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Neuroendocrine and Inflammatory Effects of Mind-Body Interventions in Healthcare Workers: A Comprehensive Review

Rose Mary Jacob Vatakencherry[1]*, Sudheeran Kannoth[2], Anand Kumar[2], Shine Sadasivan[3], Rehana C. Mukundan[4], Annamma Mathai[5], Madusudhanan M.K.[6]

[1]Department of Physiology, Amrita School of Medicine, Amrita Institute of Medical Sciences, Amrita Vishwa Vidyapeetham, AIMS Health Sciences Campus, AIMS Ponekkara P.O., Kochi, Kerala 682041, India.
[2]Department of Neurology, Amrita School of Medicine, Amrita Institute of Medical Sciences, Amrita Vishwa Vidyapeetham, AIMS Health Sciences Campus, AIMS Ponekkara P.O., Kochi, Kerala 682041, India.
[3]Department of Gastroenterology, Amrita School of Medicine, Amrita Institute of Medical Sciences, Amrita Vishwa Vidyapeetham, AIMS Health Sciences Campus, AIMS Ponekkara P.O., Kochi, Kerala 682041, India.
[4]Patient Services, Amrita School of Medicine, Amrita Institute of Medical Sciences, Amrita Vishwa Vidyapeetham, AIMS Health Sciences Campus, AIMS Ponekkara P.O., Kochi, Kerala 682041, India.
[5]Department of Neuroimmunology, Amrita School of Medicine, Amrita Institute of Medical Sciences, Amrita Vishwa Vidyapeetham, AIMS Health Sciences Campus, AIMS Ponekkara P.O., Kochi, Kerala 682041, India.
[6]University of California San Francisco Medical Center, San Francisco, California 94131, USA.
Author positions: Rose Mary Jacob Vatakencherry, Associate Professor; Sudheeran Kannoth, Associate Professor; Anand Kumar, Professor; Shine Sadasivan, Professor and Head; Rehana C. Mukundan, General Manager and Administrator, Patient Services; Annamma Mathai, Professor; Madusudhanan M.K., Surgical Neurophysiologist.
E-mail addresses: rosemaryjacob@aims.amrita.edu; sudheerank@aims.amrita.edu; anandkumar@aims.amrita.edu; shines1560@aims.amrita.edu; drbrirehana@aims.amrita.edu; neuroimmunology@aims.amrita.edu; madhumk99@gmail.com.
*Corresponding Author: Rose Mary Jacob Vatakencherry,
Postal address: AIMS Health Sciences Campus, AIMS Ponekkara P.O., Kochi, Kerala 682041, India.
E-mail: rosemaryjacob@aims.amrita.edu

ABSTRACT: Healthcare workers are exposed to sustained occupational demands arising from caseload, working hours, emotional labour and repeated acute clinical events. Prolonged exposure of this kind may affect hypothalamic-pituitary-adrenal (HPA) axis activity, autonomic regulation and inflammatory signalling. Yoga, mindfulness, meditation and structured breathing practices are increasingly offered to hospital staff, but their effect on objective biological markers of stress remains uncertain. In the first section of this review, the body's reaction to chronic stress and the mechanisms underlying the measurement of the stress response is discussed, as well as the nature of the stressors that the health care professions may encounter and the purported mechanism by which these mind–body techniques may be beneficial. We found six studies that evaluated the practices with healthcare workers that we will discuss. Cortisol was the most frequently reported outcome, and post-intervention concentrations were generally lower in the intervention groups. The size of this reduction differed considerably between studies, and one trial reported a reduction in the cortisol awakening response, the sharp rise in cortisol that follows waking, rather than in a single cortisol value. Interleukin-6 showed little change where complete data were available, CRP and hs-CRP tended to fall, and one study reported a reduction in TNF-α. Reporting was not uniform across studies, particularly with respect to the biological matrix sampled, the time of collection and the assay used, which limits the conclusions that may be drawn. Occupational exposures such as disturbed sleep and shift duty also influence the same markers, making the specific contribution of mind-body practice difficult to determine. The evidence is therefore suggestive rather than conclusive. What is needed is standardised sampling conditions, clearer reporting of how much practice participants actually completed, and studies that assess neuroendocrine, inflammatory and autonomic systems together in the same participants.

1. INTRODUCTION

Stress is a common experience in hospital work rather than an exceptional one, and surveys across settings put the proportion of affected staff high. A meta-analysis of 13 studies including 33,062 healthcare workers reported a pooled prevalence of 23.2% for anxiety, 22.8% for depression and 38.9% for insomnia, with nurses and female staff showing higher rates than medical and male staff (Pappa et al., 2020). Among intensive care nurses, a meta-analysis of four studies covering 1,986 nurses estimated that 31% had high emotional exhaustion, 18% high depersonalisation and 46% low personal accomplishment (Ramírez-Elvira et al., 2021). In emergency departments, pooled prevalence of burnout across 29 studies and more than 16,000 healthcare workers was similarly high, and worsened during the COVID-19 pandemic (Alanazy and Alruwaili, 2023). Figures of this order, drawn from different countries and different clinical settings, indicate that occupational stress in this workforce is widespread rather than confined to particular units or periods of crisis.

Typically, it is more than one of the hospital persons that are under stress. A congested ward or out-patient service may be quite manageable in itself; but the same workman may be called on to do night duty, be on call for emergencies, and have to attend constantly to seriously ill patients and their relatives. These needs are repeated all year round in the workplace. The physiological consequences of such exposure warrant attention, since sustained stress may affect not only subjective wellbeing but also bodily function. Where the stress response is activated continuously, it may influence endocrine, neural and inflammatory regulation through the hypothalamic-pituitary-adrenal (HPA) axis, the autonomic nervous system and inflammatory pathways, which together constitute the principal effector systems of the stress response.

Cortisol values require careful interpretation. Concentrations vary across the day and rise sharply after waking, and the time of collection, night duty and sleep pattern each influence the result. Cortisol measured in serum, saliva or hair does not represent the same quantity, and these matrices are therefore not interchangeable. Dehydroepiandrosterone sulfate (DHEA-S) offers a further index of adrenal function but has been examined far less often in workplace intervention studies. Inflammatory activity is commonly assessed through interleukin-6 (IL-6), C-reactive protein (CRP) or its high-sensitivity assay (hs-CRP), and tumour necrosis factor-alpha (TNF-α). These measurement issues are considered in detail in Section 4.

Mind-body interventions are therapies that involve the interplay between mental functions, the brain and the body in order to affect physical performance and health. This group conventionally includes meditation, relaxation and breathing techniques, yoga, tai chi and qigong, hypnosis/biofeedback, and is one of the most widely used group of complementary medicines (Wahbeh et al., 2008). All of them have the aim of intentionally directing attention or moving in a body position or breathing pattern to change the physiological state. In hospital settings the practices most often adopted are yoga, mindfulness-based stress reduction (MBSR), meditation and structured breathing. They appeal to institutions in part because they do not need much in terms of equipment, can be brought in as groups and can be arranged within the facilities of the institution. These are said to relieve stress and burnout. Less clear, however, is whether there is a measurable change in the endocrinology or inflammation with that subjective improvement and the published trials are inconsistent on this.

However, research assessing the impact of stress on different jobs has tended to lump all the workers and then explore a range of health outcomes. That is good insight, but it's healthcare workers that are a special case. Their work can be very challenging, and they will often have night shifts, along with disturbed sleep and emergency situations which could impact their stress level and health indicators. We felt it was more important to examine both uniquely so we didn't end up using the research from stress in other professions and applying it to these professions. In this way it will be possible to understand the impact of stress at the staff in healthcare and how to support them.

This review brings together the physiological background, the measurement considerations and the intervention evidence bearing on this question. It discusses the role that mind-body practices may play in controlling the stress response and its inflammatory by-products, reviews the most commonly used biomarkers and the information they can and cannot provide, discusses the work-related exposures that are unique to the hospital environment, explores how mind-body practices are believed to work, and presents a series of controlled studies of mind-body practices in the healthcare worker population. Findings from wider populations are considered as context. No statistical pooling was undertaken, because the eligible studies are few and differ substantially in sampling and assay conditions.

2. LITERATURE SEARCH

To qualify for this review, studies were required to be with adults who worked in the healthcare sector and incorporated elements such as yoga, mindfulness or meditation designed to benefit the mind and body. They were also required to take into account actual bodily alterations, such as in the levels of stress hormones or inflammation. The studies we did not consider were those that described only the feelings or thoughts expressed by persons, because we were interested in the direct effects of such interventions on the body.

Through the literature search, several databases were searched in order to find relevant studies: MEDLINE/PubMed, Embase, Scopus, Web of Science Core Collection, Cochrane CENTRAL and PsycINFO. The reference lists of the studies identified were also screened for other studies of potential interest, as were relevant reviews identified during the search.

Search terms: (healthcare worker* OR health personnel OR nurse* OR physician* OR doctor* OR hospital staff) AND (yoga OR mindfulness OR meditation OR breathing OR pranayama OR relaxation OR mind-body) AND (cortisol OR DHEA OR DHEA-S OR interleukin-6 OR IL-6 OR CRP OR hs-CRP OR TNF OR inflammatory biomarker* OR heart rate variability). Further targeted search of the above-mentioned databases and reference lists of the retrieved articles were used to identify literature supporting the physiological, methodological and mechanistic parts of this review. Due to the limited number of intervention studies that met the inclusion criteria, and the variety of sampling, assay and content of intervention, these studies were not pooled and are described individually.

3. PHYSIOLOGY OF THE STRESS RESPONSE AND ITS BIOLOGICAL CONSEQUENCES

3.1 The hypothalamic–pituitary–adrenal axis

The response to a threat begins in the paraventricular nucleus of the hypothalamus, where corticotropin-releasing hormone (CRH) is secreted into the hypophyseal portal circulation. This promotes the secretion of adrenocorticotropic hormone (ACTH) from the anterior pituitary which in turn increases the production and secretion of cortisol from the adrenal cortex. Cortisol subsequently interacts with receptors for glucocorticoids and mineralocorticoids in tissues around the body to mobilise glucose, alter immune function and negatively feedback at the pituitary/hypothalamus to inhibit further release of CRH and ACTH. Under normal conditions the loop is self-limiting: the response rises, achieves its purpose and resolves.

Cortisol is not secreted at a constant rate across the day. Concentrations rise steeply during the first 30 to 45 minutes after waking and then decline progressively, reaching their lowest values around midnight. This diurnal pattern is a normal feature of adrenal function, and it is the reason a single cortisol value conveys little information unless the time of sample collection is known (Stalder et al., 2016).

3.2 Allostasis and allostatic load

Allostasis describes the physiological adjustments an organism makes in order to maintain stability through change. The cumulative cost of these adjustments, when they are called upon repeatedly or fail to resolve appropriately, is termed allostatic load. The mediators of the stress response are neither simply protective nor simply harmful: while serving an adaptive function in the short term, they exert measurable wear on cardiovascular, metabolic, immune and neural systems when sustained

(McEwen, 1998). This distinction is relevant to occupational stress, where exposure is characteristically low-grade and continuous rather than acute and discrete.

An important consequence of prolonged glucocorticoid exposure is a reduction in the sensitivity of target tissues to cortisol, described as glucocorticoid receptor resistance. Where this develops, circulating cortisol may appear normal or even reduced while its restraining influence on inflammatory signalling is diminished. This may account for the apparently paradoxical observation that chronically stressed individuals can show unremarkable cortisol concentrations alongside elevated inflammatory markers.

3.3 Autonomic contribution

The autonomic nervous system responds to stressors more rapidly than the HPA axis. Sympathetic activation results in immediate cardiovascular and metabolic changes and the withdrawal of parasympathetic activity decreases the vagal restraint usually imposed on the heart. The beat-to-beat variation in cardiac intervals, known as heart rate variability, is regarded as a non-invasive indicator of this balance, with higher vagally mediated variability taken to indicate greater capacity for autonomic regulation (Shaffer and Ginsberg, 2017). The autonomic and neuroendocrine arms of the stress response are not independent, but they are commonly assessed in isolation, which yields only a partial picture of the system.

3.4 The neuroendocrine–immune interface

Stress and inflammation are reasonably well characterised at the two extremes of exposure. Acute stressors produce transient increases in circulating inflammatory mediators, whereas chronic psychosocial stress is associated with sustained low-grade elevation of markers such as interleukin-6 (IL-6) and C-reactive protein (CRP) (Rohleder, 2014). Considerably less is understood about the transition between these states, that is, how repeated acute exposures occurring over months and years give rise to a persistent inflammatory phenotype; this has been identified as a priority for the field (Rohleder, 2019).

This uncertainty bears directly on the interpretation of intervention studies. If the inflammatory consequences of chronic occupational stress accumulate over an extended period, there is little reason to expect an eight- or twelve-week programme to reverse them within the same timeframe, even where the intervention is effective. This mismatch between the timescale on which the biology develops and the timescale on which it is measured recurs throughout the literature.

4. BIOMARKERS USED TO ASSESS CHRONIC OCCUPATIONAL STRESS

So one measurement isn't a good indicator of what the stress-response system is doing. Different markers have been used in this field, with specific interpretive requirements and the discrepancies among these constitute a significant portion of the discrepancies found in different studies.

4.1 Cortisol: matrix and timing

Cortisol may be measured in serum, saliva, urine or hair, but these do not represent equivalent measurements. Serum assays capture total cortisol, the greater part of which is bound to corticosteroid-binding globulin and albumin, whereas salivary cortisol reflects the unbound, biologically active fraction. Conditions that alter binding-protein concentrations, such as oral contraceptive use, therefore affect serum and salivary values differently. Results obtained in different matrices should not be treated as interchangeable, and the matrix used should always be stated in the report.

Hair cortisol occupies a distinct position. Rather than representing secretion at a single point in time, it provides a retrospective index of integrated cortisol output over weeks to months, and has been proposed as a means of assessing sustained rather than momentary HPA-axis activity (Steudte-Schmiedgen et al., 2016). Since the exposure of interest in occupational stress is chronic, this property is conceptually attractive, although the method remains less widely used than salivary or serum sampling.

Whatever the matrix, the time of collection is decisive. Because of the steep morning decline in cortisol, a specimen obtained at 09:00 may differ markedly from one obtained at 07:00 in a participant whose physiology has not changed at all. Fixing the collection window, and reporting it, is therefore a minimum methodological requirement.

4.2 The cortisol awakening response

The cortisol awakening response is derived from a series of saliva samples collected immediately on waking and at intervals over the following 30 to 45 minutes. It reflects the dynamic reactivity of the HPA axis and cannot be substituted by a cortisol measurement taken later in the day. It is demanding to measure, since validity depends on participants adhering closely to a timed sampling schedule in the domestic setting without direct supervision. Expert consensus guidelines set out the necessary procedures, including objective verification of awakening and sampling times (Stalder et al., 2016). A subsequent evaluation found that adherence to these recommendations in published research had improved little, particularly with regard to objective time verification, and issued revised and simplified guidance (Stalder et al., 2022). Studies reporting this outcome should therefore be read with attention to whether these procedures were followed.

4.3 DHEA-S and the cortisol:DHEA-S ratio

The adrenal cortex secretes dehydroepiandrosterone (DHEA) and its sulfated form (DHEA-S) alongside cortisol, and their actions on immune and neural tissue are broadly opposing. The cortisol:DHEA-S ratio has therefore been proposed as a measure of adrenal balance, and may be more informative than either cortisol or DHEA-S measured alone. In professional caregivers who work with chronic interpersonal stressors, indices of resilience and self-care were associated with a lower cortisol:DHEA ratio, an association driven principally by higher DHEA rather than by lower cortisol (Bürgin et al., 2020). A study measuring cortisol alone would have detected nothing. It should be emphasised, however, that DHEA-S is seldom measured in occupational intervention research, and that none of the six studies reviewed here reported DHEA-S or the cortisol:DHEA-S ratio. The evidence supporting this marker therefore comes from observational work in other occupational groups, and its inclusion is proposed here as a recommendation for future study design rather than as a finding of the present review.

4.4 Interleukin-6

The pleiotropic cytokine interleukin (IL)-6 is a key mediator of the hepatic acute-phase response, and is one of the more consistently correlated markers of chronic psychosocial stress (Rohleder, 2014). It has a short circulating half-life and shows diurnal variation, so measured values are influenced by sampling conditions. Circulating concentrations are low in healthy working populations, which places demands on assay sensitivity and means that small intervention effects may not be detectable in relatively small studies.

4.5 C-reactive protein and high-sensitivity CRP

C-reactive protein is a hepatic acute-phase reactant, produced largely under interleukin-6 stimulation, and is more stable in the circulation than the cytokines that drive its production. Conventional and high-sensitivity assays measure the same protein but are not equivalent tests, and the distinction between them is frequently overlooked. Conventional assays were developed to detect the marked elevations occurring during infection and tissue injury, whereas high-sensitivity assays were developed to quantify the considerably lower concentrations relevant to cardiovascular risk stratification. At the low end of the range, which is the range of interest in an otherwise healthy working population, results obtained by the two methods are not comparable, and values obtained with a conventional assay should not be treated as equivalent to hs-CRP measurements. The clinical utility of hs-CRP is itself debated: its epidemiological association with cardiovascular disease is well established, but whether it adds incremental predictive value beyond conventional risk factors remains unsettled (Yousuf et al., 2013). Because any acute intercurrent illness raises CRP markedly, samples with values above approximately 10 mg/L are conventionally excluded or repeated.

4.6 Tumour necrosis factor-alpha

Tumour necrosis factor-alpha (TNF-α) is an early pro-inflammatory cytokine with wide-ranging metabolic and immune actions. It circulates at low concentrations in healthy individuals and, like interleukin-6, is sensitive to the assay platform used and to sample handling. It is measured less often than IL-6 or CRP in occupational studies, and where it is reported, the number of contributing participants is usually small.

4.7 Heart rate variability

Heart rate variability provides an accessible index of autonomic regulation and is commonly included in mind-body intervention research. Its interpretation requires care. Time-domain, frequency-domain and non-linear indices are not interchangeable, and normative values depend on recording duration, participant age and sex; twenty-four-hour, short-term and ultra-short-term measurements in particular should not be compared directly (Shaffer and Ginsberg, 2017). A further consideration applies specifically to breathing-based interventions, since respiratory rate directly influences respiratory sinus arrhythmia. Where participants have been trained to breathe slowly, an apparent improvement in vagally mediated variability may partly reflect altered respiratory mechanics during the recording rather than a durable change in autonomic tone. Recording under spontaneous breathing, with respiratory rate documented, allows this distinction to be examined.

4.8 Emerging and infrequently used markers

Several other measures have been proposed. Intestinal fatty acid-binding protein and related indicators of gut-barrier integrity have a plausible mechanistic connection to chronic stress but have scarcely been examined in occupational populations, and should presently be regarded as exploratory. Salivary alpha-amylase has been used as an indirect index of sympathetic activity, and markers of oxidative stress have been included in some intervention studies. None of these is sufficiently established in healthcare-worker research to support firm conclusions at present.

4.9 Implications for study design

These considerations argue against reliance on any single marker. Cortisol describes neuroendocrine output but not its immune consequences; CRP describes the inflammatory state but not its regulation; heart rate variability describes autonomic balance but conveys no information about adrenal function. A panel combining cortisol with DHEA-S, one or two inflammatory markers measured using assays appropriate to their expected range, and standardised heart rate variability would allow a study to ask whether these systems recover in a coordinated manner. Intervention research in this population has rarely been designed in that way.

5. OCCUPATIONAL DETERMINANTS OF STRESS PHYSIOLOGY IN HEALTHCARE WORKERS

Healthcare workers are not readily available stressed adults. They are exposed to a number of variables, under their work conditions, which are carriers of the physiological systems an intervention targets, a fact that is the main reason why they should be regarded as a population in their own right.

5.1 Burnout and psychological load

This is a common problem in this field. A meta-analysis of 29 studies with over 16,000 healthcare workers indicated a high pooled prevalence of overall burnout and its three subscales of emotional exhaustion, depersonalization and reduced personal accomplishment among ED staff, and the COVID-19 pandemic had a negative impact on their levels of burnout (Alanazy and Alruwaili, 2023). Most clinical departments, with the exception of emergency medicine which is at the extreme end of the spectrum, have workload, working conditions and working hours that are similar.

5.2 Shift work and circadian disruption

Such work and night shift is not a minor part of the hospital worker's job and it disrupts the work/busyness rhythm upon which cortisol interpretation hinges. Shift work has been linked to systemic chronic inflammation, and a series of dysregulated immune responses, and circadian disruption and impaired sleep have been implicated as mechanisms (Stenger et al., 2023). A scoping review of the relationship between night shift work and markers related to oxidative stress and inflammation revealed mixed evidence but showed associated findings, as well as very few studies included both oxidative stress and circadian markers (melatonin/cortisol) along with markers of inflammatory changes (Makris et al., 2023). These findings have important implications for the design of intervention research: If an individual participant's duty roster has changed from baseline to follow-up sampling the results can no longer be attributed to the intervention.

5.3 Sleep disturbance

Shift work and sleep loss go hand in hand and have distinct inflammatory implications. Irwin et al. (2015) conducted a meta-analysis of 72 studies including more than 50,000 participants, and the findings differed according to how sleep was characterised. Sleep disturbance, meaning poor sleep quality or reported insomnia, was associated with higher levels of both C-reactive protein and interleukin-6. Long sleep duration was likewise associated with higher levels of both markers. Short sleep duration, by contrast, was associated with higher C-reactive protein but not with higher interleukin-6. Tumour necrosis factor-alpha (TNF-α) was not associated with sleep disturbance or with sleep duration of either kind. Interestingly, none of these markers were associated with experimental sleep deprivation or sleep restriction, indicating that the inflammatory effects may be due to chronic rather than acute sleep loss. Here this directly applies as it suggests that recurrent sleep disruption in shift workers can have as great an impact on inflammatory markers as one might expect from an intervention.

5.4 Implications for design and interpretation

All these exposures together suggest recording duty pattern at each sampling time in this population and also habitual sleep, and randomizing according to shift pattern if possible. Without them, an apparently null result could be because of uncontrolled occupational exposure, not an ineffective intervention, and an apparently positive, because of a favourable change of roster.

6. MIND-BODY INTERVENTIONS: PROPOSED MECHANISMS

Mind-body practices are heterogeneous, and the label describes interventions which vary widely in their physical, breathing and focus aspects. Several possible mechanistic pathways have been suggested as a way to explain how the above practices may affect the biological marker(s) discussed in this review.

6.1 Autonomic and vagal pathways

The most direct of the proposed mechanisms is autonomic. Slow, regulated breathing is understood to increase vagal outflow, and a vagal circuit has been described through which vagal activity may restrain inflammatory signalling. In this circuit, acetylcholine acting at the alpha-7 nicotinic receptor on cytokine-producing macrophages inhibits tumour necrosis factor-alpha production in the spleen. The acetylcholine is supplied by a memory-phenotype T cell population, and action potentials originating in the vagus nerve regulate these cells (Rosas-Ballina et al., 2011). This suggests a biologically plausible pathway from a breathing practice to a measurable inflammatory outcome, although plausibility of mechanism is not in itself evidence of effect in this population. It is important to note, however, that the circuit is mostly characterised in experimental models and how far it is active when a voluntary breathing practice is used in human beings is unknown.

6.2 HPA-axis regulation

A second proposed mechanism involves reduced HPA-axis drive. If a practice were to lower the frequency or intensity of stress-response activation, cortisol output might be expected to fall and glucocorticoid receptor sensitivity to improve over time, although this sequence has not been demonstrated directly in healthcare workers. Meta-analytic evidence is consistent with this proposal, though only in part: yoga asana interventions compared to an active control group were associated with lower levels of cortisol in the evening and at wake, as well as with decreases in ambulatory blood pressure (systolic only), resting heart rate, and several metabolic measures (Pascoe et al., 2017). The interventions in that analysis were heterogeneous, and the authors framed their conclusion in terms of improved regulation of the sympathetic nervous system and the HPA axis rather than a specific effect on any single marker.

6.3 Transcriptional and molecular effects

The third type of evidence relates to gene expression. A systematic review of 18 studies of mindfulness, yoga, Tai Chi, Qigong, relaxation response and breath regulation together reported a downregulation of the nuclear factor kappa B pathway which is the opposite of the transcriptional pattern induced by chronic stress; this suggests a possible reduction in the risk of disease related to inflammation (Buric et al., 2017). The authors were appropriately cautious, noting the small number of studies available and the difficulty of comparing these effects with those of exercise or nutrition. The work nonetheless helps explain why circulating markers may respond only modestly: a change in transcriptional regulation need not translate into a detectable change in plasma cytokine concentrations within an eight-week window.

6.4 Non-specific and shared components

Other common components of many interventions are also present in mind-body programmes: regular light to moderate physical activity, group contact, protected time away from clinical duties, and the expectation of benefit. These are not trivial confounders, and they form part of the argument that an active control arm is methodologically preferable to a wait-list control. In a wait-list design, the comparison group receives no intervention during the study period and is offered the programme only after the final assessment; it therefore lacks the physical activity, group contact, protected time and expectation of benefit that the intervention group receives. Any effect observed against such a control includes the contribution of these shared components as well as any specific effect of the mind-body practice itself.

7. EVIDENCE FROM CONTROLLED INTERVENTION STUDIES IN HEALTHCARE WORKERS

7.1 Characteristics of the included studies

Table 1. Characteristics of included studies.

Study	Population	Intervention	Duration	Comparator	Biomarkers	Comment
Mandal et al., 2021	Nursing staff, India	Structured yoga	12 weeks	Wait-list	Cortisol, hs-CRP	High attrition; conflicting hs-CRP values within the paper
Sharma et al., 2023	Healthcare workers/nurses, India	Common Yoga Protocol	8 weeks	Control	Cortisol, hs-CRP, IL-6, TNF-α	Complete arm-level reporting
Errazuriz et al., 2022	Non-physician health workers, Chile	MBSR	8 weeks	Stress-management/wait-list	Cortisol awakening response	Cortisol awakening response only
Balasubramanian et al., 2024	Healthcare workers, South India	Sudarshan Kriya Yoga	12 weeks	Control	Cortisol, CRP, IL-6	Complete arm-level reporting
Naveen et al., 2024	Healthcare workers on COVID-19 duty, India	Tele-yoga	8 weeks	Control	Cortisol, IL-6, TNF-α	Arm-level summary statistics incompletely reported
Panzeri et al., 2025	Healthcare professionals	MBSR	8 weeks	Control	Cortisol	Complete arm-level reporting

Abbreviations: MBSR, mindfulness-based stress reduction; CRP, C-reactive protein; hs-CRP, high-sensitivity C-reactive protein; IL-6, interleukin-6; TNF-a, tumour necrosis factor-alpha.

7.2 Cortisol and HPA-axis outcomes

Cortisol was reported in all six studies, although not in the same form. Sharma et al. (2023), Balasubramanian et al. (2024) and Panzeri et al. (2025) reported post-intervention single-point cortisol with complete data for both arms. In each of these, concentrations were lower in the intervention group at the end of the programme, but the magnitude of the difference varied considerably: the reduction reported after MBSR by Panzeri et al. (2025) was appreciably larger than the small changes described after the yoga-based programmes. Errazuriz et al. (2022) reported an approximately 23% reduction in the cortisol awakening response after MBSR. This is a dynamic measure of HPA-axis function and is not interchangeable with a single specimen obtained later in the day, so it is described separately here. Mandal et al. (2021) and Naveen et al. (2024) also measured cortisol, but high attrition in the former and incomplete arm-level statistics in the latter limit what can be drawn from them. Across these reports the biological matrix, assay platform and time of collection were either variable or incompletely stated, which restricts direct comparison between studies.

7.3 Interleukin-6

Three studies reported IL-6 (Sharma et al., 2023; Balasubramanian et al., 2024; Naveen et al., 2024). In the two that provided complete data for both arms, post-intervention values in the intervention and control groups were similar and neither study described a clear reduction. Naveen et al. (2024) reported findings in a favourable direction after tele-yoga, but the summary statistics given for each arm were not detailed enough for the size of the difference to be judged. Taken together, these reports do not indicate a consistent effect of mind-body practice on circulating IL-6 in this population.

7.4 CRP and hs-CRP

CRP or hs-CRP was reported by three studies. Sharma et al. (2023) and Balasubramanian et al. (2024) both described post-intervention values that favoured the intervention group, although the two studies differed considerably in the size of the change. Mandal et al. (2021) is difficult to interpret, because separate tables within the same publication give conflicting post-intervention hs-CRP values for the control group; the direction of the study-level result depends on which table is used, and the finding is therefore reported here without further interpretation. A further difficulty is that conventional CRP and high-sensitivity assays are both represented within this small group of studies. Since hs-CRP detects low-grade inflammation below the reliable detection limit of a routine CRP assay, results obtained by the two methods are not strictly comparable at low concentrations.

7.5 TNF-α and other inflammatory outcomes

TNF-α was reported by two studies. Sharma et al. (2023) described a moderate reduction after the yoga programme, with complete numerical data for both arms. Naveen et al. (2024) also measured TNF-α after tele-yoga, but the arm-level data were insufficient to establish the size of any change. A single adequately reported study is not a basis for concluding that mind-body interventions have a reproducible effect on TNF-α, although the observation is worth pursuing in better-reported trials. DHEA-S was not reported in any of the included studies, despite its relevance to adrenal regulation.

8. EVIDENCE FROM WIDER POPULATIONS

Because the healthcare-worker literature is small, it is useful to consider what has been found in broader samples, while recognising that findings from other populations cannot simply be transferred to hospital staff.

8.1 Meta-analytic findings on physiological outcomes

The most directly relevant synthesis compared interventions including yoga asanas, with and without mindfulness-based stress reduction, against active controls across 42 studies, and reported favourable effects on evening and waking cortisol, ambulatory systolic blood pressure, resting heart rate, high-frequency heart rate variability, fasting blood glucose, cholesterol and low-density lipoprotein (Pascoe et al., 2017). A separate systematic review and meta-analysis of yoga, meditation and pranayama examined 25 biomarkers across 44 studies; of these, only interleukin-6, cortisol and tumour necrosis factor-alpha produced statistically significant pooled changes, and the authors noted that these results carry much less certainty than individual study reports suggest, with considerable heterogeneity and publication bias observed (Shah et al., 2022).

8.2 Immune outcomes

A comprehensive review of randomised controlled trials of mindfulness meditation and immune system parameters examined circulating and stimulated inflammatory proteins, transcription factors and gene expression, immune cell counts, immune cell aging and antibody responses. It found substantial heterogeneity across studies in patient population, design and assay procedures, and concluded that possible effects on specific markers of inflammation, cell-mediated immunity and biological aging were tentative and required replication (Black and Slavich, 2016). A decade on, that assessment still describes the state of the evidence reasonably well.

8.3 Workplace-specific syntheses

Studies that look at how workplace programs affect people in occupational settings usually focus on general physical or metabolic outcomes for a mixed group of employees. Reviews of this kind have examined broad physiological or cardiometabolic outcomes across mixed employee populations (Kronenberg et al., 2025; Khanal et al., 2026). Because such syntheses aggregate groups whose baseline occupational exposures differ substantially, as discussed in Section 5, their findings are informative about workplace programmes in general but provide limited insight into effects specific to hospital staff.

8.4 What transfers and what does not

Here we've just made two important observations. First, with the direction of the effects in larger groups of people we observe some interesting patterns. For example, a few reductions in cortisol and some inflammatory markers and that's more or less what we've observed in studies of healthcare workers. That's good because it indicates there is some uniformity in the results. On the other hand, when we think about the size of these effects, we can't just assume that they'll be the same in different groups of people. This is because, the type of stress health care workers encounter such as working night shifts are very dissimilar to what individuals in the general population experience. For example, someone who practices yoga in their free time isn't dealing with the same kind of pressure as a healthcare worker who's working long hours at night.

9. DISCUSSION

The intervention studies described in Section 7 do not show a consistent biomarker response to mind-body practice in healthcare workers. Cortisol was generally lower in the intervention groups, but the size of the change varied widely between studies. IL-6 showed little evidence of change. CRP and hs-CRP moved in a favourable direction in the two studies that reported comparable CRP profiles, that is, post-intervention values with measures of dispersion given separately for each study arm. TNF-α was reduced in the one study that reported arm-level values and dispersion for this marker, which is of interest but cannot on its own establish a reproducible anti-inflammatory effect. Set against the mechanistic evidence described in Section 6, the overall picture is one of biological plausibility that the clinical data have not yet confirmed.

Cortisol is especially difficult to interpret in this setting. The value obtained from a single sample depends on when the participant woke, the time of collection, the previous night's sleep, the current duty pattern, recent food intake and any acute event occurring before sampling. For a hospital worker, several of these can change from one day to the next, which makes it hard to separate a true intervention effect from ordinary biological and pre-analytical variation. In the studies reviewed here, one MBSR trial showed a comparatively large short-term change while the yoga-based trials showed smaller or near-null effects. Three studies with broadly comparable cortisol data are not enough to determine whether that difference arose from the interventions themselves, from differences between the participants, or from the way cortisol was sampled. The cortisol awakening response was therefore considered separately from single-point cortisol, since the two reflect related but not identical aspects of HPA-axis function.

The inflammatory findings require similar caution. IL-6 showed no clear reduction in any study with complete data. The two studies providing a comparable CRP profile, with post-intervention values and dispersion reported for each arm, differed considerably from one another, and a third could not be interpreted because conflicting values appear within the same paper. With an evidence base of this size, a single inconsistent dataset materially alters the impression the literature gives, so reporting quality is not a minor issue here; it determines what can be concluded at all.

Restricting the intervention evidence to healthcare workers was intentional, for the reasons set out in Section 5. This population is physiologically distinctive: rotating shifts, night duty, disrupted sleep, emotional demands and acute patient-care stress can each alter cortisol rhythms and inflammatory activity independently of any intervention. Several of the included studies were also conducted during the COVID-19 period, which reflects a stress context that may not generalise to routine hospital work.

No particular mind-body method can be preferred on the basis of these studies. Yoga, MBSR and tele-yoga each produced favourable findings somewhere in the included trials, but no approach repeated its success reliably across biomarkers. Adherence and intervention exposure are plausible moderators, particularly in hospital settings where duty rosters limit attendance and home practice, but exposure was inconsistently reported across the included studies.

Another consideration in this field (whose scope is further limited by the biomarkers selected in that section) concerns the presence of subtle gradients in the stratigraphic control of these systems. Measurement of cortisol is an almost universal requirement and DHEA-S and integrated cortisol/DHEA-S-ratio are not normally implemented in intervention trials of healthcare workers and were not reported in any of the included studies. A defined panel comprising cortisol, DHEA-S, IL-6 and hs-CRP, together with heart rate variability recorded under standardised conditions, would be of value in future mechanistic studies. Such a panel would allow the question of whether the neuroendocrine, inflammatory and autonomic systems recover in a coordinated manner to be addressed, rather than relying on a single marker. Gut-barrier markers such as intestinal fatty acid-binding protein (I-FABP) remain exploratory in this occupational setting and have yet to be examined in healthcare-worker intervention studies.

Finally, psychological improvement and biochemical normalisation should not be treated as two readings of the same dial. A participant may report substantially reduced stress while cortisol and inflammatory markers remain unchanged, and the perceived benefit is real on its own terms. The converse also holds: an unaltered biomarker panel does not argue against a genuine improvement in wellbeing. Timing may account for part of this. Biological adjustment may lag behind psychological change, fluctuate, or appear only transiently, and a single post-intervention sample captures one point in that sequence.

9.1 Strengths and limitations

This review concentrates on objective biological outcomes, and cortisol, cytokines and acute-phase proteins are considered separately rather than combined into a single physiological category. The values reported in each study were checked against the original data tables, and where figures were incomplete, or where numbers conflicted between tables within the same publication, this was stated rather than resolved by estimation. Describing each study individually also keeps visible the differences between them, in sampling conditions as well as in the type and content of the intervention, which a single summary measure would tend to conceal.

The limitations of this review arise from two sources: the format of the review itself, and the state of the available literature. This is a narrative review. The intervention studies were identified through a database search but were not screened in duplicate against prespecified criteria, and no formal risk-of-bias instrument was applied, so the selection and appraisal of studies are less protected against reviewer judgement than in a systematic review. No quantitative synthesis was undertaken, and the direction of findings is therefore described rather than estimated; publication bias cannot be assessed. Within the studies themselves, there was considerable variation in how the interventions were delivered and, more importantly for the biological outcomes, in how samples were obtained. This applies particularly to cortisol, since specimens collected at different times of day, or in different biological matrices, may yield different values even when the participant's stress physiology has not changed. Conventional CRP and hs-CRP also appear within the same small body of evidence despite their differing analytical sensitivity at low concentrations. Incomplete and inconsistent numerical reporting restricts interpretation further. Generalisability is also limited, as several studies were conducted during the COVID-19 period, when working conditions were not typical of routine practice. Few studies followed participants long enough to establish whether biochemical changes persisted after the intervention ended, and the available literature is too small to support reliable comment on differences by profession, sex, shift pattern, sleep or baseline stress. Taken together, these limitations indicate the need for more rigorous and more systematic research in this area.

10. CONCLUSION

Controlled studies of mind-body interventions in healthcare workers are few in number and their findings are inconclusive. Cortisol concentrations tended to fall, but variability between studies was high. IL-6 showed little change, while CRP and hs-CRP moved in a favourable direction in those studies where the data were adequately reported. One study reported a reduction in tumour necrosis factor-alpha (TNF-α), a finding that requires confirmation in further investigations. These findings should not be read as evidence that mind-body practice has no biological effect. Rather, the studies conducted to date are few, their sampling methods are not sufficiently uniform, and the same markers are influenced by occupational exposures characteristic of this workforce. Larger studies are needed, with interventions described in sufficient detail to be reproduced, cortisol sampling standardised for time of collection and biological matrix, and duty pattern and sleep recorded at each assessment. It would also be preferable to assess several related physiological systems within the same participants, for example cortisol together with DHEA-S, selected inflammatory markers and heart rate variability, rather than relying on any single measure. Follow-up after supervised practice has ended is equally necessary if the persistence of any biochemical change is to be established. The mechanistic evidence reviewed here is consistent with a biological effect of these practices, but greater standardisation and a more integrated approach to measurement will be required before such an effect can be regarded as established. Only then can the potential of mind-body practices to support the health and wellbeing of healthcare workers be assessed with confidence.

Declarations

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Consent for publication: Not required.

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