of CVD, obesity, decrease injury, improve wellbeing, QOL, immunity, decrease perceived stress, pregnancy complications, improves pain management	exercise-training effects for improved cardiovascular and respiratory health, decrease in food consumption and speed of eating and positive food choices, attenuated weight gain, increase muscular strength and balance, decreases salivary cortisol, enhanced deep sleep leading to less P substance, stimulates Gate theory.
Hegde et al. [17]	2011	controlled clinical trial	reduced oxidative stress, diabetes management	reduces body mass index, improves glycemic control, levels of malondialdehyde, glutathione and vitamin C.
Innes et al. [14]	2005	systematic review	prevention of CVD, decrease risks associated with insulin resistance syndrome	metabolism of glucose, insulin, lipid profiles anthropometric characteristics, blood pressure, oxidative stress, coagulation profiles, sympathetic activation, cardiovagal function.
Kiecolt-Glaser et al. [18]	2010	controlled clinical trial	minimizes stress and inflammation	minimizes inflammatory response and endocrine response
Kinser et al. * [22]	2012	review	mitigate depressive symptomatology	hormonal regulation (decrease cortisol), HPA axis, increase levels of gamma-aminobutyric acid (GABA), vagus nerve stimulation via neurotransmitter, behaviour modification and group effect on mood.
Kulkarni et al. * [32]	2009	preliminary review	optimal health, stress reduction, increase immunity, heightened awareness, stillness by increasing the body's store of 'prana', or flow of vital energy	cortical and hypothalamo-pituitary-adrenal axis (HPA) interactions with a deep reach molecular action on cellular, neuro-humoral and immune system.
Kuntsevich et al. * [35]	2010	review	optimize health, delay aging, ameliorate chronic illness and stress from disability	promotes restoration of physiologic setpoints to normal after derangements secondary to disease or injury, promotes homeostatic negative feedback loops over nonhomeostatic positive feedback loops in molecular and cellular interaction, quenches abnormal "noise" in cellular and molecular signaling networks arising from environmental or internal stresses.
Oswal et al. [11]	2011	randomized controlled trial	speed healing of bone fracture	HPA axis, oxytocin, vasodilation and increased blood flow.
Sahay [26]	2007	review	diabetes management	glycemic control (lower levels of fasting, postprandial blood glucose), insulin kinetics, improved body composition.
Sengupta [12]	2012	review	obesity, diabetes management, CVD prevention, cancer treatment, mood enhancement, improved sleep	decrease blood lipids, assist ideal body weight and body density, increase cardiorespiratory fitness, increase sensitivity of pancreatic B-cells to the glucose signal, hormonal regulation (noradrenaline, dopamine, aldosterone, luteinizing hormone, testosterone, cortisol, melatonin).
Sharma et al. [27]	2012	review	diabetes management	decrease in fasting blood glucose.
Streeter et al. [23]	2012	review	treatment of epilepsy and depression	reduces allostatic load in stress response systems and restore optimal homeostasis; increases PN, decreases HPA axis; increases GABA activity; stretches receptors in the alveoli, baroreceptors, chemoreceptors, and other sensors throughout the respiratory structures sends information about the state and activity of the respiratory system through vagal afferents and brainstem relay stations to other CNS structures.
Vera et al. [19]	2009	controlled clinical trial	enhances subjective sleep quality (SSQ)	hormonal modulation (cortisol, ACTH).
Wren et al. [24]	2011	review	pain management	decreases SNS activity, reduces inflammatory markers (tumor necrosis factor, interleukin-2, C-reactive protein), reduces stress markers (cortisol), increases strength, flexibility, circulation and cardiorespiratory capacity, reduces social isolation, fosters networks that reinforce physical activity, increases awareness of physical and mental states.

\*Articles include hypotheses without empirical evidence.

Note: Outcome effects and mechanisms are described as reported by authors.

**Table 1:** Characteristics of included studies (ordered by study ID).

Reference	Reason for exclusion
Chiesa A, Serretti A (2010) A systematic review of neurobiological and clinical features of mindfulness meditations. <i>Psychol Med</i> 40: 1239-52.	Includes interventions other than yoga
da Silva TL, Ravindran LN, Ravindran AV (2009) Yoga in the treatment of mood and anxiety disorders: A review. <i>Asian J Psychiatr</i> 2: 6-16.	Mechanisms of yoga are not the focus of the text
Omkar SN, Vishwas S, Tech B (2009) Yoga techniques as a means of core stability training. <i>Journal of Bodywork and Movement Therapies</i> 13: 98-103.	Insufficient empirical evidence
Ospina MB, Bond K, Karkhaneh M, Tjosvold L, Vandermeer B, Liang Y, et al. (2007). Meditation practices for health: State of the research. <i>Evid Rep Technol Assess</i> 155: 1-263.	Includes interventions other than yoga
Posadzki P, Ernst E (2011) Yoga for low back pain: A systematic review of randomized clinical trials. <i>Clin Rheumatol</i> 30: 1257-62.	Mechanisms of yoga are not the focus of the text
Posadzki P, Parekh S, Glass N (2010) Yoga and qigong in the psychological prevention of mental health disorders: A conceptual synthesis. <i>Chin J Integr Med</i> 16: 80-6.	Includes interventions other than yoga

**Table 2:** Characteristics of excluded reviews.

aminobutyric acid (GABA) [23], regulate the hypothalamic-pituitary-adrenal (HPA) axis to improve outcomes in mood disorders [18], stress [24], well-being and provides an anxiolytic effect [22].

**Physical health:** Physical health includes cardiorespiratory fitness, kinesiology, and biomechanics including balance, flexibility and anthropometric characteristics. Yoga interventions to increase strength and balance have demonstrated a capacity to decrease falls and risk of injury in a geriatric population [25]. Exercise training effects in lowering resting heart rate, oxygen consumption rate, decrease in basal metabolic rate (BMR) and decreasing body mass index (BMI) and fat mass indicate preventative effects for cardiovascular disease, diabetes and obesity [8,12,14,17].

**Metabolism:** The metabolic effects of yoga have been most intensely studied for glycemic control. Evidence for improved glucose tolerance and insulin sensitivity suggests that regular asana practice may replace drug therapies in type 2 diabetics [14]. Measureable improvements of clinical significance after yoga intervention are noted in fasting plasma glucose (FPG) and postprandial plasma glucose (PPPG) [17,26,27]. Balaji et al. [21] note increased hepatic lipase and lipoprotein lipase at the cellular level affects the metabolism and subsequent increase in uptake of triglycerides by adipose tissues.

**Circulatory system:** The circulatory pathways of health-related outcomes include lowering blood pressure and improving arterial function. Three authors discuss the potential circulatory benefits that include: lowering blood pressure, enhancing cardiovagal function and slowing atherosclerosis to prevent cardiovascular disease [14] increasing blood flow with the prompting of visual techniques [11] and restoring baroreceptor sensitivity [10].

**Behavioural/social:** A decrease in food consumption, eating speed and positive food choices following a yoga treatment program is shown to be effective for binge eating [28]. Enhancing sleep quality to improve psychological well-being is noted in two studies [14,19]. Reducing social isolation, fostering networks that reinforce physical activity and self-care could lead to improved pain management [24] and healthier physical and psychological responses to stress [21].

**Antioxidant:** Oxidative stress results from an imbalance in the pro-oxidant-antioxidant equilibrium and is associated with a number of diseases [29]. Numerous findings identify an increase in levels of total antioxidant status (TAS) and other naturally occurring antioxidants in human cells such as glutathione (GSH) and plasma vitamin E following yoga intervention [14,17,30]. Preventative and treatment effects for cardiovascular disease, cancer, arthritis, diabetes and Alzheimer's have also been indicated in these research findings. One 3-month clinical

trial with diabetic yoga practitioners achieved a 20% reduction in oxidative stress following long-term regular sessions [17].

**Inflammation:** Yoga's effect on decreasing inflammatory markers is a recent addition to research. With a focus on pain management and effective treatment of depression, the partial role of reducing proinflammatory cytokines such as IL-6, interleukin-2, C-reactive protein is attributed to yoga's capacity to stimulate the vagus nerve [18,21,26]. The vagus nerve in turn decreases heart rate, blood pressure or both to improve responses to stress and which may have further effects on decreasing obesity and improving immunity [31].

**Psychology and cognition:** In two articles, increased feelings of satisfaction, self-confidence and self-control are linked to decreased perceived stress and increased well-being following yoga practice [14,20]. Another author states that "if yoga therapy offers an awareness of physical and mental states, benefits for pain management for back pain and cancer-related therapies including breast cancer may result [21]", though the empirical evidence is insufficiently robust to confirm predictions.

## Emerging Hypotheses

The following group of mechanisms belong to hypothetical areas of effect that depend on limited or indirect research for evidence.

### Immunity

Two papers identify immunology for cancer treatment and stress reduction as a possible mediating factor and benefit of yoga practice [8,32]. Field [8] suggest yoga stimulates the vagal nerve that in turn reduces cortisol, the detriment of natural killers (NK) cells in the human body. This hypothesis was tested in women with breast cancer [33]. Results indicate that both lymphocytes and NK cells were increased following treatment and authors suggest the same effect may be triggered by yoga practice. Kulkarni et al. [32] propose further investigation of the molecular action on cellular, neuro-humoral and immune systems to reverse stress following yoga intervention.

### Nerve conduction

For pain reduction, improved nerve conduction through 'Gate theory stimulation' and enhanced deep sleep to decrease 'substance P' as indicated through massage therapy may also demonstrate key benefits of yoga therapy [8], though empirical evidence is speculative.

### Bioelectromagnetism

Various health effects and biological interactions are being explored through analysis of electrical and magnetic currents within our internal,

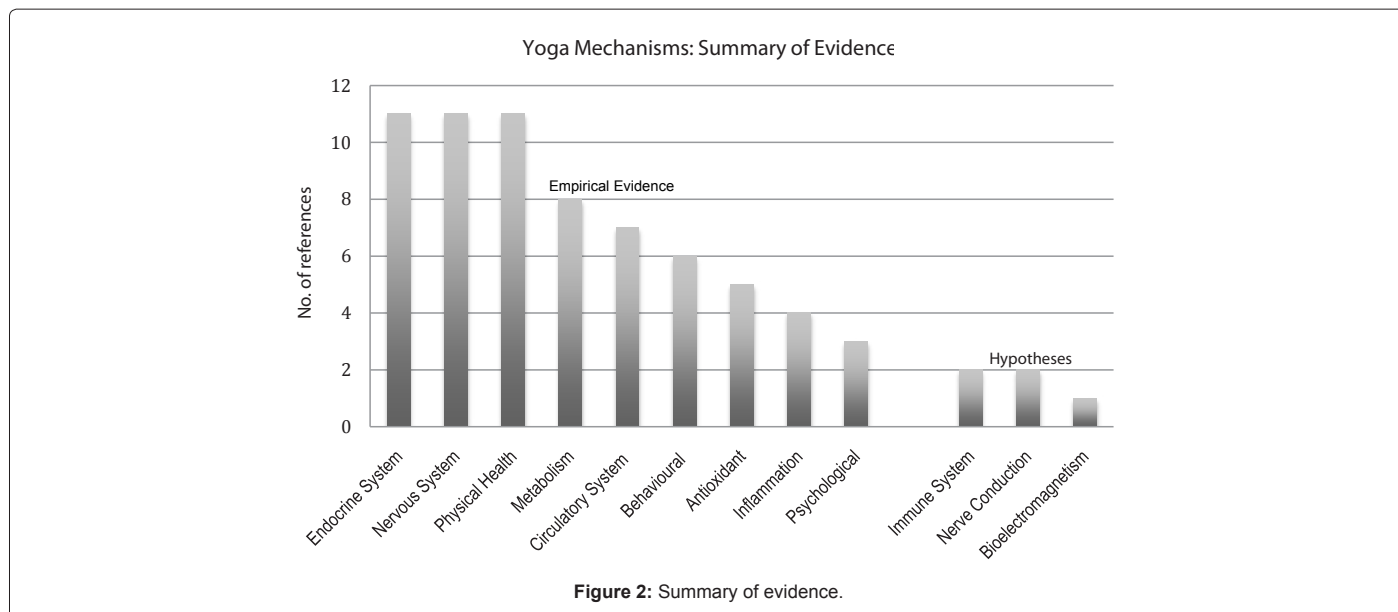


Figure 2: Summary of evidence.

cellular structures and external, environmental surroundings (i.e., low-frequency magnetic fields) [34]. As an effective agent to optimize health, delay age and treat various chronic illnesses, yoga’s pranayamic breathing and meditation may positively influence the transduction pathways, including bioelectromagnetism [35]. Empirical evidence to support this theory is not currently available.

## Discussion

There are several published theories and hypotheses for yoga’s effect on health outcomes in healthcare databases. Some of these theories seek to inform biomedical perspectives including neurological and biochemical underpinnings, while some theories compare yoga to massage, or explore alternative concepts such as bioelectromagnetism. Consensus on the biological plausibility or causal pathways of how yoga might work is not indicated in this review. The evidence to support current hypotheses is relatively weak; though 2000 yoga articles are published online, only 18 appear to be relevant to this research question and inclusion criteria. As a complementary therapy, yoga is becoming popular in both research and the wider community and it is important to address the fundamental questions regarding yoga’s impact on health outcomes. That is, not only does it work but if it does, how does it work?

Yoga as a complex intervention includes components with varying degrees of physical movement, mind-body exercises and in-depth philosophical teachings. Even though yoga literature emphasizes the psychological aspects of practice, current evidence focuses on conventional underlying effects of disease including hormone regulation and metabolism. Perhaps empirical study from new or integrated perspectives could include changes in behaviour or philosophical beliefs to increase the understanding and breadth of yoga as a health intervention. Some preliminary analysis of multiple yoga effects are offered in review papers [12,14], and will be helpful in evolving the discussion for causal pathways in disease-specific outcomes. A component-outcome analysis may also assist in improving evidence and dialogue.

## Limitations of this review

The content of this review is largely limited by the quality and availability of publications in online health databases from three countries, the Netherlands (Scopus), United Kingdom (Cochrane Collaboration) and United States (PubMed). An in-depth search that includes other sources of information may yield different results. This search is current as of December 2012 and due to the pace of new research in this field, may be out of date by the time of publication. Still, the framework and rapid search offers an important structure to advance the quality and knowledge base for underlying mechanisms in yoga.

The author chooses to include clinical trials and reviews to increase the pool of evidence though some low quality studies did not include adequate randomization may expose results to bias or confounding variables. As the purpose of this review is to summarize the potential underlying mechanisms of yoga therapy for health benefit, no conclusions should be drawn regarding the accuracy of hypotheses or efficacy of treatment for outcome effects.

## Recommendations for future research

Previous authors state that immune function is underrepresented in yoga research [8] and these findings agree that immunology is a potential area for future consideration. In addition, oxidative stress, effects of behavioural, social and psychological experiences of yoga need to be better understood from a western medical point of view. The internal and external validity of future studies could be improved to address current worries of bias, limited generalizability and exposure to confounding variables. These methodological considerations should include the implementation of high-quality randomized controlled trials that measure disease-specific health outcomes, the use of well-defined characteristics of intervention and parallel testing of hypothetical underlying effects with components and specific outcome measures.

## Conclusion

The effects of yoga on the endocrine system, nervous system, and physical health are documented with high frequency in the literature.

The strongest empirical evidence suggests yoga's capacity to regulate hormones is a factor in providing health benefit, with a decrease of cortisol and increase of serotonin and melatonin levels following regular practice. Psychological, behavioural, religious or kinaesthetic effects of yoga seem deemphasized in the evidence. Emerging theories that warrant further investigation include biomarkers of immune function, oxidative stress and evidence for facilitating nerve conduction to relieve pain and stress. The extensive and varied components of yoga intervention (asana, pranayama, dhyana, philosophical teaching) indicate yoga is a complex intervention, therefore, to improve the clinical understanding of how yoga might work as a whole, empirical investigation into the components of yoga and testing of their specific outcomes is prospect for future study.

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