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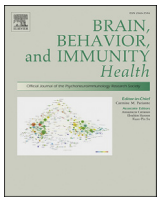

The role of yoga in inflammatory markers

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ABSTRACT

Yoga is an ancient system for integrating the mind, body, and spirit. In the *hatha* yoga *ashtanga* tradition (the eight limb Patanjali Yoga), three of the limbs are meditation, breathwork (*pranayama*) and physical postures (*asana)*, which are widely practised in yoga classes. The benefits of yoga for mental and physical health are rooted in the practice's origins: in yoga, stress is said to be the root of all diseases.

The established fields of psychoneuroimmunology and immunopsychiatry study the interplay between the immune system and mood or mental states. This mini-review has shifted the emphasis from research that focuses on yoga's benefits for stress, the most commonly studied outcome of yoga research, to a summary of the research on the effects of yoga practices on the immune system. The current literature bears strong evidence for the benefits of yoga on the levels of circulating cortisol and classical inflammatory markers, such as C-reactive protein (CRP) and cytokines such as interleukin-1 beta (IL-1β), interleukin 6 (IL-6), tumour necrosis factor-alpha (TNF-α) and interferon-gamma (INF-γ). The evidence for other less studied markers, telomerase activity, β-endorphins, Immunoglobulin A (IgA) and brain-derived neurotrophic factor (BDNF) is also growing. This mini-review centres around the interplay between yoga and these markers in stress management and depression, vascular and immune function in the older population, cardiovascular and metabolic diseases, auto-immune diseases, breast cancer and pregnancy.

Overall, the literature examined reveals the novelty of this field of research and sheds light on methodological challenges; however, it uncovers the potential for yoga to be used as adjuvant therapy in conditions with an inflammatory component.

1. Introduction

Research on the health benefits of yoga is a relatively recent topic: the first paper dedicated to this was published in 1978 (Tandon, 1978). Yoga is an ancient mind-body practice that originated in India around 5000 BCE. The word "yoga", in the classical Indian language Sanskrit, means "to yoke" or "to unite", hence its purpose of uniting mind, body and spirit (Feuerstein, 2011). The holistic approach of yoga encompasses the promotion of mental and physical health through lifestyle guidelines (Basavaraddi, 2509). Modern western yoga, for the most part, falls under the *hatha* yoga *ashtanga* (eight limbs) tradition, in which, the physical postures (*asana*), breathwork (*pranayama*) and meditation (*dhyana)* are three of the eight limbs (Chapman and Bredin, 2010). Due to this disproportional focus on the physical component of yoga (*asana)* in yoga research, this mini-review reflects this trend, selecting studies focused on the physical practice of yoga and its effects on classical immune markers.

Before it was distributed globally as a physical exercise system, yoga was intended as a holistic healing system, under clear instructions and guidelines. This healing system is rooted in the belief that a practitioner's mental state is the key to the healing process (Desikachar et al., 2008). Current medical knowledge also recognises the role of stress on the development of psychiatric conditions and its interplay with the immune system; specifically, the field of psychoneuroimmunology, or, taking it a step further, immunopsychiatry, which, reversely, recognises the role of the immune system in modulating behaviour and emotions (Pariante, 2015).

Acute and chronic stress, through mainly the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system, play a crucial role in immune system dysregulation and psychiatric disorders, as the last few decades of psychiatric research have unveiled (Vinkers et al., 2021; Belvederi Murri et al., 2014; Turner-Cobb, 2005; Tsigos and Chrousos, 1994). Chronically high levels of cortisol, the "stress hormone", can induce the production of inflammatory cytokines, leading to the suppression of homeostatic cellular and humoral functions. High levels of cortisol have been linked to Parkinson's disease (Soares et al., 2019), Alzheimer's disease (Umegaki et al., 2000), psoriasis (Evers et al.,

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2010), and cardiovascular disease (Manenschijn et al., 2013), among others. Recently, high levels of cortisol have also been identified as biomarkers in psychiatric diseases such as depression (Pariante, 2009, 2017; Jia et al., 2019; Burke et al., 2005), psychosis (Mondelli et al., 2010), bipolar disorder (Gallagher et al., 2007) and schizophrenia (Walder et al., 2000).

Similarly, inflammatory cytokines such as interleukin-6 (IL-6) and interleukin-1 beta (IL-1β), as well as tumour necrosis factor-alpha (TNF-α) and C-reactive protein (CRP) play a central role in conditions such as arthritis, cardiovascular disease, rheumatoid arthritis, Alzheimer's disease, ageing-related conditions, and of course, mood disorders (Kiecolt-Glaser et al., 2002; Raison et al., 2006; Pitharouli et al., 2020).

Mind-body practices have been shown to induce positive effects on stress perception (Wolever et al., 2012; Dusek and Benson, 2009; GRD et al., 2002) and the immune system (Morgan et al., 2014; Oh et al., 2020; Jones, 2001; Bower and Irwin, 2016). Yoga gained popularity in recent decades in medical research, with the building evidence of the practice's immune-boosting benefits, despite methodological limitations in published studies. This mini-review has explored the benefits of yoga practices on classical inflammatory biomarkers in stress management and depression, cardiovascular and metabolic diseases, vascular and immune function in the older population, breast cancer and pregnancy. A selection of the most relevant findings will be discussed below, as well as the clinical implications of such findings.

2. Body

2.1. Stress management and depression

The effect of yoga on stress management in healthy individuals is the most studied field within yoga research. Yoga for mental health has also started to take space in the media (Estevao, 2020; Gray, 2021; BBC, 2021). Countless research studies have focused on the psychological effects of yoga practice, mainly in the areas of anxiety (Cramer et al., 2018; Hofmann et al., 2016; Gupta et al. et al.; D'Silva et al., 2012; Balasubramaniam et al., 2013) and depression (Cramer et al., 2013; Pilkington et al., 2005; Kinser et al., 2012; Smith et al., 2007; Chattha et al., 2008). Recently, the interplay between the immune system, stress, and mind-body practices (such as yoga) has been attracting increasing attention in research.

In a 2010 comparative randomised study, 50 novice and expert female yoga practitioners were assessed for the effects of a single yoga session on their inflammatory and endocrine functions after experiencing a set of stressors. This study found that IL-6 serum levels were 41% higher in novices, who were also 4.75 times more likely to have detectable CRP (Kiecolt-Glaser et al., 2010). Note, an increase in these markers suggest an increase in systemic inflammation. These participants underwent a *hatha* yoga session or control sessions (movement control or passive-video control), which would have dissected the concomitant effects of movement on participants' immune and endocrine systems, suggesting that the effects found were due to the *hatha* yoga session.

A non-randomised prospective study that recruited 86 participants, investigated the effects of a short-term yoga programme of 10 days on stress and inflammation. This study unveiled a significant effect on blood serum β-endorphins, IL-6, and TNF-α levels of yoga participants. While β-endorphin levels increased, IL-6 and TNF-α levels decreased from baseline to day 10, indicating a change in the participants' inflammatory milieu within 10 days of beginning the yoga practice (Yadav et al., 2012). β-endorphins are released upon HPA-axis stimulation and have inhibitory effects on the immune system, including the reduction of the production of cytokines, such as IL-6 and TNF-α, suggesting their downstream regulation. However, the study investigated the short-term effects of a holistic intervention including *asanas*, *pranayama*, stress management, lectures, group discussions and individual advice. Due to the holistic nature of this intervention, the yoga specific effect may be indissociable from the other aspects of the intervention.

A preliminary study on a longer-term yoga intervention in 60 students, examined the effects of daily yoga sessions for 12 weeks versus control sessions and then measured the stress response before an exam, the stressor in this study (Gopal et al., 2011). During the exam, the increase in cortisol and decrease in INF-α (both indicating an increase in the stress and inflammatory responses) in the yoga group was less significant than in the control group. The yoga group had significantly lower perceived stress alongside lower serum cortisol, findings expected with a more intensive regimen of yoga than the above-mentioned studies. This points to the possibility of a direct relationship between the intensity of practice and immune and psychological benefits, where the practice of yoga dampens the stress and immune responses to a stressful event.

A study on depressed individuals (n = 54 participants) analysed the effects of three interventions: yoga therapy only, yoga therapy with antidepressants, or antidepressants-only on the brain-derived neurotrophic factor (BDNF), a growth factor in the central nervous system pivotal in neuroplasticity and neuroinflammation (Calabrese et al., 2014), and on cortisol levels. In both yoga groups, there was a significant improvement in depression scores, increased BDNF levels and a reduction in serum cortisol (Naveen et al., 2016). This study is of particular interest as it has considered anti-depressant pharmacotherapy alongside the mood-improving effects of yoga practices. Another important aspect of this study is the follow-up period (3 months), which is commonly absent in studies in this field of research.

A 2021 report on a randomised clinical trial examining CRP, IL-6, and TNF- α levels after a *hatha* yoga intervention versus a health education control group in 84 depressed patients, discovered a significant reduction in serum IL-6 levels in the yoga group. However, the study found no significant effects in TNF- α or cortisol levels, which are, interestingly, regulated independently of IL-6 (Pariante, 2017; Del Giudice and Gangestad, 2018). This study focused on a 10-week bi-weekly yoga intervention, that included *pranayama*, meditation and *asana* (Nugent et al., 2021).

Telomerase is an enzyme responsible for the length of telomeres, implicated in chronic inflammation and cancer (Gallagher et al., 2007; Walder et al., 2000). A recent metanalysis has shown an association between telomere length and psychiatric disorders (Kiecolt-Glaser et al., 2002). A pilot randomised controlled trial investigated the effects of yogic meditation for caregivers with depressive symptoms and found that daily meditation for eight weeks improved their depressive scores and telomerase activity (Lavretsky et al., 2013). These improvements were statistically significant compared with the control relaxation-music group, suggesting that yogic meditation as a mindful activity, independent of its relaxation properties, may be of superior therapeutic value for the management of depressive symptoms and regulating inflammation. Although this intervention is not a strict *asana* intervention, it highlights the uniqueness of yogic practices on biological outcomes.

Yoga and meditative therapies are just as effective as standard medication for treating depression and anxiety (Cramer et al., 2013; Chen et al., 2012). A recent systematic review demonstrated that most published studies provide strong evidence that yoga interventions improve blood pressure, cortisol and cytokine levels, including IL-6, TNF-α and IL-1β (Pascoe and Bauer, 2015). This supports the high-level mechanistic hypothesis that yoga, by reducing stress and regulating

mood, can positively influence the immune response.

The studies above highlight the effects of yoga practises on IL-6, TNF-α, endorphins, and CRP levels, all of which are classic markers of inflammation. Interestingly, these studies found rapid changes in the immune system (within 10 days of the start of the practice) but also in the longer term. Cortisol was also one of the outcomes analysed in these studies, with reductions in its levels alongside a reduction in depressive scores.

Nonetheless, a subset of a controlled trial (n = 28) investigated the effects of a bi-weekly yoga intervention, lasting eight weeks, on women reporting psychological distress. The research measured the effects of the intervention on IL-6, TNF-α, CRP levels and DNA methylation of the above-mentioned genes. There was a trend of moderate between-group effect for elevated IL-6 in the yoga group, a cytokine with pleiotropic activity in inflammation and immunity. Even though the findings for IL-6, TNF- α, and CRP levels were not significant, there was a decrease in DNA methylation of the TNF region in the yoga group (Harkess et al., 2016). The authors attributed the lack of significance for IL-6, TNF- α, and CRP levels to the trial's limited statistical power.

2.2. Vascular and immune function in the older population

Studies on the benefits of yoga frequently focus on older populations (aged 55 and above). Alongside the ageing process, there are changes in the immune system, with many age-related degenerative diseases now linked to a clear immune function dysregulation. A recent study that investigated the immune function in middle-aged and older women found that cortisol concentration and secretion were lower, and testosterone secretion was higher following a yoga intervention, suggesting a reduced stress response (Secretory Immunoglobulin, 2021). Furthermore, the levels of secretory immunoglobulin A (SIgA) concentration and secretion rates were higher after yoga sessions (Eda et al., 2018), indicating a dampening effect on the immune response. SIgA levels are reduced with age (Challacombe et al., 1995) and lower levels of this immunoglobulin have been associated with increased risk of respiratory infections (Gleeson et al., 2012; Fahlman and Engels, 2005) and interestingly, psychological stress (Bosch et al., 2001; Knight and Rickard, 2001).

From an inflammatory standpoint, vascular disease is characterised, by changes in albumin and CRP levels (Abramson et al., 2002). A small study of 14 participants, that divided the group into an elderly-customised *hatha* yoga group or a control group. Results showed that a *hatha* yoga practice for 10 weeks resulted in lower levels of CRP and higher levels of albumin that, among other markers, pointed towards improvements in the systemic inflammatory status of participants (Kim and Ju, 2017). This extremely small study may be positively biased but indicates an elderly-adapted *asana* intervention as a low risk and potentially effective adjunctive lifestyle intervention for a myriad of conditions characterised by inflammatory pathways in older populations.

A randomised controlled trial subjected 38 older adults (over 55 years old) to an eight-weekly Iyengar yoga programme or usual daily routine. The yoga regimen in this study was more intensive than most, with two 90-min sessions weekly. This study failed to find a significant relationship between the intervention and salivary IgA or lysozyme outcomes, but there was a more pronounced (non-significant) difference in salivary IgA and a reduction in salivary lysozyme in the yoga group, suggesting a trend of reduction in inflammation (Vogler et al., 2011). Moreover, this study investigated the benefits of yoga practice in other aspects (well-being, muscle strength and range of motion), which yoga showed benefits for and which are important outcomes for this specific population.

2.3. Cardiovascular and metabolic diseases

Chronic heart failure, a common ailment in the western world, has a pathogenesis directly linked to immune dysfunction (Mari et al., 2002; Perticone et al., 2019; Zhang et al., 2017) and has a mortality rate at 1-year of around 25% (Taylor et al., 2019). A small clinical trial (n = 19) found that a yoga therapy treatment, twice weekly for 70min, over 8 weeks, had significantly superior outcomes in the reduction of IL-6 and CRP levels when compared with a standard medical therapy control. Elevated CRP and IL-6 levels are linked to heart failure in this population, implying that yoga could be an effective preventative lifestyle adoption (Chin et al., 2003; Harris et al., 1999). In addition, there was a trend towards improvements in perceived quality of life, indicating that yoga enhances wellbeing in this patient group (Pullen et al., 2008).

A randomised controlled study compared an intensive 6-days per week, 3-month yoga intervention against a wait-list control, in a group of adults at risk of metabolic disease (n = 48 adults) in India. The yoga intervention led to significant reductions in cholesterol, IL-6, TNF-α and CRP levels (Shete et al., 2017), indicating that an intense, short-term regimen can have clinically significant results in reducing inflammation in this population. These results, although promising, involved a very intensive intervention that is not employed in western yoga research (possibly due to low adherence by participants) and so it may not be translatable to western clinical settings.

Another intensive clinical study enrolled overweight men at risk of cardiovascular disease, into a yoga-based lifestyle intervention. Following the 10-day intervention that included *asana* and *pranayama,* participants experienced a significant reduction in body mass index, adiponectin and plasma endothelin-1 and IL-6 (Sarvottam et al., 2013), pointing towards the benefits of yoga on certain biomarkers that underpin obesity. These two studies offer a solid indication that the effects of yoga on IL-6 can be seen immediately after a 10-day intervention and may be sustained after three months of continuous practice.

However, a randomised controlled study tested whether 12-weekly yoga classes: with an instructor, yoga classes at home or usual care, would have an impact on inflammatory biomarkers of metabolic risk factors on participants with hypertension (n = 83) (Wolff et al., 2015). The yoga interventions did not result in significant effects on the inflammatory biomarkers studied, which included CRP and IL-6, biomarkers that are reduced following yoga interventions, as per the studies above.

2.4. Auto-immune diseases

The effect of yoga on rheumatoid arthritis was explored in a randomised study that recruited 72 participants (Gautam et al., 2019). Participants were on routine disease-modifying anti-rheumatic drugs (standard therapy) and yoga, or just standard therapy. The yoga group received an intense intervention of 120 min per day for 5 days a week, for a total of 8 weeks. The yoga group had a significant decrease in CRP, IL-6, and TNF-α, as well as an increase in telomerase activity, adding to the body of evidence that yoga is beneficial in auto-immune diseases. Another randomised controlled study on the same patient group recruited 80 participants and allocated them to either a 6-day a week, 1.5 h per day, 7-week yoga intervention or a wait-list control. Yoga significantly reduced CRP in the yoga group, among other outcomes explored in this study (Singh et al., 2011). A less intense yoga regimen was employed in a small, randomised study with 16 participants with rheumatoid arthritis (Bosch et al., 2009). The yoga group performed three 75-min yoga classes per week and the control group was placed on a waiting list. The yoga intervention yielded positive outcomes for participants but

there were no significant changes in awakening or diurnal cortisol. This study may have been underpowered, but it is worth considering that there may not be significant effects due to the less intensive regiment of yoga practice in comparison to the study above.

A study on inflammatory bowel disease recruited 100 participants for a randomised clinical trial. Participants were assigned to either a yoga intervention that included 8 weeks of *asana*, *pranayama*, and meditation or standard medical therapy alone (Sharma et al., 2015). While other parameters studied (anxiety, stiffness, and pain) improved, there were no significant differences between groups in inflammatory markers. Overall, the limited evidence on yoga for auto-immune diseases is not conclusive, with contradictive evidence, and further studies into the biological outcomes of yoga in auto-immunity are necessary.

2.5. Breast cancer

Yoga has long been prescribed to cancer patients as a complementary therapy for stress and pain management because of its safety during chemotherapy and radiotherapy. In recent years, the focus of yoga's benefits in this diverse population has shifted from wellbeing to research on its effects on the immune system. A large randomised clinical trial that recruited 200 women, investigated the impact of yoga on inflammation, mood, and fatigue in cancer breast survivors. The control group was offered the yoga intervention later, as a wait-list control. The yoga group had higher vitality while having lower levels of IL-6, TNF-α, and IL-1 β. Lower levels of IL-6 and IL-1β were consistently found at follow-up, three months after the end of the treatment in the yoga group (Kiecolt-Glaser et al., 2014), indicating a long-term effect on the above-mentioned inflammatory markers. This intervention was done twice weekly, for 12 weeks, and provides an insight into the effects of a longer and more intensive intervention schedule than other interventions reported in this mini-review (Yadav et al., 2012; Kiecolt-Glaser et al., 2014).

Another study that focused on mood and immune outcomes in 98 breast cancer patients awaiting surgery (the additional stressor in this study), found that a yoga intervention resulted in decreased anxiety and depression scores, and increased quality of life following surgery (Rao et al., 2008). The yoga intervention consisted of *pranayama* and yogic relaxation techniques. The control comparator was supportive therapy and exercise rehabilitation, controlling for the emotional therapy and physical exercise components of yoga. Results also revealed lower blood levels of CD56 and IgA in the yoga group following surgery. CD56 is a marker of natural killer and other immune cells including T cells, and alterations in CD56 levels are associated with infectious and autoimmune diseases, and malignant tumours (Van Acker et al., 2017). In breast cancer, IgA is directly associated with tumour load (Ahmad et al., 2002) and so it can be used as an indicator of disease severity. Thus, lower blood levels of CD56 after yoga may indicate a beneficial outcome in disease severity or at least the immune status of yoga participants.

Another controlled clinical trial on 75 patients with early-stage breast cancer, looked at the effects of a yoga mindfulness-based stress reduction (MBSR) intervention versus a control group that received the study assessments only on immune function and quality of life. MBSR was delivered for 2.5 h per week, for 8 weeks, and it included yogic techniques such as breath awareness exercises, meditation, and mindful yoga (Witek-Janusek et al., 2008). Women enrolled in the intervention had lower cortisol levels, higher quality of life scores and increased coping effectiveness following the sessions. Over time, the women in the MBSR group also had lower interleukin 4 (IL-4) and IL-6 levels. These results from a larger controlled trial, highlight the potential of yoga-based interventions for immunity outcomes in breast cancer patients in addition to the known benefits for emotional wellbeing.

Despite these promising findings, another randomised controlled trial found no change in CRP, IL-1, IL-6 or cortisol levels in breast cancer patients undergoing a 12-week restorative Iyengar yoga intervention (Bower et al., 2014). This small study (n = 16 yoga, n = 15 health education control) found significant effects in other markers that have not been explored in this mini-review: reduced activity of the pro-inflammatory transcription factor nuclear factor kappa B, increased activity of the anti-inflammatory glucocorticoid receptor and reduced activity of cAMP response element-binding protein family transcription factors. The control group had increased soluble TNF receptor type II and IL-1 receptor levels.

Another marginally larger randomised study (n = 20), where participants were randomised to 3 h of yoga per week comprehensive exercise or comparison exercise for six months, found no significant effects on IL-6, IL-8, TNFα, or CRP in any of the groups (Long Parma et al., 2015). The study did find improvements in body composition (lean muscle mass) in the yoga group and authors suggested that a larger study, sufficiently powered, would be necessary to determine the effect of yoga interventions on inflammatory markers in this population of interest; larger studies have been reported above in this section.

2.6. Pregnancy

Prenatal yoga is ubiquitous in the western world as an adjuvant for mothers in the management of pregnancy stress and preparation for birth. Prenatal yoga classes are modified to adapt to a pregnant body and have a higher focus on relaxation techniques and breathing exercises than other *asana*-based practices. Despite a wealth of studies on the effects of yoga on prenatal stress, there is a paucity of studies done on pregnant women with an emphasis on immunity. A randomised controlled trial that recruited 94 healthy pregnant women, compared 20 weeks of two weekly 70-min yoga sessions versus routine prenatal care for stress and immune function. Results showed that the intervention reduced cortisol and enhanced IgA during pregnancy, indicating a dampening of the inflammatory response. The higher levels of salivary IgA were present long term in the intervention group that also had better birth outcomes than the control group, including infant birth weight, the most reported birth outcome (Chen et al., 2017). Given the promising results of this small-scale study, further research is warranted on the benefits of yoga on the immune milieu of pregnant women and their foetuses.

3. Conclusion

Overall, there is a growing body of evidence on the effects of yoga practices on the modulation of inflammatory markers, namely IL-1β, IL-6, TNF-α, INF-γ, CRP and hormones such as cortisol. When the effect sizes of the studies investigating these parameters are considered, the most conclusive data points towards beneficial effects for IL-1β and IL-6 levels. These two markers are particularly researched in auto-immune diseases such as rheumatoid arthritis and diabetes (Dinarello, 2011; Ren and Torres, 2009). IL-6 has also been implicated in diabetes, as well as in cancer, obesity and cardiovascular disease (Hunter and Jones, 2015), in addition to the scope explored in this mini-review. The level decreases in CRP that the studies in this review found are of extreme importance, as CRP is a well-researched marker for systemic inflammation, in conditions ranging from chronic obstructive pulmonary disease (Gan et al., 2004) to obesity (Visser et al., 2001), cancer (Køstner et al., 2016) and depression (Felger et al., 2020), among others. Hence, IL-1β, IL-6 and CRP could be used in future studies as some of the standard inflammatory markers to be explored in yoga interventions, allowing for a direct comparison between studies.

There are several limitations in this field of research that are highlighted in the literature discussed in this review. Mainly, there is great heterogeneity in the style of yoga used for the interventions (whether just meditation, just poses from different traditions or a combination of these with *pranayama* and relaxation techniques) and some studies lack detail in the yoga intervention delivered, adding an extra layer of complexity when discussing different studies. Another limitation of the studies found is the variety of the dosing regimens, which ranged from a single session to over 12 weeks of daily yoga sessions. Additionally, the relatively short follow-up periods result in a near absence of data on long-term effects of yoga interventions in inflammatory markers, considering the very plausible possibility that practitioners may continue their practice after the study intervention is concluded. Methodologically, there are limitations in study design as most studies are pilot single-arm studies, lacking the rigorous methodology of randomised controlled studies. Furthermore, limitations in biomarker analysis must be taken into consideration; especially the levels of salivary cortisol, the predominant collection route for cortisol, which is influenced by medications (including antidepressants), caffeine, smoking, the presence of blood in the saliva and eating and drinking before sample collection. The collection of samples by the study participant without trained research supervision is another limitation in cortisol and other measures (Pascoe and Bauer, 2015). This mini-review focused on the most widely studied serum and salivary inflammatory markers but other research avenues, such as in pro-inflammatory gene expression and DNA methylation, could be incorporated into a full-length review of yoga and inflammatory markers (Harkess et al., 2016; Bower et al., 2014). These novel aspects may help explain the effects reported in inflammation explored in this review.

In summary, this review discussed a selection of studies that have examined the inflammatory outcomes of yoga practices on stress management and depression, vascular and immune function in older populations, cardiovascular and metabolic diseases, breast cancer and pregnancy. Future research should investigate the effects of yoga on the above inflammatory parameters in larger sample-sized randomised controlled trials and with an array of time points (including long-term follow-up), to identify optimal treatment regimens in more representative and appropriately powered samples.

Yoga as a physical and spiritual practice may be beneficial for the immunity of populations suffering from mental or physical health disorders or could be employed as a preventative intervention for at-risk groups. Yoga, because of its low risk of physical and psychological illness, could be offered to patients from diverse backgrounds and with diverse medical histories if practised safely under the supervision of a trained and certified professional.

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Declaration of competing interests

None to declare.

References

Abramson, B., Derzko, C., Lalonde, A., et al., 2002. Hormone replacement therapy and cardiovascular disease. J. Obstet. Gynaecol. Can. 24, 577–582. https://doi.org/10.1016/s1701-2163(16)31062-3.

Ahmad, S., Faruqi, N.A., Arif, S.H., et al., 2002. Serum immunoglobulin levels in neoplastic disorder of breast. J. Indian Med. Assoc. 100, 495–496.

Balasubramaniam, M., Telles, S., Doraiswamy, P.M., 2013. Yoga on our minds: a systematic review of yoga for neuropsychiatric disorders. Front. Psychiatr. 3. https://doi.org/10.3389/fpsyt.2012.00117.

Basavaraddi, I.V.. Yoga: its origin, history and development. Ministry of External Affairs. https://www.mea.gov.in/in-focus-article.htm?25096/Yoga+Its+Origin+History+and+Development.

BBC. BBC Two - Trust Me, I'm a Doctor, Mental Health Special - What's the Best Way to Beat Stress? BBC. https://www.bbc.co.uk/programmes/articles/5yzVvcPpdDXm2LC3NHD2rpf/what-s-the-best-way-to-beat-stress (accessed 16 Nov 2021).

Belvederi Murri, M., Pariante, C., Mondelli, V., et al., 2014. HPA axis and aging in depression: systematic review and meta-analysis. Psychoneuroendocrinology 41, 46–62. https://doi.org/10.1016/j.psyneuen.2013.12.004.

Bosch, J.A., Geus, EJC de, Kelder, A., et al., 2001. Differential effects of active versus passive coping on secretory immunity. Psychophysiology 38, 836–846. https://doi.org/10.1111/1469-8986.3850836.

Bosch, P.R., Traustadóttir, T., Howard, P., et al., 2009. Functional and physiological effects of yoga in women with rheumatoid arthritis: a pilot study. Alternative Ther. Health Med. 15, 24–31.

Bower, J.E., Irwin, M.R., 2016. Mind–body therapies and control of inflammatory biology: a descriptive review. Brain Behav. Immun. 51, 1–11. https://doi.org/10.1016/j.bbi.2015.06.012.

Bower, J.E., Greendale, G., Crosswell, A.D., et al., 2014. Yoga reduces inflammatory signaling in fatigued breast cancer survivors: a randomized controlled trial. Psychoneuroendocrinology 43, 20–29. https://doi.org/10.1016/j.psyneuen.2014.01.019.

Burke, H.M., Davis, M.C., Otte, C., et al., 2005. Depression and cortisol responses to psychological stress: a meta-analysis. Psychoneuroendocrinology 30, 846–856. https://doi.org/10.1016/j.psyneuen.2005.02.010.

Calabrese, F., Rossetti, A.C., Racagni, G., et al., 2014. Brain-derived neurotrophic factor: a bridge between inflammation and neuroplasticity. Front. Cell. Neurosci. 8. https://doi.org/10.3389/fncel.2014.00430.

Challacombe, S.J., Percival, R.S., Marsh, P.D., 1995. Age-related changes in immunoglobulin isotypes in whole and parotid saliva and serum in healthy individuals. Oral Microbiol. Immunol. 10, 202–207. https://doi.org/10.1111/j.1399-302x.1995.tb00143.x.

Chapman, K.L., Bredin, S.S.D., 2010. Why Yoga? An introduction to philosophy, practice, and the role of yoga in health promotion and disease prevention. Health Fit J. Can. 3, 13–21. https://doi.org/10.14288/hfjc.v3i2.54.

Chattha, R., Raghuram, N., Venkatram, P., et al., 2008. Treating the climacteric symptoms in Indian women with an integrated approach to yoga therapy: a randomized control study. Menopause 15, 862–870. https://doi.org/10.1097/gme.0b013e318167b902.

Chen, K.W., Berger, C.C., Manheimer, E., et al., 2012. Meditative therapies for reducing anxiety: a systematic review and meta-analysis of randomized controlled trials. Depress. Anxiety 29, 545–562. https://doi.org/10.1002/da.21964.

Chen, P.-J., Yang, L., Chou, C.-C., et al., 2017. Effects of prenatal yoga on women's stress and immune function across pregnancy: a randomized controlled trial. Compl. Ther. Med. 31, 109–117. https://doi.org/10.1016/j.ctim.2017.03.003.

Chin, B.S.P., Conway, D.S.G., Chung, N.A.Y., et al., 2003. Interleukin-6, tissue factor and von Willebrand factor in acute decompensated heart failure: relationship to treatment and prognosis. Blood Coagul. Fibrinolysis 14, 515–521. https://doi.org/10.1097/00001721-200309000-00001.

Cramer, H., Lauche, R., Langhorst, J., et al., 2013. Yoga for depression: a systematic review and meta-analysis. Depress. Anxiety 30, 1068–1083. https://doi.org/10.1002/da.22166.

Cramer, H., Lauche, R., Anheyer, D., et al., 2018. Yoga for anxiety: a systematic review and meta-analysis of randomized controlled trials. Depress. Anxiety 35, 830–843. https://doi.org/10.1002/da.22762.

Del Giudice, M., Gangestad, S.W., 2018. Rethinking IL-6 and CRP: why they are more than inflammatory biomarkers, and why it matters. Brain Behav. Immun. 70, 61–75. https://doi.org/10.1016/j.bbi.2018.02.013.

Desikachar, K., Bragdon, L., Bossart, C., 2008. The yoga of healing: exploring yoga's holistic model for health and well-being. Inter J. Yoga Therapy 15, 17–39. https://doi.org/10.17761/ijyt.15.1.p501l33535230737.

Dinarello, C.A., 2011. Interleukin-1 in the pathogenesis and treatment of inflammatory diseases. Blood 117, 3720–3732. https://doi.org/10.1182/blood-2010-07-273417.

Dusek, J.A., Benson, H., 2009. Mind-body medicine. Minn. Med. 92, 47–50. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2724877/. (Accessed 4 May 2021).

D'Silva, S., Poscablo, C., Habousha, R., et al., 2012. Mind-body medicine therapies for a range of depression severity: a systematic review. Psychosomatics 53, 407–423. https://doi.org/10.1016/j.psym.2012.04.006.

Eda, N., Ito, H., Shimizu, K., et al., 2018. Yoga stretching for improving salivary immune function and mental stress in middle-aged and older adults. J. Women Aging 30, 227–241. https://doi.org/10.1080/08952841.2017.1295689.

Estevao, C., 2020. Yoga philosophy and mental health: dare to go beyond the downward-facing dog. Medium. https://medium.com/inspire-the-mind/yoga-philosophy-and-mental-health-dare-to-go-beyond-the-downward-facing-dog-ca5c0c35e383. (Accessed 18 May 2021).

Evers, A.W.M., Verhoeven, E.W.M., Kraaimaat, F.W., et al., 2010. How stress gets under the skin: cortisol and stress reactivity in psoriasis. Br. J. Dermatol. 163, 986–991. https://doi.org/10.1111/j.1365-2133.2010.09984.x.

Fahlman, M.M., Engels, H.-J., 2005. Mucosal IgA and urti in American College football players: a year longitudinal study. Med. Sci. Sports Exerc. 37, 374–380. https://doi.org/10.1249/01.MSS.0000155432.67020.88.

Felger, J.C., Haroon, E., Patel, T.A., et al., 2020. What does plasma CRP tell us about peripheral and central inflammation in depression? Mol. Psychiatr. 25, 1301–1311. https://doi.org/10.1038/s41380-018-0096-3.
Feuerstein, G., 2011. The Path of Yoga: an Essential Guide to its Principles and Practices. Shambhala Publications.
Gallagher, P., Watson, S., Smith, M.S., et al., 2007. Plasma cortisol-dehydroepiandrosterone (DHEA) ratios in schizophrenia and bipolar disorder. Schizophr. Res. 90, 258–265. https://doi.org/10.1016/j.schres.2006.11.020.
Gan, W.Q., Man, S.F.P., Senthilselvan, A., et al., 2004. Association between chronic obstructive pulmonary disease and systemic inflammation: a systematic review and a meta-analysis. Thorax 59, 574–580. https://doi.org/10.1136/thx.2003.019588.
Gautam, S., Tolahunase, M., Kumar, U., et al., 2019. Impact of yoga based mind-body intervention on systemic inflammatory markers and co-morbid depression in active Rheumatoid arthritis patients: a randomized controlled trial. Restor. Neurol. Neurosci. 37, 41–59. https://doi.org/10.3233/RNN-180875.
Gleeson, M., Bishop, N., Oliveira, M., et al., 2012. Respiratory infection risk in athletes: association with antigen-stimulated IL-10 production and salivary IgA secretion. Scand. J. Med. Sci. Sports 22, 410–417. https://doi.org/10.1111/j.1600-0838.2010.01272.x.
Gopal, A., Mondal, S., Gandhi, A., et al., 2011. Effect of integrated yoga practices on immune responses in examination stress – a preliminary study. Int. J. Yoga 4, 26–32. https://doi.org/10.4103/0973-6131.78178.
Gray, C., 2021. International Day of Yoga: Yoga Mental Health Benefits. Stylist. https://www.stylist.co.uk/fitness-health/wellbeing/mental-health-yoga-benefits/400342. (Accessed 16 November 2021).
GRD, M.D., KMB, M.S., Michael Hoyt MA, C., et al., 2002. The evaluation of a mind/body intervention to reduce psychological distress and perceived stress in College students. J. Am. Coll. Health 50, 281–287. https://doi.org/10.1080/07448480209603446.
Gupta N, Khera S, Vempati RP, et al. Effect of yoga based lifestyle intervention on state and trait anxiety. Indian J. Physiol. Pharmacol.;:7.
Harkess, K.N., Ryan, J., Delfabbro, P.H., et al., 2016. Preliminary indications of the effect of a brief yoga intervention on markers of inflammation and DNA methylation in chronically stressed women. Transl. Psychiatry 6. https://doi.org/10.1038/tp.2016.234 e965–e965.
Harris, T.B., Ferrucci, L., Tracy, R.P., et al., 1999. Associations of elevated Interleukin-6 and C-Reactive protein levels with mortality in the elderly. Am. J. Med. 106, 506–512. https://doi.org/10.1016/S0002-9343(99)00066-2.
Hofmann, S.G., Andreoli, G., Carpenter, J.K., et al., 2016. Effect of Hatha yoga on anxiety: a meta-analysis. J. Evid. Base Med. 9, 116–124. https://doi.org/10.1111/jebm.12204.
Hunter, C.A., Jones, S.A., 2015. IL-6 as a keystone cytokine in health and disease. Nat. Immunol. 16, 448–457. https://doi.org/10.1038/ni.3153.
Jia, Y., Liu, L., Sheng, C., et al., 2019. Increased serum levels of cortisol and inflammatory cytokines in people with depression. J. Nerv. Ment. Dis. 207, 271–276. https://doi.org/10.1097/NMD.0000000000000957.
Jones, B.M., 2001. Changes in cytokine production in healthy subjects practicing Guolin Qigong : a pilot study. BMC Compl. Alternative Med. 1, 8. https://doi.org/10.1186/1472-6882-1-8.
Kiecolt-Glaser, J.K., McGuire, L., Robles, T.F., et al., 2002. Emotions, morbidity, and mortality: new perspectives from psychoneuroimmunology. Annu. Rev. Psychol. 53, 83–107. https://doi.org/10.1146/annurev.psych.53.100901.135217.
Kiecolt-Glaser, J.K., Christian, L., Preston, H., et al., 2010. Stress, inflammation, and yoga practice. Psychosom. Med. 72, 113. https://doi.org/10.1097/PSY.0b013e3181cb9377.
Kiecolt-Glaser, J.K., Bennett, J.M., Andridge, R., et al., 2014. Yoga's impact on inflammation, mood, and fatigue in breast cancer survivors: a randomized controlled trial. J. Clin. Oncol. 32, 1040–1049. https://doi.org/10.1200/JCO.2013.51.8860.
Kim, S., Ju, S., 2017. Elderly-customized hatha yoga effects on the vascular inflammation factors of elderly women. J. Phys. Ther. Sci. 29, 1708–1711. https://doi.org/10.1589/jpts.29.1708.
Kinser, P.A., Goehler, L.E., Taylor, A.G., 2012. How might yoga help depression? A neurobiological perspective. Explore 8, 118–126. https://doi.org/10.1016/j.explore.2011.12.005.
Knight, W.E.J., Rickard, N.S., 2001. Relaxing music prevents stress-induced increases in subjective anxiety, systolic blood pressure, and heart rate in healthy males and females. J. Music Ther. 38, 254–272. https://doi.org/10.1093/jmt/38.4.254.
Køstner, A.H., Kersten, C., Löwenmark, T., et al., 2016. The prognostic role of systemic inflammation in patients undergoing resection of colorectal liver metastases: C-reactive protein (CRP) is a strong negative prognostic biomarker. J. Surg. Oncol. 114, 895–899. https://doi.org/10.1002/jso.24415.
Lavretsky, H., Epel, E.S., Siddarth, P., et al., 2013. A pilot study of yogic meditation for family dementia caregivers with depressive symptoms: effects on mental health, cognition, and telomerase activity. Int. J. Geriatr. Psychiatr. 28, 57–65. https://doi.org/10.1002/gps.3790.
Long Parma, D., Hughes, D.C., Ghosh, S., et al., 2015. Effects of six months of Yoga on inflammatory serum markers prognostic of recurrence risk in breast cancer survivors. SpringerPlus 4, 143. https://doi.org/10.1186/s40064-015-0912-z.
Manenschijn, L., Schaap, L., van Schoor, N.M., et al., 2013. High long-term cortisol levels, measured in scalp hair, are associated with a history of cardiovascular disease. J. Clin. Endocrinol. Metabol. 98, 2078–2083. https://doi.org/10.1210/jc.2012-3663.
Mari, D., Di Berardino, F., Cugno, M., 2002. Chronic heart failure and the immune system. Clin. Rev. Allergy Immunol. 23, 325–340. https://doi.org/10.1385/CRIAI:23:3:325.
Mondelli, V., Pariante, C.M., Navari, S., et al., 2010. Higher cortisol levels are associated with smaller left hippocampal volume in first-episode psychosis. Schizophr. Res. 119, 75–78. https://doi.org/10.1016/j.schres.2009.12.021.
Morgan, N., Irwin, M.R., Chung, M., et al., 2014. The effects of mind-body therapies on the immune system: meta-analysis. PLoS One 9, e100903. https://doi.org/10.1371/journal.pone.0100903.
Naveen, G.H., Varambally, S., Thirthalli, J., et al., 2016. Serum cortisol and BDNF in patients with major depression-effect of yoga. Int. Rev. Psychiatr. 28, 273–278. https://doi.org/10.1080/09540261.2016.1175419.
Nugent, N.R., Brick, L., Armey, M.F., et al., 2021. Benefits of yoga on IL-6: findings from a randomized controlled trial of yoga for depression. Behav. Med. 47, 21–30. https://doi.org/10.1080/08964289.2019.1604489.
Oh, B., Bae, K., Lamoury, G., et al., 2020. The effects of tai chi and qigong on immune responses: a systematic review and meta-analysis. Medicine 7, 39. https://doi.org/10.3390/medicines7070039.
Pariante, C.M., 2009. Risk factors for development of depression and psychosis. Ann. N. Y. Acad. Sci. 1179, 144–152. https://doi.org/10.1111/j.1749-6632.2009.04978.x.
Pariante, C.M., 2015. Psychoneuroimmunology or immunopsychiatry? Lancet Psychiatr. 2, 197–199. https://doi.org/10.1016/S2215-0366(15)00042-5.
Pariante, C.M., 2017. Why are depressed patients inflamed? A reflection on 20 years of research on depression, glucocorticoid resistance and inflammation. Eur. Neuropsychopharmacol 27, 554–559. https://doi.org/10.1016/j.euroneuro.2017.04.001.
Pascoe, M.C., Bauer, I.E., 2015. A systematic review of randomised control trials on the effects of yoga on stress measures and mood. J. Psychiatr. Res. 68, 270–282. https://doi.org/10.1016/j.jpsychires.2015.07.013.
Perticone, M., Zito, R., Miceli, S., et al., 2019. Immunity, inflammation and heart failure: their role on cardiac function and iron status. Front. Immunol. 10. https://doi.org/10.3389/fimmu.2019.02315.
Pilkington, K., Kirkwood, G., Rampes, H., et al., 2005. Yoga for depression: the research evidence. J. Affect. Disord. 89, 13–24. https://doi.org/10.1016/j.jad.2005.08.013.
Pitharouli, M.C., Hagenaars, S.P., Glanville, K.P., et al., 2020. Elevated C-reactive protein in patients with depression, independent of genetic, health, and psychosocial factors: results from the UK biobank. Aust. J. Pharm. 20060947. https://doi.org/10.1176/appi.ajp.2020.20060947, 2021;:appi.ajp.
Pullen, P.R., Nagamia, S.H., Mehta, P.K., et al., 2008. Effects of yoga on inflammation and exercise capacity in patients with chronic heart failure. J. Card. Fail. 14, 407–413. https://doi.org/10.1016/j.cardfail.2007.12.007.
Raison, C.L., Capuron, L., Miller, A.H., 2006. Cytokines sing the blues: inflammation and the pathogenesis of depression. Trends Immunol. 27, 24–31. https://doi.org/10.1016/j.it.2005.11.006.
Rao, R.M., Nagendra, H.R., Raghuram, N., et al., 2008. Influence of yoga on mood states, distress, quality of life and immune outcomes in early stage breast cancer patients undergoing surgery. Int. J. Yoga 1, 11–20. https://doi.org/10.4103/0973-6131.36789.
Ren, K., Torres, R., 2009. Role of interleukin-1β during pain and inflammation. Brain Res. Rev. 60, 57–64. https://doi.org/10.1016/j.brainresrev.2008.12.020.
Sarvottam, K., Magan, D., Yadav, R.K., et al., 2013. Adiponectin, interleukin-6, and cardiovascular disease risk factors are modified by a short-term yoga-based lifestyle intervention in overweight and obese men. J. Alternative Compl. Med. 19, 397–402. https://doi.org/10.1089/acm.2012.0086.
Secretory Immunoglobulin - an Overview | ScienceDirect Topics. https://www.sciencedirect.com/topics/neuroscience/secretory-immunoglobulin (accessed 6 May 2021).
Sharma, P., Poojary, G., Dwivedi, S.N., et al., 2015. Effect of yoga-based intervention in patients with inflammatory bowel disease. Inter J. Yoga Therapy 25, 101–112. https://doi.org/10.17761/1531-2054-25.1.101.
Shete, S.U., Verma, A., Kulkarni, D.D., et al., 2017. Effect of yoga training on inflammatory cytokines and C-reactive protein in employees of small-scale industries. J. Educ. Health Promot. 6. https://doi.org/10.4103/jehp.jehp_65_17.
Singh, V.K., Bhandari, R.B., Rana, B.B., 2011. Effect of yogic package on rheumatoid arthritis. Indian J. Physiol. Pharmacol. 55, 329–335.
Smith, C., Hancock, H., Blake-Mortimer, J., et al., 2007. A randomised comparative trial of yoga and relaxation to reduce stress and anxiety. Compl. Ther. Med. 15, 77–83. https://doi.org/10.1016/j.ctim.2006.05.001.
Soares, N.M., Pereira, G.M., Altmann, V., et al., 2019. Cortisol levels, motor, cognitive and behavioral symptoms in Parkinson's disease: a systematic review. J. Neural. Transm. 126, 219–232. https://doi.org/10.1007/s00702-018-1947-4.
Tandon, M.K., 1978. Adjunct treatment with yoga in chronic severe airways obstruction. Thorax 33, 514–517. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC470924/. (Accessed 4 May 2021).
Taylor, C.J., Ordóñez-Mena, J.M., Roalfe, A.K., et al., 2019. Trends in survival after a diagnosis of heart failure in the United Kingdom 2000-2017: population based cohort study. BMJ 364, l223. https://doi.org/10.1136/bmj.l223.
Tsigos, C., Chrousos, G.P., 1994. Physiology of the hypothalamic-pituitary-adrenal Axis in health and dysregulation in psychiatric and autoimmune disorders. Endocrinol Metab. Clin. N. Am. 23, 451–466. https://doi.org/10.1016/S0889-8529(18)30078-1.

Turner-Cobb, J.M., 2005. Psychological and stress hormone correlates in early life: a key to HPA-axis dysregulation and normalisation. Stress 8, 47–57. https://doi.org/10.1080/10253890500095200.

Umegaki, H., Ikari, H., Nakahata, H., et al., 2000. Plasma cortisol levels in elderly female subjects with Alzheimer's disease: a cross-sectional and longitudinal study. Brain Res. 881, 241–243. https://doi.org/10.1016/S0006-8993(00)02847-X.

Van Acker, H.H., Capsomidis, A., Smits, E.L., et al., 2017. CD56 in the immune system: more than a marker for cytotoxicity? Front. Immunol. 8. https://doi.org/10.3389/fimmu.2017.00892.

Vinkers, C.H., Kuzminskaite, E., Lamers, F., et al., 2021. An integrated approach to understand biological stress system dysregulation across depressive and anxiety disorders. J. Affect. Disord. 283, 139–146. https://doi.org/10.1016/j.jad.2021.01.051.

Visser, M., Bouter, L.M., McQuillan, G.M., et al., 2001. Low-grade systemic inflammation in overweight children. Pediatrics 107. https://doi.org/10.1542/peds.107.1.e13 e13–e13.

Vogler, J., O'Hara, L., Gregg, J., et al., 2011. The impact of a short-term iyengar yoga program on the health and well-being of physically inactive older adults. Inter J. Yoga Therapy 21, 61–72. https://doi.org/10.17761/ijyt.21.1.e15852u665l710r1.

Walder, D.J., Walker, E.F., Lewine, R.J., 2000. Cognitive functioning, cortisol release, and symptom severity in patients with schizophrenia. Biol. Psychiatr. 48, 1121–1132. https://doi.org/10.1016/S0006-3223(00)01052-0.

Witek-Janusek, L., Albuquerque, K., Chroniak, K.R., et al., 2008. Effect of mindfulness based stress reduction on immune function, quality of life and coping in women newly diagnosed with early stage breast cancer. Brain Behav. Immun. 22, 969–981. https://doi.org/10.1016/j.bbi.2008.01.012.

Wolever, R.Q., Bobinet, K.J., McCabe, K., et al., 2012. Effective and viable mind-body stress reduction in the workplace: a randomized controlled trial. J. Occup. Health Psychol. 17, 246–258. https://doi.org/10.1037/a0027278.

Wolff, M., Memon, A.A., Chalmers, J.P., et al., 2015. Yoga's effect on inflammatory biomarkers and metabolic risk factors in a high risk population - a controlled trial in primary care. BMC Cardiovasc. Disord. 15, 91. https://doi.org/10.1186/s12872-015-0086-1.

Yadav, R.K., Magan, D., Mehta, N., et al., 2012. Efficacy of a short-term yoga-based lifestyle intervention in reducing stress and inflammation: preliminary results. J. Alternative Compl. Med. 18, 662–667. https://doi.org/10.1089/acm.2011.0265.

Zhang, Y., Bauersachs, J., Langer, H.F., 2017. Immune mechanisms in heart failure. Eur. J. Heart Fail. 19, 1379–1389. https://doi.org/10.1002/ejhf.942.

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