

Important components of yoga practice for mediating the stress response

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Statement of originality

This is to certify that to the best of my knowledge; the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes.

I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

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Supervisor's Statement

As supervisors of Gandhar Vishwas Mandlik's doctoral work, we certify that we consider his thesis "Important components of yoga practice for mediating the stress response" sufficiently well presented to be examined and certify that it does not exceed the prescribed word limit or any extended word limit for which prior approval has been granted.

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Abstract

Introduction

Yoga, a multimodal activity, is very popular around the world as a fitness technique, it is a common and popular adjuvant treatment for lifestyle related diseases. However, having spiritual origins in India, traditionally yoga practice involves many components like pranayama (breathing techniques), meditation, chanting, relaxation and lifestyle modifications that are not always included in western practices. Yoga practice has shown promise in attenuating stress responses, which is thought to be a key mechanism for its benefits related to various physical and mental health conditions. However, different composition of yoga styles in terms of components have not been explored in the overall contribution to stress reactivity effects.

Research questions

This thesis aimed first to understand the typical composition of yoga classes of different yoga styles. Second, we evaluated the evidence of the effects of these components on acute stress responses to understand their potential for additive benefit in relieving stress and related physical and mental illnesses. Finally, we compared the effects of a traditional yoga class which is more holistic (including non-physical components of pranayama, meditation, chanting, relaxation) with a physical exercise-based yoga class (including only physical practice of yoga postures) on stress reactivity.

Methods

An online, world-wide survey (study 1) of yoga teachers described teaching practice in different yoga styles. General characteristics of yoga classes, inclusion of different components, their duration, and importance attached to these components were analysed. A systematic review (study 2) including 28 studies summarised and synthesised the effects of a single session of yoga or separate components, specifically breathing techniques and meditation, on stress reactivity to an acute stress task in healthy adults. A randomized crossover trial (RCT) (study 3) aimed to compare the effect of traditional yoga and exercise-based yoga practice on acute stress reactivity using both an active (walking) and a resting control condition.

Findings

The thesis studies defined important differences in modern yoga classes across styles and benefits of various yoga components, and the combined effects in attenuating acute stress reactivity. In study 1, the online survey of yoga teachers (n=968), the reported yoga styles were categorized into three over-arching styles: ‘traditional yoga’ (closeness of the yoga style to ancient texts or traditions), ‘exercise-based yoga’ (focus of the yoga style on physical exercise), ‘therapy yoga’ (the closeness of such type of yoga to therapy). A significantly greater proportion of traditional yoga style teachers incorporated pranayama, chanting, and cleansing in classes compared to exercise-based and therapy yoga style teachers. Breath techniques, meditation, relaxation and chanting duration was significantly greater in the traditional and therapy classes compared to exercise-based classes.

Nevertheless, teachers of all styles regarded yoga poses, breathing, meditation and relaxation as equally important in the yoga class. In study 2, a systematic review, 21 out of 28 studies (n=2574) including 31 interventions of meditation (n=22), breathing (n=4) and yoga (n=5) found beneficial effects of all types of intervention on stress reactivity. Seventy-one percent of studies measuring physiological outcomes and 65% of studies measuring psychological outcomes reported attenuated acute stress reactivity attributed to the effect of interventions. Study 3, a RCT (n=68), reported a pattern of differences, including significant findings that showed the traditional yoga lowered anxiety and negative affect post-intervention and resulted in higher positive affect post-intervention and post-stress. Traditional yoga led to a reduced sympathetic activation ((galvanic skin response) and increased parasympathetic activation (heart rate variability) in response to stress compared to exercise-based yoga.

Conclusion

This thesis found that the majority of yoga styles practiced around the world, incorporate diverse yoga components, but that inclusion and duration of non-physical components was typically greater in styles of yoga closer to traditional descriptions. This emphasises the importance of the holistic nature of yoga practice and underscores yoga's wider role as a philosophy of life, especially in traditional styles. This thesis demonstrated that even a single session of separate practice of the non-physical components of yoga (breathing, meditation) can effectively reduce acute stress reactivity. Finally, it was demonstrated that traditional yoga practice incorporating higher duration of these non-physical

components is superior to moderate intensity exercise-based yoga styles and light intensity exercise such as walking in mitigating acute stress responses. Findings here support yoga's stress management effect through top-down neurocognitive and bottom-up neurophysiological mechanisms. In conclusion, the non-physical components of yoga practice can play a significant role in stress responses and therefore stress management. Recommendations for styles of yoga should consider this when motives for practice are stress and health related.

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Chapter 1. Yoga, Health & Stress

1.1 Yoga Introduction

Yoga is a spiritual system practiced in India that dates back several thousand years [1] and has become extremely popular across the modern world. Particularly in the Western world, yoga has become a popular physical activity to develop or maintain fitness, attracting millions of people especially women [2, 3]. This popularity is largely attributed to its perceived benefits for both physical and mental well-being [4].

A nationally representative survey in the US found overall wellness, prevention of diseases and improving energy as primary motivators for the practice of yoga, while relief from back pain, stress, and arthritis were the main health benefits associated with practicing yoga [5]. Research suggests that yoga practices can promote other healthy lifestyle behaviours including vegetarianism, non-smoking, reduced alcohol consumption, increased exercise and reduced stress levels [6, 7].

The benefits of yoga appear to extend across various age groups. Evidence shows that along with adults, yoga offers health benefits to children [8], adolescent populations [9], older adults [10], and pregnant women [11]. Notably, yoga offers a wide spectrum of benefits ranging from physical fitness to spiritual well-being and the benefits apply regardless of factors like sex, race and age [2, 5, 6].

1.1.1 Yoga history

The origin of yoga can be traced back to the ancient (before 2500 BCE) Vedic texts, including the *Veda*, *Brahmana*, and the *Upanishad* [12]. Yoga traditions include the

belief that Lord Shiva (a Hindu god) also called Adinath in *hatha* yoga tradition, is the origin of yoga [1]. There is archaeological evidence of yoga practices and divine symbols from *Veda* discovered in the Indus valley civilization that flourished around 2500 BCE. One of the symbols discovered was the 'Pasupati seal'. This seal shows Lord Shiva sitting in a yoga posture [13]. However, the appearance of yoga literature in written texts emerged much later. The *Bhagavad Gita*, written in around the 4th Century BCE [14, 15] and the *Katha Upanishad* and *Svetasvatar Upanishad* written in around the 3rd Century BCE [13] have made explicit references to yoga and its practices. The first systematic exposition of yoga is found in *ashtanga* yoga or *yoga sutra* of Patanjali written in around the 2nd century BCE [16]. While the origin of *hatha* yoga is much later and can be traced back to Matsyendranath and Gorksanath around 12th century AD [13]. This timeline highlights the long evolving history of yoga practices.

Coming to the nineteenth century, the philosophy and spirituality of yoga was presented to the West for the first time [17], and the end of the nineteenth century and first half of the twentieth century was the start of popular modern yoga. This new presentation of modern yoga was focused on physical postures derived mainly from *hatha* yoga traditions but was also influenced by Western exercise culture [13]. The twentieth century also saw the use of yoga practices as an alternative therapy especially for managing stress of modern life [18]. Yoga has now evolved from a spiritual science to a system of fitness and well-being in the twenty-first century and is being increasingly used for its beneficial effects on physical and mental health [19]. Modern adaptations of yoga have given rise to a wide variety of yoga styles, most of

which retain their connection to traditional yoga practice [20]. Although the main feature of these modern yoga practices is their focus on the physical component of yoga postures, to a varying degree these styles include other traditional components of yoga as well [13]. In later sections of this introduction the different components of yoga and the divergence between traditional and modern yoga will be explored.

1.1.2 Purpose of yoga

Yoga is a multifaceted system of practices designed to achieve the union of individual consciousness with the cosmic consciousness, leading to absolute freedom [16]. This idea of absolute freedom is thought to be the rise of human consciousness beyond barriers set by time and space [21]. Aurobindo [22] expands the idea of the union of consciousness and perceives yoga as a thread that brings together all experiences of life. He proposes yoga as a systematic effort of striving for self-perfection, and through awakening dormant potential, finally reaching the highest goal of the union of human and universal consciousness. Similarly, Vivekananda [23] describes yoga as an inward journey, where the extraverted mind needs to be introverted to fully realise the dormant potential and allow the union of consciousness. Although yoga is a multidimensional system of practices, all different yoga types and schools are in principle focused on the state of being or the state of consciousness [24]. What prevents this evolution of consciousness is pain, suffering and ignorance. The system of yoga is designed to help transcend the human suffering in the quest of achieving absolute freedom [16].

1.1.3 Reasons for suffering and pain

The philosophy of yoga explores the source of human suffering and associates it with the sensory organs, objects, perceptions and conditionings of the mind. The reasoning suggests that although sensory experiences can initially bring pleasure they ultimately lead to suffering [16]. The *Bhagavad Gita*, considered the pinnacle of Indian spirituality [16] and the most authoritative text on yoga, [25] offers a multifaceted analysis of suffering and its origin.

The lack of control over the functions of mind, intellect and ego has been identified as the main root cause of pain and sufferings [25, 26]. The *Bhagavad Gita* describes the pathway through which the uncontrolled mind results in pain and suffering. Highlighting the need for the mind to remain in a state of harmony during the experience of extremes such as pleasure - pain or success - failure [27]. The extreme experiences are the results of uncontrolled sensory desires and ego. These strong desires create attachments to the objects of desire and distract the mind. This distracted state of mind is vulnerable to extreme emotions such as anger, sadness or fear. This state of mind hinders the intellect in making the good decisions, ultimately leading to harmful behaviours and stress, anger, anxiety or sadness. This cycle finally concludes in pain, suffering and health problems [26].

Similarly, Patanjali's *ashtanga* yoga (now widely recognised in the west) [16], identifies the lack of control over various mental activities as the reason for pain and suffering referred to as *klesha* [25]. There are five *kleshas* including ignorance, ego, attachments,

dislikes and fear of death [28]. The *kleshas* manifest as *Antaraya* (obstacles) such as laziness, self-doubt, procrastination, overindulgence in sensory pleasures, distortion of the perception, making the mind unstable and distracted and finally resulting in various diseases. Moreover, the instability of mind brings various psychological problems such as sadness, depression, tremors and irregular breathing patterns [29, 30].

In essence, yoga is an ancient Indian system that integrates diverse practices, philosophy and wisdom to evolve the individual consciousness by controlling the mind to transcend the pain and sufferings of life. Understanding the definitions, philosophy and practices is therefore crucial to understand the applications of yoga.

1.2 What is yoga?

The *sanskrit* word *yoga* originates from the *sanskrit* verb ‘*yuj*’, means to join, unite or yoke, or in other words the experience of oneness or the union of individual with cosmic consciousness [28]. *Katha Upanishad* and *Svetasvatara Upanishad* while defining *yoga* as a state of consciousness give greater importance to the control of the five sensory organs and mind leading to a stable and balanced state of intellect. This particular state of mind is necessary to eliminate pain and suffering. [31, 32].

To achieve the goal of *yoga* of the union of consciousness, there is no one system rather there are different types of *yoga* harmonising important aspects of body-mind and consciousness. For example, *bhakti yoga* is to harmonise emotions, *karma yoga* is to harmonise karmas or actions, *jnana yoga* is to harmonise intellectual activity, *ashtanga yoga* is to harmonise mental functions and *hatha yoga* is to harmonise body-mind functions [25, 33]. It is therefore recommended that all these *yoga* types should be practiced together as they complement each other. Combined practice of these types together make *yoga* a holistic practice involving every aspect of life [33].

1.2.1 *Karma, bhakti and jnana yoga*

Bhagavad Gita discusses the importance of *karma* (action) and its impact on the mind. It emphasizes that attachment to the outcome of an action triggers reactions based on pain-pleasure or success-failure. Such attachment brings stress, anxiety and may lead to disappointment, sadness, or anger when the desired outcome is not achieved. In this context, *karma yoga* emerges as a practice of performing actions with a sense of

responsibility while maintaining non-attachment with the fruit of action. Such non-attachment leads to a balanced state of mind and intellect [26].

Bhagavad Gita offers a unique perspective to the meaning of word yoga [26], especially underscoring the interconnected nature of life, linking all living beings to all objects in mother nature. The intertwined relationship of objects in nature (human beings, animals, plants, trees, oceans, mountains, rivers, etc.) originating from the same energy source highlights the idea of equality and divinity [26]. This understanding of equality is essential for a peaceful coexistence without discrimination and ultimately develops compassion, empathy and unconditional love towards every other object in nature. This path is called *bhakti* yoga which is deeply rooted in universal love [26].

Jnana yoga is a system of intellectual transformation to achieve wisdom leading to self-realization. Jnana yoga helps discover the true connection with nature and the cosmos through development of a meditative state and inner wisdom. The meaning of the word *jnana* is 'knowledge' or 'wisdom', when combined with the word yoga, it indicates higher awareness leading to enlightenment and self-realisation [34].

The *Bhagavad Gita* describes the characteristics of a *yogi* (yoga master) who has attained mastery through independent pursuit of *karma*, *bhakti*, or *jnana*, or a combination thereof [26]. The *yogi* does not have any *kleshas*; anger, hatred, excitement, obsessions, sadness, fear and depression but instead demonstrates contentment, peace, empathy, equality, non-attachment, non-discrimination, unconditional love and has a balanced intellect at all times [26].

Therefore, the *Bhagavad Gita* recommends yoga practice for cultivating a steady and balanced mind - intellect [26]. Along with *karma*, *bhakti* and *jnana* yoga practices, meditation, *pranayama*, *asana* and lifestyle modifications are also recommended for achieving this balanced state [26].

1.2.2 Ashtanga yoga

Patanjali's yoga *sutras* rooted in *Samkhya* philosophy defines yoga from the viewpoint of *Ashtanga* yoga. The definition is centred around the idea of restraint of mental functions and activities [29, 35]. In other words, yoga is the control over all activities of the mind such as thoughts, emotions and other cognitive functions [36]. For this reason, to eliminate the suffering or *kleshas*, Patanjali recommends eight steps of yoga popularly known as *ashtanga* yoga (*ashta* = eight, *anga* = parts). The eight parts, limbs or components are *yama* (social discipline), *niyama* (self-discipline), *asana* (postures), *pranayama* (breathing techniques), *pratyahara* (introversion), *dharana* (concentration), *dhyana* (meditation) and *samadhi* (self-realization) [29, 30]. The mastery over the processes of *pratyahara*, *dharana*, and *dhyana* together leads to a state of absolute concentration which is called *samyam*. The word '*samyam*' means mastery over all mental functions and conditionings (thoughts, emotions, reactions, memory, intellectual functions etc.). This *samyam*, is the starting point of awakening of higher consciousness and has been recommended for gaining knowledge of the objects, and cosmos. This state of *samyam* finally leads to *samadhi* [30]. *Samadhi*, the final step, is

described as the state of self-realization where consciousness perceives its true nature or unites with the cosmic dimension called '*purusha*' [30].

1.2.3 Hatha yoga

Hatha yoga, with '*hatha*'; signifying union of *ha* (vital energy or *prana* or sun principle) and *tha* (mental energy or moon) [16] is currently one of the most commonly practiced forms [37]. The most important and one of the oldest available text of hatha yoga tradition is '*Hatha Yoga Pradipika*' [16] which defines yoga as a system of practices to reach the highest state of *rajyoga*. *Rajyoga* is synonymous with the state of *samadhi* or liberation or self-realisation or the union of individual consciousness with the cosmic consciousness [21]. Interestingly, the ultimate state of *rajyoga* is frequently described as a state of immortality, achieved through union of the consciousness with an energy called *kundalini* [16]. *Kundalini* is considered a dormant form of energy which needs to be awakened to achieve the goals of *hatha* yoga. Moreover, *hatha* yoga also promises the end of pain and sufferings (physical, mental and others) through a regular and dedicated *hatha* yoga practice [21]. To achieve the end of suffering, awakening of *kundalini* to achieve the state of *rajyoga*, *hatha* yoga recommends a sequential approach to the practice of components starting with *asana* (yoga poses), *pranayama* (breathing), *mudra* (gestures), *bandha* (energy locks) and meditation and includes optional *satkarma* (six purification practices) [21]. In *hatha* yoga tradition, *mudra* and *bandha* practices have been given greater significance as compared to *asana* and *pranayama* and are particularly important to awaken the dormant *kundalini* energy [38].

These practices of *mudra* and *bandha* have been described as anti-aging techniques particularly for mastering the functions of the mind [21, 38]. For further reading on this subject of *mudra* and *bandha*, texts of ‘*Hatha Yoga Pradipika*’ and *Gherand Samhita* can be useful.

1.2.4 Summary

Across all types of yoga, the ultimate goal is to reach the union of individual consciousness and cosmic consciousness. However, the journey is often obstructed by overindulgence in sensory or bodily pleasures. Such overindulgence is the root cause of stress, anxiety, sadness, anger and finally leading to physical and mental health problems. Therefore, to alleviate these sufferings and to cultivate a positive state of mind, although different texts provided different descriptions, all prescribed a multifaceted approach.

This approach incorporates various yoga components aimed at:

1. Achieving a healthy body free of physical and mental illnesses: *asana* (yoga poses), *pranayama* (breath control), cleansing techniques, lifestyle modifications.
2. Controlling desires: practices such as *yama* and *niyama*, disciplined lifestyle, non-attachment, and behaviour modifications etc.
3. Concentrating the mind: practices like meditation, *pranayama* (advance), chanting of *mantra*, *karma yoga*, *bhakti yoga*, *jnana yoga* etc.
4. Achieving samadhi or union of consciousness

The traditional practice of yoga has included these components in varying degrees.

Therefore, it is important to understand these components for their application in the practice of yoga.

1.3 Yoga components

This section discusses meaning, types and practices related to various yoga components practiced in different traditional yoga styles with specific references to ancient texts. While the inclusion of specific yoga components may vary across yoga traditions, several core components consistently appear within most traditions. The relative emphasis placed upon these components, however, differs between these yoga traditions. Research evidence has been presented for some of the yoga components here in this section while the evidence for other components is discussed in greater detail in later chapters of the thesis. Most studies included yoga interventions consisting of a combination of yoga components of yoga poses, pranayama, and meditation [39]. A large body of evidence has supported a role of these yoga components in improving physical and mental health. Section 1.6 discusses evidence related to components and their effect on physical and mental health in more detail. The discussion of yoga components includes yoga poses, breathing, meditation and relaxation and includes critical evaluation of the evidence.

1.3.1 *Asanas* or yoga poses

Asana is probably the most well-known practice within yoga. It is recommended in all ancient yoga texts. [16]. *Asana* or yoga pose is defined in *ashtanga yoga* as ‘*Sthiram Sukham Asanam*’ translating to a steady and comfortable physical posture. Notably, *ashtanga yoga* only offers an outline of *asana* practice in three *sutras* (concise statements). Although, the practice of *asanas* is recommended for achieving perfect

physical health and making the body resistant to fatigue and stress, its main purpose is to transcend the bodily experiences of opposites such as pleasure-pain, hot-cold. This transcendence further attenuates the physical experiences of instability, pain, fatigue and irritation [35]. *Asana* practice further assists the mind in achieving focus and control over its functions. Advanced *asana* practice refers to the meditative postures, where physical effort and body awareness diminishes. The mind can then redirect its focus towards experiencing the expanded states of consciousness in meditation [16, 26, 35].

Hatha yoga places greater emphasis on *asanas* in contrast to *ashtanga* yoga. *Hatha* yoga texts provide more detailed description of *asana* practice, elaborating on diverse benefits and effects [16, 35]. *Hatha Yoga Pradipika* lists general benefits of *asana* practice including flexibility, overall physical and mental well-being and good health [21].

Hatha Yoga Pradipika and *Gherand Samhita*, another prominent *Hatha* yoga text, describe 15 and 32 *asanas*, respectively [21, 38]. These *asanas* include a variety of postures including forward bends, back bends, twists, relaxing postures, balancing postures and sitting meditative postures. The texts suggest that *asanas* impact different parts of the body promoting health in various body systems and organs [21, 38]. Interestingly, out of 47 *asanas* in these two ancient texts, 19 *asanas* are meditative postures and the names given to all these *asanas* in *hatha* yoga often reference various objects in nature [25] reflecting a strong relationship of yoga with nature.

Yoga interventions improve various aspects of physical and mental health and have been shown to attenuate risk factors for various physical illnesses such as cardiovascular disease which is the leading cause of death worldwide [40] and diabetes [41].

1.3.2 *Pranayama* or yoga breathing

Pranayama holds a more prominent position than *asana* in the *Upanishad* [32], *Bhagavad Gita* [26], *ashtanga* yoga and *hatha* yoga [16]. Considered an integral component of yoga practice [28], *pranayama*'s primary goal is to discipline the breathing rhythm to control the mental functions [16]. The *sanskrit* word of *pranayama* is composed of two words, '*prana*' which is a life force governing both the human body and the creation [21, 28] and '*ayama*' means regulation, control or restraint.

Pranayama, therefore, translates as the control of vital energy. The most central practice of *pranayama* is *kumbhaka* or breath hold [25, 38]. Regarding *kumbhaka* (holding of breath), Swami Niranjanananda argues that the *kumbhaka* through altered levels of carbon dioxide and oxygen, may train the central nervous system (CNS) and increase voluntary control over the CNS [42]. In *ashtanga* yoga, *pranayama* is the fourth step, is recommended after mastering the *asana* and is defined as cessation of the process of inhalation and exhalation or *kumbhaka* [16, 35]. *Ashtanga* yoga mentions four different types of *pranayama*, and each includes *kumbhaka*. *Ashtanga* yoga describes the benefits of *pranayama* as the control and preparation of the mind for meditation by improving its ability to concentrate [35].

Similarly, *hatha* yoga, also elaborates *pranayama* as a breathing practice involving *kumbhaka* and gives more details. In *hatha* yoga, *pranayama* is the second limb after *asana* [21]. The vital energy '*prana*' is categorised into five different types (*prana*, *apana*, *samana*, *udana*, and *vyana*) based on its functional area within the body and related physiological processes such as digestion, cardio-respiratory function, excretory function etc [21, 28]. According to *Hatha Yoga Pradipika*, this *prana* circulates through 72000 *nadis* (channels) and seven *cakras* (centres of *prana* coinciding with nerve plexus) influencing physical and mental functions [16]. Altogether, *hatha* yoga discusses eight different types of *pranayama* (*ujjayi*, *bhramari*, *sitkari*, *sitali*, *bhastrika*, *suryabhedan*, *murchha* and *plavini*) and each include *kumbhaka* [21].

The practice of *pranayama* is described to purify the *nadis* and *cakras* and awaken the *kundalini* [16] which facilitates reaching the highest state of *rajyoga* or *samadhi* [21]. *Hatha* yoga further highlights the benefits of *pranayama* practice including complete mastery over the mind, its functions and improving physical and mental health [21]. Evidence suggests that *pranayama* practices benefits autonomic nervous system activity especially in attenuating the stress response [41]. *Pranayama* has been shown to improve cardiorespiratory parameters such as reduction in blood pressure and heart rate [43], and improve general well-being [44].

1.3.3 Meditation

The term 'meditation' encompasses a broad spectrum of practices, ranging from relaxation techniques to deeper practices for improving sense of well-being [45]. In the absence of a clear definition of meditation, Goleman and Davidson described it as a generic term involving various contemplative practices [46]. Others view meditation as a collection of complex strategies for controlling emotions and attention aimed at achieving emotional balance and well-being [47]. Regardless of the specific type, any form of meditation has been suggested to improve mental health to some extent [46].

Within yoga, meditation is more specifically described as concentration on a single object, which can be physical, metaphysical or cosmic consciousness [16].

Interestingly, the most commonly recommended object of meditation in *Upanishad* texts, *ashtanga yoga*, *hatha yoga* and *Bhagavad Gita* is cosmic consciousness, which is the omnipotent, omniscient and divine principle of immortality where suffering ends [16, 21, 26, 30, 32]. However, the primary practices of meditation include concentration on *prana* the vital energy or *cakras* (centres for *prana*), breath or other external objects like the sun, moon or mental objects such as thoughts, memories, [35, 36]. In *ashtanga yoga*, meditation comprises of four steps (*pratyahara*, *dharana*, *dhyana* and *samadhi*) which are collectively called as '*antarang yoga*'. These practices aim to internalise the awareness and detach it from the external world. The internalised awareness is expanded using various concentration methods until the expansion reaches the final goal of *samadhi*, or self-realisation or union of individual consciousness with the cosmic [30].

Evidence suggests that meditation practices reduce stress response and inflammatory markers[46], as well as enhance emotional stability and well-being [45].

1.3.4 Yoga *nidra* – a concentrated, relaxed, and awakened mind

Yoga *nidra*, translated as ‘yogic sleep’ or ‘meditative sleep’ is a deep relaxation technique having its roots in ancient *Tantric* traditions and modern yoga lineages [48, 49]. Swami Satyananda Saraswati, credited with developing the modern practice of yoga *nidra* [50] describes it as a practice that induces deep relaxation at physical, mental and emotional levels and designates it as a preparatory practice for meditation [48, 49].

Satyananda recommends the practice of yoga *nidra* for about 20 to 40 minutes in *savasana*, a supine yoga pose used for relaxation. The practice starts with a *sankalpa*, a positive resolve and has often been associated with the purpose of practice [49]. It then progresses through steps as recommended by Satyananda including:

- Body scan: rotation of awareness through different body parts with mental effort.
- Breathing awareness: focusing on breath to induce physical relaxation.
- Opposite sensations: developing opposite feelings for achieving emotional harmony.
- Visualization: imagination of images, often positive, to bring concentration and deeper relaxation.

Research evidence suggests that yoga *nidra* techniques can be effective in alleviating various physical and mental health conditions. Research evidence has reported efficacy of yoga *nidra* in reducing stress, anxiety, depression, post-traumatic stress disorder and pain [51-55]. Yoga *nidra* has been found to significantly improve risk factors for diabetes [56], blood pressure [57] and hormonal imbalances in women [58]. Additionally, yoga *nidra* can improve heart rate variability [59], sleep quality [53], cognitive functions including memory [60] and self-esteem [61, 62].

Yoga *nidra* is a relaxation technique which is practiced in savasana posture. But this yoga *nidra* is not included in traditional yoga practice of hatha yoga [21]. However the posture of savasana is recommended as relaxation practice in hatha yoga and has been included in almost all styles of yoga [63].

1.3.5 Lifestyle

Bhagavad Gita emphasises disciplined management of every aspect of daily life including diet, sensory indulgence, routines, behaviour, proper sleep and other physical and mental activities for eradication of pain and suffering [26]. In addition, the *Bhagavad Gita* gives great importance to food. Particularly, ‘*satvik*’ food (comprised primarily of plant-based food including whole grains, lentils, legumes, fresh vegetables, and fruits) is recommended for increasing life expectancy, strength, positive physical and mental health, happiness and love [26]. This emphasis aligns with *Hatha* yoga recommendations of ‘*satvik*’ food as a prerequisite for success in yoga practice. In addition to the importance of what to eat, *hatha* yoga also recommends eating 75% of the total capacity of the stomach as an important aspect of maintaining health [21].

Bhagavad Gita has placed great importance on quality and optimum quantity of sleep (not too much and not too less) for achieving good health [26]. This emphasis on behaviours known to have positive effects on health is likely a strong indirect pathway for the effects of yoga practice.

1.3.6 Mystic syllable *Om*

Across all systems of yoga, the syllable “*Om*” holds exceptional importance. Firstly, *Om* is regarded as the representation of cosmic or supreme consciousness in *Bhagavad Gita*, *Veda*, and the *Upanishad*. Notably, the *Mandukya Upanishad* is entirely dedicated to exploring *Om* while it remains a subject of discussion in many other *Upanishad* texts [16, 26]. *Om* is believed to encompass the three dimensions of time (past, present and future) and transcends them altogether. Similarly, *Om* is correlated with four states of human consciousness (conscious, sub conscious, unconscious and superconscious states of mind) [64]. This perspective aligns with the emphasis Patanjali has placed in *ashtanga* yoga. Patanjali recommends the practice of *Om* for eradicating all the *antaraya* or obstacles including physical and mental ailments. *Om* chanting is considered as a fundamental component of yoga practice and is often performed even before starting all other practices including yoga poses, pranayama and meditation [30, 35]. Within the *hatha* yoga tradition, *Om* plays an important role in awakening the kundalini which is a dormant energy seated in deeper layers of consciousness as unmanifest potential [16, 65]. Lastly, *Om* is incorporated in various yoga practices, including chanting, meditation and *pranayama* [16].

Although a small number of studies have analysed effects of *Om*, some studies have reported that *Om* chanting for even 5 to 10 minutes can deactivate parts of the limbic system (amygdala, anterior cingulate gyrus, hippocampus, and thalamus) [66], reduce output in emotion processing brain regions (insula, anterior cingulate and orbitofrontal cortices) [67] and improve PNS activity [68] highlighting deactivation of the stress response.

1.3.7 *Yama and niyama*

Within the path of *ashtanga* yoga *yama* (restraints) and *niyama* (disciplines) are the first two steps. These principles work as ethical and moral guidelines, considered essential for advanced yogic practices such as meditation [16]. However, the primary focus is on managing mental and emotional disturbances arising out of uncontrolled sensory or bodily desires, greed, anger and attachments [35]. The five *yamas* (restraints) include *ahimsa* (non-violence), *satya* (truth), *brahmacharya* (sexual abstinence), *asteya* (non-stealing) and *aparigraha* (non-possessiveness). Similarly, five *niyama* (disciplines) consists of *sauca* (cleanliness), *santosa* (contentment), *tapas* (austerities), *svadhyaya* (study of yoga metaphysics) and *isvara pranidhan* (self-surrender to divine consciousness) [16, 30]. Likewise, the *Bhagavad Gita* has also emphasized importance of these restraints for yogic progress [26]. On the contrary, although *hatha* yoga gives importance to these restraints and disciplines, they are not considered as essential practices [21].

1.4 Traditional and modern practice of yoga

1.4.1 Divergence between traditional and modern yoga

The traditional system of yoga includes a range of components influencing every aspect of life, from mental aspects (thoughts, emotions, intellect, reactions etc.), behaviour, routines, physical activity, diet and sleep to social aspects, relationships, connection with nature, spirituality, and one's goal of life. However, modern yoga, especially in the West, is seen as a fitness activity rather than the holistic practice of yoga as a philosophy of life [69]. This significant divergence between the traditional yoga approach and modern yoga practices is especially seen in respect of priority to physical postures and minimal emphasis on *pranayama*, meditation, philosophy, lifestyle and other yoga practices [13, 39]. This shift away from the holistic approach outlined in traditional yoga texts may limit the potential benefits of yoga practices in the modern world.

1.4.2 Physical component of yoga postures

One of the main ancient texts often used by modern postural yoga practice is *ashtanga* yoga (Yoga *sutras* of Patanjali) which hardly offers any information about *asanas* [13]. Similarly, ancient texts of *hatha* yoga, often credited as the origin of many modern physically oriented styles [20] like Iyengar, Kundalini, Kripalu [69] includes only a handful of yoga poses (15 to 32 postures) and does not mention any movements, warm ups or posture sequences [21, 38]. However, most modern styles focus on warmups,

movements and various new postures (not mentioned in ancient texts) and this addition seems to have developed through the influence of gymnastics and exercise culture on yoga teachers of the 20th and 21st century [13]. For example, Iyengar yoga mentions more than 200 yoga postures [25] and the Ashtanga vinyasa style includes more than 50 postures in addition to a dynamic flow of standing postures [70] and most of these postures are not mentioned in *ashtanga* yoga (Patanjali's Yoga Sutra) or in *Hatha Yoga Pradipika* [21, 35]. Another divergence in relation to yoga poses is the emphasis on alignment and use of props, especially to support the body, prevent injuries and enhance the benefits of yoga [71, 72] which again are not mentioned in ancient texts [21, 38].

Among various modern yoga styles, many styles that are associated with traditional yoga such as hatha yoga, include breathing, meditation and relaxation practices along with physical postures whereas the exercise-based styles primarily include physical postures with less inclusion and emphasis on other components [13, 20].

1.4.3 Non-physical components (pranayama, meditation, and relaxation)

Although the main focus of modern yoga practice has been physical postures, especially in yoga classes, many studies involving modern yoga interventions have included various yoga components and found benefits of yoga in clinical applications. A scoping review by Elwy and colleagues that included 465 studies evaluating the effect of yoga interventions related to various health outcomes reported that nearly two thirds

of yoga interventions most commonly included components such as breathing, meditation and relaxation [73]. A meta-synthesis of 19 meta-analyses of yoga studies found that yoga interventions that included traditional yoga components like breathing, meditation and relaxation were more effective in management of diseases (such as depression, hypertension, diabetes, asthma, and COPD) as compared to the interventions that did not include these components. This meta-synthesis concluded that the addition of more traditional components make the interventions more beneficial in improving physical and mental health outcomes [74].

1.4.4 Summary

Taken together, modern yoga styles show large variations in importance placed on different yoga components. These variations are found specifically in the inclusion of breathing practices, meditation, relaxation, *mantras* and chanting. [74]. These style differences make it very challenging to compare and analyse separate effects of these components and understand the effectiveness of a particular yoga style. The inclusion of non-physical components (breathing, meditation, relaxation, Om chanting), ethical components (*yama-niyama*), lifestyle (diet, routine, sleep), and philosophy may play an important role in enhancing the beneficial effects of yoga practice and needs further exploration.

1.5 Stress, reactivity & health

1.5.1 What is stress? Definitions

There is no single, universally accepted definition of stress. Selye [75], was the first to discuss the concept of stress and has offered a broad perspective, defining stress as “a non-specific response of the body to any demand”. This stress response is primarily for ensuring survival and is called ‘Fight or Flight’ response [76, 77]. McEwen [78] offered a more experience-based definition, describing stress as “a commonly used word referring to experiences that cause feelings of anxiety and frustration because they push us beyond our ability to successfully cope”. McEwen [79] also emphasizes the challenge aspect of stress, defining it as an experience related to emotional and physiological challenges. Others have defined stress from a physiological perspective, defining it “as a state of threatened homeostasis”, followed by physical and behavioural adaptive responses to re-establish the homeostasis [80]. Homeostasis refers to a self-regulatory process to maintain balance among internal systems and organs during the changes in external conditions [81]. To maintain this homeostasis during daily activities, major life events, and abuse or trauma, the body responds directly through autonomic and neuroendocrine processes and indirectly through changes in health behaviours [82].

1.5.2 Stress response

The acute adaptive response of the body to a stressor primarily involves the autonomic nervous system (ANS), central nervous system (CNS) and endocrine system

(hormones) forming two primarily distinct but interrelated systems [82]. The first one is the sympathetic-adrenomedullary system (SAM) and the second pathway involves the hypothalamic–pituitary–adrenal (HPA) axis [83, 84]. The SAM system is activated by the brainstem and with further influence of the hypothalamus. This sympathetic activation stimulates the adrenal medulla to secrete catecholamines (epinephrine and norepinephrine) into the blood stream. Epinephrine enhances sympathetic activity in all tissues further affecting the activities of various organs such as an increase in heart rate, breathing rate, blood pressure etc. [85]. The second system, the HPA axis acts through a different pathway. The hypothalamus while influencing SAM activity, also signals the pituitary gland to release adrenocorticotrophic hormone (ACTH), which triggers the adrenal cortex to secrete glucocorticoid (cortisol). Cortisol during the stress response increases glucose levels, memory function, energy conversion, etc., and inhibits digestive function and the immune system [85].

1.5.3 Stress, allostasis and allostatic load

Sterling and Eyer (1988) coined a term ‘allostasis’ to refer to a process of adaptive body response to daily events for maintaining the state of homeostasis [76]. Allostasis describes the process of adaptation to acute stressors, characterized by the release of stress hormones including epinephrine and cortisol, which help to restore homeostasis in response to a challenge [86]. In the presence of an acute stressor both the stress systems (SAM and HPA) are switched on. This activation is protective and adaptive as long as the stress systems switch on in the presence of a stressor and switch off in a

balanced way in the absence of the stressor [82]. However, repeated and long-term activation of this stress response results in wear and tear of the body. McEwen [76] called this wear and tear of the body 'allostatic load or overload', which describes how chronic stress can have detrimental effects on biological systems. This allostatic load can lead to chronic dysregulation of homeostasis correlated to physical and mental health as well as life expectancy [87]. This process of allostatic overload is complex, starting with release of the primary mediators including stress hormones (such as cortisol, adrenaline) and inflammatory cytokines (such as interleukin-6, tumor necrosis factor-alpha) negatively influencing allostatic mechanisms [88]. Chronic stress exposure causes over or under production of these primary mediators forcing biological systems to compensate. The compensatory actions of biological systems result in secondary outcomes negatively influencing metabolic (insulin, glucose, total cholesterol, triglycerides, visceral fat depositing), cardiovascular (systolic and diastolic blood pressure) and immune (c-reactive protein (CRP)) markers [88]. Finally, this allostatic overload results in various diseases referred to as tertiary outcomes. Various studies have found association between allostatic load and health including chronic conditions, mental disorders, poor lifestyle habits and higher mortality [89]. This concept underscores the multi-systemic nature of stress responses, highlighting how interconnected biological systems interact to adapt and respond to perceived stressful environmental demands [82].

1.5.4 Stress and health

Stress responses can alter the autonomic, cardiovascular, gastrointestinal, and immune system physiology and there is a significant evidence that acute and/or chronic stress is a significant risk factor in development of diseases [90].

Acute stress can initiate asthma attacks, eczema or urticaria, migraines, hypertension, myocardial infarctions, headaches, pelvic and low back pain, chronic pain fatigue syndrome, gastrointestinal problems such as abdominal pain, indigestion, diarrhea, constipation, anxiety, panic attacks, depression, post-traumatic stress disorder (PTSD), eating disorders and psychotic episodes [87, 91-94].

Chronic stress results in increased HPA activation and elevated levels of cortisol. This hypercortisolemia is associated with depression, generalised anxiety, panic disorder, anorexia nervosa, diabetes, hyperthyroidism etc., [87]. But over a period, this hypercortisolemia phase may transit to compensatory HPA down regulation with reduced cortisol. This hypocortisolemia can also be associated with depression, chronic fatigue syndrome, fibromyalgia, hypothyroidism, and post-traumatic stress disorder etc. [87]. In addition, chronic stress has been found to be associated with many different pathologies, including executive and/or cognitive impairment, hypertension, obesity, metabolic syndrome, chronic inflammation, type 2 diabetes mellitus; cardiovascular diseases; atherosclerosis, Alzheimer's disease, amyotrophic lateral sclerosis, osteopenia and osteoporosis, insomnia or excessive daytime sleepiness and reduced life expectancy [87, 91, 95]. In fact, research suggests chronic

stress may be a common risk factor for a staggering 75-90% of chronic, non-communicable diseases [87].

1.5.5 Stress reactivity

Stress reactivity can be defined as “the deviation of a physiological response parameter from a comparison or control value that results from an individual’s response to a discrete, environmental stimulus” [96]. These individual acute stress responses or reactivity exhibit significant variations, for example, the same stressor can invoke different magnitudes of stress responses in different individuals [97]. Firstly, these individual differences in responses are due to variations in appraisals of stressful events and subsequent emotional reactivity. This suggests the role of prefrontal and limbic activity (for example, heightened reactivity in individuals with hostile attitude). Secondly, the research reports that these differences may also be related to variable activation of the hypothalamus, brainstem (for example, borderline hypertensive individuals producing higher cortisol response while visiting the lab for the first time) and peripheral tissues and organs (for instance, exaggerated BP response to cold pressor test or exercise in at risk population) [85]. These differences in stress reactivity in terms of psychological and physiological variations are proposed to contribute to different health outcomes [85].

Recent evidence links these individual differences in stress reactivity to both mental and physical health, with differences thought to contribute to the complex and varied relationship between stress and specific disorders [77].

Negative effects of heightened stress reactivity on health are well documented especially related to cardiovascular pathology. In 1931 Edgar A. Hines, Jr. developed a cold pressor test to analyse the BP response associated with sympathetic activation. Later in 1980's the reactivity hypothesis was presented [98] which emphasizes the link between exaggerated increase in heart rate (HR) and blood pressure (BP) in response to a stressor and development of cardiovascular diseases. In recent years overwhelming research evidence has emerged in support of this reactivity hypothesis [99]. More evidence has linked heightened reactivity to increased risk of myocardial infarction, stroke, hypertension, and immune system dysregulation [85]. Also, blunted or slower recovery from the laboratory stressors has been found to be a predictor of cardiovascular disease and adverse events including all-cause mortality [100].

However, emerging research suggests a more nuanced picture regarding risk for health and stress responses. Blunted stress reactivity may also be linked to impairments in cognitive functioning, difficulties with behavioural regulation, fluctuations in mood, often characterized by a propensity for negative emotions, impulse control disorders and obesity [85]. Blunted reactivity is even linked to risk prone behaviours including unhealthy lifestyle choices such as poor diet, alcohol, and recreational drug use [85]. Taken together, research has shown that both 'too small' or 'too big' stress reactivity is linked with greater levels of chronic stress and a greater risk of physical and mental health problems. This nonlinear inverted-U relationship between cortisol reactivity

levels (higher and lower) and overall health indicates that both extremes are detrimental [82].

Evidence suggests that the exaggerated stress response as measured using a laboratory stressor is positively correlated with future development of physical (such as insulin resistance, hypertension, coronary heart diseases) [101-103] and/or mental health conditions (for example, depressed mood) [104].

1.5.6 Determining stress reactivity

The question of how to quantify the stress reactivity is worth a brief discussion. Typically, research has taken the approach of standardising the stimulus (stressor) in experimental studies in contrast to measuring stress reactivity in ecologically valid situations. These laboratory stressors are necessarily specific (e.g., a mathematical stress task) and may elicit different patterns of response depending on individual differences [105]. Although, measuring stress in natural environment is most relevant, it is very difficult to establish and quantify the cause of the stress in such settings [106], with reviews showing only approximately half of studies using ecological momentary assessment found associations between everyday acute stress exposure and physiological responses [107]. While the evidence is inconsistent, there are positive correlations between laboratory and daily life stressors. For example, HR responses to laboratory stressors are associated with stress-related HR reactivity in real life. [108].

Laboratory measurement of stress reactivity provides a controlled environment, which permits measurement of stress response and recovery with the opportunity to control for various confounding variables. [105]. For this purpose, various laboratory stressors have been used for analysing the effects of stress reactivity in the majority of studies in this area.

There are a variety of laboratory stressors such as mental arithmetic tests, public speaking, anger recall or other cognitive challenges used in the experimental set up. The physiological stress responses evoked by these different laboratory stressors can be quite different. For example, a mental arithmetic task produced SNS activity comprising of alpha and beta-adrenergic receptor activation, while cold pressor test (CPT) and exercise (cycling) produced alpha-adrenergic, and beta-adrenergic activation dominated responses respectively [109]. The trier social stress test (TSST) has been shown to evoke greater HPA axis response compared with CPT [110, 111]. Bosch, de Geus [112] reported activation of PNS response along with SNS activity in response to watching a surgical video while increases in SNS and decreases in PNS activity were found for a memory task.

In conclusion, laboratory stressors provide a valuable tool for assessing stress reactivity and its potential links to future health outcomes. However, it is important to note that there are inherent differences in the physiological responses elicited by various stressors when interpreting their findings.

1.6 Yoga effects on health – evidence and mechanisms

1.6.1 Yoga and health

A myriad of studies have shown a positive effect of yoga practice on physical and mental health. Although spirituality is the goal of yoga practice especially in experienced practitioners [113], in the great majority of people, surveys have identified factors such as general wellness or disease prevention, or to manage a specific physical and/or mental health conditions as the motivations for regular yoga practice. These applications of yoga further support its role as a complementary and alternative medicine approach [5-7]. Even among medical professionals, acceptance of yoga as a complementary and alternative medicine approach has increased in recent times. For example, 12.1% of family doctors in rural Australia recommended specific yoga therapies and protocols to their patients according to a survey [114].

A national survey in Australia by Penman and colleagues in 2012, National Health Interview Survey by government of United States of America in 2012, and a recent cross-sectional survey in UK by Cartwright and colleagues in 2020 all reported that an overwhelming majority of people perceived the benefits of yoga mainly in musculoskeletal conditions (such as back pain, arthritis etc.), mental health (stress, anxiety, depression, sleep problems, etc.), and to a smaller extent in other health conditions including cardiovascular diseases, hypertension, diabetes, obesity, gastrointestinal (irritable bowel syndrome, constipation etc.), women's health (pregnancy, menopause, etc.), neurological disorders (headaches, migraine, etc.), and

other illnesses (cancer, thyroid disorders, allergies, etc.) [5-7]. Further adding to the beneficial effects of yoga, these surveys reported positive association between yoga practice and engagement in positive health behaviours and lifestyle choices (for example, higher physical activity levels, lower rates of smoking and alcohol, plant-based diet etc.) compared to the general population [6, 7]. Another National Health Interview Survey by the government of the United States of America in 2018, found yoga as the most commonly used complementary health approach for health and wellness in the United States of America [2].

1.6.1.1 Yoga and diseases - scientific evidence

Not only are benefits of yoga self-reported and perceived but various studies have also confirmed yoga's benefits for a range of physical and mental illnesses and its use as an alternative and complementary health approach.

One of the most common yoga benefits reported by studies is chronic pain management. Various systematic reviews analysing yoga effect on chronic pain have supported the role of yoga in relieving headaches, chronic low back pain, neck pain, pain associated with rheumatoid arthritis, labour pain, carpal tunnel syndrome, osteoarthritis and fibromyalgia [115-120].

Other reviews have reported promising evidence of yoga interventions for reducing the risk factors of cardiovascular diseases (CVD) (e.g., BMI, SBP, DBP, Total cholesterol, LDL, HDL, Triglycerides, insulin resistance and metabolic syndrome) [40, 121, 122].

Similarly, evidence for the use of yoga as an adjuvant treatment for hypertension [123-126], in management of type 2 diabetes [41, 127, 128] and management of weight in overweight adults have been reported by different reviews [129, 130].

Benefits of yoga have been reported in chronic obstructive pulmonary diseases to improve exercise capacity and lung function [131, 132], in management of asthma related symptoms [133], and in digestive disorders such as irritable bowel syndrome (as a feasible, low cost and safe complementary treatment) [134-136].

Reviews have also reported yoga's usefulness as an adjunct treatment for patients with neurological disorders (such as stroke, epilepsy, multiple sclerosis, Parkinson's disease, dementia, cerebrovascular disease, Alzheimer disease, neuropathy, etc.) [137, 138].

Yoga interventions have been found to be useful in disorders related to immune function, such as inflammatory diseases including osteoarthritis [139, 140].

Several reviews have also found evidence favouring yoga practices for cancer patients and survivors, especially for improving psychological health [141, 142], quality of life, psychosocial symptoms [143, 144] and physical symptoms [142-144].

1.6.1.2 Yoga and mental health – scientific evidence

There is significant evidence for the beneficial effects of yoga practice on mental health. Yoga practices are effective in reducing stress and anxiety while improving

mood and general well-being. Various systematic reviews have recommended yoga as an adjunctive treatment option for patients with depressive disorders [145], anxiety disorders [146, 147], post-traumatic stress disorder (PTSD), eating disorders and obsessive-compulsive disorder (OCD) [148]. In addition, a review suggested that yoga improves emotional reactivity, neurocognitive behavioural responses, and overall neurocognitive efficiency [149].

In summary, increasingly more and more people are practicing yoga mainly for physical and mental health. Self-reported benefits of yoga are corroborated by scientific evidence suggesting that yoga interventions are supportive and effective in clinical population. Yoga's benefits have been observed in most non-communicable, lifestyle disorders and mental disorders particularly those with stress as a significant risk factor.

1.6.2 Yoga and stress

A thread that connects the effects of yoga on health outcomes is through its connection to stress and stress responses. Several systematic reviews have found positive effects of multiple session or yoga training intervention and single session yoga practice in the management of stress. Although not a formal search, our literature search (conducted in January 2024 and updated in June 2024) found seven systematic reviews studying of the effect of yoga interventions on stress. All, seven reviews reported effectiveness of yoga interventions on stress or stress management [150-156]. Two of the seven reviews evaluated workplace stress for workers and employees at workplace [151, 154]. Two

reviews only included healthy adults [153, 155], while other reviews included different population such as pregnant women as well as clinical population suffering from various physical and mental health conditions (for example, different types of cancers, hypertension, metabolic syndrome, diabetes, osteoarthritis, restless leg syndrome, Crohn's disease, anxiety disorders, depression and alcohol dependency) [150, 152]. Two reviews only included RCT's [150, 155] for analysing the effect of yoga on stress outcomes. Out of the total 114 studies included in seven reviews, 12 studies were included in two reviews and two studies in three reviews leaving the final tally to 98 unique studies in seven reviews. Out of these 98, 82 studies were RCT's, and the remaining studies included pre-post design, observational studies and even a semi-structured interview. Inclusion of studies other than RCT's and reported study limitations may have influenced the overall quality of evidence. A large variation was recorded in duration of the yoga practice included in studies (from single session practice of 20 minutes to yoga training intervention practice of 3 years), with most interventions within the duration of 4 to 8 weeks. Single session acute practice of yoga was included in eight studies analysed by two reviews and 75.0% (six out of eight) acute yoga interventions reported beneficial effects of yoga on stress outcomes. The remaining studies included long-term (1 week to 3 years) yoga interventions and 91.0% (81 out of 90 studies) reported beneficial effects of yoga training intervention yoga interventions.

A large variety of modern yoga styles were used in these studies and irrespective of the style, results display effectiveness of yoga interventions in reducing stress related

parameters. The stress reduction was reported among healthy as well as clinical populations highlighting clinical application of yoga in health conditions where stress is a risk factor. Most studies measured stress using psychological self-report questionnaires such as perceived stress scale, state-trait anxiety inventory and other questionnaires (mood, workplace stress, burnout, positive and negative affect, sleep, well-being, and quality of life) and 92.8% studies (91 out of 98) reported beneficial effects of yoga on these outcomes. Similarly, 85.7% studies (36 out of 42) involving physiological stress markers of HR, BP, cortisol, heart rate variability (HRV) and other measures (respiratory function, DHEA, melatonin, GABA, inflammatory markers, blood lipids, DHEA, and melatonin) reported reduction of stress markers with yoga interventions.

However, many studies had limitations, such as small sample size, or absence of a control group or no randomization [152, 155, 156]. Research quality was lowered due to various reasons. Firstly, not all of the studies included in these reviews were randomised trials (82% RCT's). Secondly, only 2 out of 7 reviews analysed risk of bias for the included studies. Additionally, only 1 out of 7 reviews conducted meta-analysis for stress related outcomes. Another limitation was the diverse outcome measures used for measuring stress. All reviews reported extreme variations in the yoga interventions used. Notably, the majority of studies in these reviews did not give details of included yoga components, sequence and yoga poses making the study replication very difficult. Finally, all reviews highlighted the need for high quality clinical studies involving sound methodology.

1.6.3 Yoga and stress reactivity

Given that stress reactivity is associated with health and disease outcomes [157] and that yoga is found to be of benefit in reducing stress, it has been suggested that yoga's effect on health may be through its effect on stress reactivity [158]. Some evidence and support has emerged and found lower stress reactivity in experienced yoga practitioners as compared to beginners as measured using psychological and physiological laboratory stressors [159, 160]. Yoga training interventions have been evaluated for their effect on stress reactivity and positive evidence has been reported.

To our knowledge six RCTs have been published examining the effect of yoga interventions on stress responses to a laboratory stressor. A RCT by Gothe, Keswani [161] employing eight-week yoga intervention (1 hour session 3 times a week) and stretching control group in sedentary older adults (mean age=62 years old) found a significant decrease in cortisol reactivity, self-reported stress and anxiety in the yoga group. A computer based cognitive task involving cognitive assessments were used as the psychological stressor. Similarly, another RCT of eight-weeks of Bikram yoga (2 sessions of 90 minutes per week) with a wait list control group found significant reduction in cortisol reactivity to the TSST in females (aged 25– 46 years old) at risk for obesity and related illnesses [162]. Furthermore, Kanojia, Kumar Sharma [163] found notable effects on stress reactivity measured using outcomes such as HR, BP, anger, depression, and anxiety response to the CPT in the group randomised to yoga practiced for 3 menstrual cycles (35-40 minutes session, six times per week) compared with the no activity control condition in 50 healthy females (aged 18-20 years old). Similarly,

three more RCT's found positive evidence for yoga interventions. First, a RCT by Casden [164] with 48 healthy participants (aged 19 – 38 years old) including a six-week ashtanga yoga intervention (75 minutes sessions 2 times a week) and wait list control groups reported improvement in reactivity measured using positive mood and reduction in fatigue but found no effect on autonomic measures such as HRV. In this study an arithmetic task to induce the cognitive stress was administered. Second, a RCT involving 70 participants (mean age = 34 years old) and eight-weeks yoga with a wait list control group found faster recovery in DBP after an anger recall and arithmetic task in yoga group but no difference in SBP and HR. [165]. Finally, Rajak and colleagues found that 24 weeks regular yoga practice (80 minutes, twice a day) significantly reduced the cardiovascular reactivity to physiological stressor (CPT) [166]. Overall, the evidence suggests that yoga practice attenuates stress and stress reactivity. However, the actual mechanisms by which yoga practices influence health remains an area of exploration.

1.6.4 Proposed yoga mechanisms

The volume of evidence for the connection between yoga and health has led to the examination of potential mechanisms. Although few studies have tried to formulate theoretical frameworks and network systems models to explain the effects of yoga, research suggests yoga practices are associated with quantifiable changes in physiological outcome variables, self-report psychological variables, and cognitive functioning [167]. Systematic reviews have evaluated different proposed psychological and biological mechanisms through which yoga affects health [168, 169]. The prevailing

proposed model is based on yoga's effects via the top-down neurocognitive model, bottom-up neurophysiological model and integration of both these approaches [167, 170].

1.6.4.1 Top-down neurocognitive model

In the proposed top-down model, executive mechanisms or cognitive forms of self-regulation, especially those controlled by high-level brain networks (for example, central executive network involved in planning or problem solving or Default mode network (DMN) associated with mind-wandering etc.) are responsible for the effects of yoga through cognitive reappraisal, attentional control, response inhibition, etc. [167, 170]. The top-down model describes how the psychological changes due to yoga practices influence brain and nervous system activities [171-173].

The most discussed psychological mechanism for the effect of yoga is mindfulness [168, 169, 174]. Mindfulness is the awareness achieved through staying in the present moment, and observing the experience impartially moment by moment [175]. Increases in mindfulness with yoga practice are thought to reduce stress by increasing interoception [176], which is awareness of the body's internal sensations, and plays an important role in mental health and well-being [177]. Yoga's stress reducing benefits can also be attributed to various other psychological mechanisms. These include promoting positive affect, self-compassion [168], enhancing emotion regulation [174, 178] and mitigating rumination, a thought pattern characterized by a focus on negative and depressive feelings [169].

Yoga practice has been reported to influence brain structure and functions such as increased volume of the hippocampus and prefrontal cortex, deactivation of the amygdala for negative stimuli [179], and decreased activity in DMN [170]. The hippocampus is associated with memory, mood, anxiety, stress response and other cognitive functions and its atrophy is linked to memory and cognitive decline, and mood disorders [180-182]. Deactivation of the amygdala on the other hand, indicates successful emotion regulation and deactivation of stress response [183, 184]. Reduced activity of DMN is indicative of attention or focused state and decreased abstract thoughts or rumination [185, 186].

Other evidence suggests yoga practices increase alpha brainwave activity, often associated with calmness, improved memory performance and reduced pain [187]. Furthermore, yoga practice increases levels of neurotransmitters such as brain derived neurotrophic factor (BDNF), an important neurotransmitter promoting development, survival and plasticity of neurons (decreased BDNF is often related to anxiety and depression) [188] and gamma-aminobutyric acid (GABA) which relate to changes in many cognitive processes including stress responses and anxiety [189].

Although meditation is an important component of yoga practices, often it is practiced as a standalone technique. Many different reviews analyzing the mechanisms of meditation on stress suggest changes in neural activity [190] and neuroplasticity in different parts of the brain and CNS. In addition, meditation produces significant

changes in emotional regulation, attention regulation, subjective experience [190, 191] and body awareness resulting in enhanced self-regulation [191]. Evidence for these effects of mindfulness align with effects found for yoga as would be expected given the importance of this component in yoga practice.

In conclusion, beneficial adaptive changes in cognitive, emotional, and behavioural responses to stressors as evidenced by changes in high-level brain networks, structures and neurotransmitters supports the top-down neurocognitive model as a mechanism for yoga's effect on health.

1.6.4.2 Bottom-up neurophysiological model

The proposed effects of yoga via bottom-up approach or neurophysiological model of self-regulation are due to the involvement of biological mechanisms. This bottom-up model focuses on processes, which are controlled by low-level brain networks (for example, autonomic systems, vagal complex, etc.) and are influenced by a range of peripheral inputs including somatic, visceral, sensory, cardiovascular, and immune signals [170]. This model suggests that increased parasympathetic control, improved baroreceptor functioning, and increased vagal tone are associated with the practice of yoga postures, and pranayama which reduces allostatic load in several ways [167, 170]. Pranayama (involving slow, and rhythmic breathing), practice of various postures (increasing depth of breathing and strengthening of diaphragm) effectively increases baroreflex sensitivity and subsequently the vagal tone [167]. In addition, yoga postures activate interior muscles stimulating peripheral vagal afferents [167]. Increased vagal

tone is indicative of increased PNS activity [192], it is a known moderator of the HPA axis and has been suggested to mediate brain regions associated with emotion regulation [193]. In this way the 'up' signal can affect the subsequent response to a stressor. Emerging evidence suggests that vagal activity, has been linked to glucose regulation, HPA axis function, and inflammatory processes, all of which are key allostatic systems [193]. Studies involving yoga training interventions have reported reduction in inflammatory and endocrine reactions to stress [159], hypothalamic-pituitary-adrenal axis (HPA) activity [150], and deactivation of sympathetic nervous system (SNS) activity [150, 194, 195] and increased vagal tone, (parasympathetic nervous system (PNS) activity) [171, 173, 196].

In addition to PNS activation, yoga practice increases oxytocin [197] which induces feelings of calm and promotes social bonding. These changes can also affect stress reactivity by altering affect and potentially changing the social elements of a stressor which are reflected in the finding that increased oxytocin can ameliorate the stress response [198].

In summary, deactivation of HPA axis, SNS activity and reduction in inflammation while increase in vagal tone (PNS activity) along with hormonal changes is suggestive of yoga's beneficial role via low-level brain networks in deactivating the stress responses.

1.6.4.3 Integration of top-down and bottom-up models

Unlike most cognitive behavioural therapies which act via top-down neurocognitive pathways, yoga is proposed to effect stress responses via top-down as well as bottom-up mechanisms [170]. For example, voluntary breath awareness as advised in yoga postures, pranayama, meditation may synchronize cortical areas with a subsequent positive effect on executive functions (top-down) while various postures and pranayama practices enhance depth of breathing, strengthen the diaphragm, and increase the baroreceptor sensitivity increasing vagal tone (bottom-up) [167]. Through integration of both these models, yoga promotes cognitive, emotional, behavioural and autonomic self-regulation while deactivating the stress response [170].

1.6.5 Summary

A growing body of evidence supports yoga's physical and mental health benefits especially in health conditions where stress is a risk factor. A large number of studies have reported that yoga training intervention and single session yoga practice is effective in reducing stress and stress reactivity. Proposed mechanisms for yoga's effect emphasize the deactivation of stress response via top-down and bottom-up models as the main pathway for its effect on health. However, yoga is a multimodal activity that includes various physical and non-physical components acting on the stress response via different pathways. In addition, there is a large variation in yoga styles especially in the component inclusion and intensity of physical components. There is evidence that non-physical components effect stress responses when

practiced alone, and thus it is suggested that their inclusion in the specific yoga style practiced may be important in increasing effectiveness of yoga interventions on this outcome. Given the evidence for yoga effects on health and the work done to establish possible mechanisms, this gap in identifying the effect of inclusion of different components or the specific differences between style of yoga used must be addressed. In this way we aim to understand the most effective applications for yoga in health and specifically stress related disease.

1.6.6 Thesis aim and outline

This thesis specifically addresses three main questions:

- Are different yoga styles practiced around the world different in terms of the included components, their allocated importance and duration?
- Is there any difference in effects of a single session of yoga or its components (yoga poses, breathing techniques and meditation) on stress reactivity to an acute stress task?
- Is there any difference between traditional yoga (style including postures, breathing, meditation, chanting and relaxation) and exercise-based yoga (style mainly focused on postures) related to acute stress reactivity?

After this chapter 1 of introduction to the topics, there are three chapters describing and discussing three studies conducted as a part of this thesis. Chapter 2 discusses an international survey of yoga teachers and includes characteristics of a yoga class such as included components, their importance and duration as practiced in various yoga

styles. Chapter 3 is a systematic review comparing the effects of a single session of yoga components (yoga poses, breathing, meditation) on stress reactivity in response to a laboratory stressor. Chapter 4 is a randomised crossover trial comparing traditional yoga to exercise-based yoga with active (walking) and passive (watching a video) control conditions for their effect on acute stress reactivity using psychological and physiological stress outcome measures and a mathematical laboratory stressor. These chapters are followed by a discussion and conclusion of the thesis (chapter 5).

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Chapter 2. Not All Yoga Styles Are the Same: An International Survey on Characteristics of Yoga Classes

2.1 Publication and dissemination

This chapter has been published as Mandlik, G. V., Nguyen, B., Ding, D., & Edwards, K. M. (2023). Not All Yoga Styles Are the Same: An International Survey on Characteristics of Yoga Classes. *Journal of Integrative and Complementary Medicine*, 29(5), 321-326. It is presented here with supporting information placed in the Appendix at the end of the thesis.

2.2 Abstract

Objectives: Yoga is a multicomponent activity that has been associated with many health benefits. Different yoga styles contain different combinations and durations of components (e.g., postures, breathing, meditation, relaxation and chanting). A better description and quantification of yoga components within different styles is important in understanding how different yoga styles contribute to health outcomes. This survey aims to understand the general characteristics and components taught in different yoga styles.

Design: An online international survey was sent to yoga teachers (18+ years with >1 year teaching experience) using snowball recruitment. Survey questions included demographic and professional characteristics of participants, specialised yoga style, and details of components typically taught in the class. The analysis included descriptive statistics and a comparison between teachers of traditional vs exercise-based vs therapy styles using chi-square and Kruskal Wallis tests.

Results: 968 yoga teachers (76.8% female, mean age 43.8 ±11.1 years) from 64 countries participated in the survey. When grouped according to primary yoga style taught, 70.6% of participants taught traditional (e.g., hatha or ashtanga), 18.4% exercise-based (e.g., vinyasa or power) and 11.0% therapy (e.g., restorative or gentle) styles. Nearly all teachers included physical postures, but breath techniques, chanting, and cleansing were included by significantly more traditional teachers (95.2%, 68.3%, 25.8% respectively) compared to exercise-based (88.6%, 42.5%, 7.2%) and therapy teachers (93.0%, 43.0%, 10.0%). Variations were reported in the time allocated to each of these class components. Physical postures took up 50.0% of total class time for traditional styles, 60.9% for exercise-based and 53.9% for therapy styles ($p < 0.001$). Conversely, breath techniques, meditation, relaxation and chanting took significantly more of the class time for traditional and therapy compared to exercise-based styles. However, teachers from all styles regarded yoga poses, breathing, meditation and relaxation as equally important in the yoga class.

Conclusions: Exercise-based yoga styles unsurprisingly dedicate more time to physical postures and less time to non-physical components than traditional and therapy yoga styles. However, all yoga teachers report valuing and including multiple components of yoga practice regardless of the primary style of teaching which is reflective of the holistic nature of yoga practice. Further research into the benefits of the specific component combinations in different yoga styles is needed to better understand the full potential of yoga practice for health.

2.3 Introduction

Yoga, a multi-component practice, is growing rapidly in popularity worldwide.[1, 2] According to a National Health Interview Survey conducted in the United States in 2017, yoga was the most commonly used complementary health approach with 14.3% of American adults practicing it at least once in the prior 12 months.[3] Widely considered as a type of physical activity (PA) due to its physical components, yoga has been shown to convey similar or greater benefit than various types of PA on health parameters such as blood glucose, lipids, cortisol, heart rate variability and oxidative stress.[4]

Besides the physical postures (*Asana*), yoga also consists of different practice components, such as breath techniques (*Pranayama*), meditation (*Dhyana*), relaxation, social and self-discipline (*Yama-niyama*), chanting (*Mantra*), cleansing and lifestyle (e.g., diet).[5] These different components contribute differently to health. For example, the physical components of yoga improve balance, muscle strength, aerobic PA, gait, coordination, and physical function.[6] Breath techniques improve cardiorespiratory parameters,[7] reduce stress and improve general well-being,[8] while meditation has been found to reduce stress reactivity and inflammation,[9] and increase emotional balance and well-being.[10] In addition, the relaxation practice of *Savasana* was found to be effective in reducing stress,[11] and *Om* chanting resulted in the deactivation of the limbic system suggestive of an important role in stress management.[12] Moreover, yoga practitioners often report healthier lifestyle choices (such as vegetarian dietary choice) compared to general population.[13] This suggests that yoga contributes to health through different mechanisms,[14] and it is important to differentiate between

the components in various yoga styles to understand the contributions of style specific combinations to health.

Yoga styles vary from gentle to vigorous, and from exercise-based to spiritually focused. Having moved away from eastern traditional styles as described in ancient yoga texts, western yoga styles tend to focus more on physical poses for fitness and exercise over other components such as breath techniques,[15] meditation and relaxation, which is less holistic than the traditional styles.[16] Also, the different yoga styles vary in the intensity of PA (e.g., light, moderate, or vigorous) which depends on the duration of the postures, the speed of the sequence of postures, and types of poses (e.g., standing or balancing).[17]

Considering the ubiquity and diverse range of yoga styles and the inclusion of different components, it is important yet challenging to quantify yoga practice for the examination of its health benefits at the population level, particularly in terms of its physical activity components. Without a better description of yoga components within styles, understanding the contribution of yoga to physical and mental health through PA as well as other components is limited. Based on an online survey, our study is the first international study to describe the general characteristics of different styles of yoga classes taught around the world, including inclusion and duration of components.

2.4 Methods

2.4.1 Study design and recruitment

Between February and August 2020, we conducted a cross-sectional survey using an online questionnaire. Participants were recruited using snowball sampling. An invitation to participate (including the survey link) was emailed to yoga institutes, studios, and associations (Supplementary file 1), with a request for distributing the questionnaire link to associated yoga experts/teachers. Social media posts including the survey link were distributed on platforms such as WhatsApp and Facebook, targeting various yoga teachers' groups (Supplementary file 1). For this anonymous survey, all the participants provided online informed consent. The data were collected using the secure web-based Research Electronic Data Capture (REDCap) application. The study was approved by the University of Sydney Human Ethics Committee (HREC 2020/007). The study was reported using STROBE checklist (STROBE checklist cross-sectional).

2.4.2 Participants

Yoga teachers aged 18 years and above who had at least one year of teaching experience in any style, and had access to the internet, were eligible to participate in the survey.

2.4.3 Measurement

The online survey included the following questions regarding the participants and the classes they ‘typically’ teach.

Participants’ characteristics

Participants were asked to provide information about their yoga certification/training, teaching experience (e.g., years of teaching), yoga training in hours, country of residence and place of teaching (e.g., yoga studio, gym, park).

Style of teaching

Participants were asked to report the yoga styles they typically taught and if reporting more than one, identify their primary teaching style. The primary reported style was used to group teachers into three over-arching styles: ‘traditional yoga’ (characterised by the proximity of the yoga style to its lineage based on ancient texts or traditions), ‘exercise-based yoga’ (characterised by the focus of the yoga style on physical exercise), ‘therapy yoga’ (characterised by the gentle or restorative forms and the closeness of such type of yoga to therapy) or ‘unspecified’ (for the styles that we could not include in the above three categories). Examples of specific styles in each category are provided in Table 1.

Yoga class characteristics

Participants were asked to describe the details of each class component (physical poses, breath techniques, meditation, relaxation (including the number of *Savasana* included in a class), chanting, cleansing, lifestyle, social and self-discipline), such as

duration and percentage of class time allocated to each of these components in a 'typical' class they taught. Additionally, participants were asked to rate the importance of each of the following components (i.e., physical poses, breath techniques, meditation, relaxation, and chanting) that they use in their yoga class using a 5-point Likert scale ranging from 'not important' to 'most important'. These response options were further combined as 'most/very important' vs 'not/less/somewhat important'.

2.4.4 Statistical analysis

Data were extracted from REDCap and analysed using SPSS version 25 (IBM Corp). Participants were included in the analysis if they provided complete data on the three main questions related to the yoga style they teach, and the components included in their yoga class. Descriptive statistics for participants' demographic and professional characteristics were computed for the three different yoga style categories (traditional yoga, exercise-based yoga and therapy yoga). Differences in yoga styles with regard to selection and relative importance of components were analysed using chi-square tests for these categorical variables with a Bonferroni adjustment for post hoc analysis. Kruskal-Wallis test was performed to assess differences between the duration of the components among different yoga styles with a Bonferroni adjustment for pair-wise comparison. In a question asking respondents about the percentage of time allocated to the different yoga components in their class, the responses were adjusted to 100% if the sum of percentages was below/above 100%.

2.5 Results

Yoga teachers from 64 countries (Supplementary file 3) teaching over 60 different yoga styles participated in the survey. A total of 968 yoga teachers (76.8% female, mean age: 43.8 ±11.1 years) were included in the final analysis (Supplementary file 2). When grouped according to their reported primary style of teaching, 70.6% of teachers reported typically using traditional yoga styles, 18.4% exercise-based yoga styles and 11.0% therapy yoga styles (Table 2). However, in our sample, 72.2% of teachers reported teaching more than one style of yoga. Over a quarter of responses were from India (25.6%), followed by the United States (US) (12.5%), Australia (11.8%), Singapore (6.5%) and the United Kingdom (UK) (6.2%). Demographic and professional characteristics of yoga teachers in the traditional yoga, exercise-based and therapy yoga categories are presented in Table 2. Participants' reported yoga teaching experience ranged from one to three years (30.2%) to over 10 years (27.0%). Just under half of the participants had > 500 hours of yoga training (48.2%). Teachers reported a wide range of teaching locations.

Table 1 – Yoga style categories

Style categories	Selected styles by participants
Traditional Yoga	Traditional, Hatha, Ashtanga, Sivananda, Satyananda, Integral, Iyengar, Kripalu
Exercise-based Yoga (Vinyasa)	Power, Vinyasa, Ashtanga Vinyasa, Anusara, Jivamukti, Bikram, Hot, Aerial
Yoga Therapy	Restorative, Prenatal, Chair, Gentle, Yin
Unspecified	All other styles not mentioned above

Table 2 - Demographic and professional characteristics of yoga teachers

	Traditional Yoga	Exercise-based (Vinyasa)	Therapy Yoga
Total	n = 640	n = 167	n = 100
Male	174 (27.2%)	24 (14.4%)	11 (11.0%)
Female	465 (72.7%)	143 (85.6%)	89 (89.0%)
Other	1 (0.2%)	0 (0.0%)	0 (0.0%)
Mean Age (years) & SD	43.9 (\pm 11.2)	41.6 (\pm 9.8)	46.9 (\pm 12.3)
Teaching Experience			
1-3 years	210 (32.8%)	43 (25.7%)	30 (30.0%)
4-6 years	153 (23.9%)	49 (29.3%)	27 (27.0%)
7-10 years	107 (16.7%)	29 (17.4%)	17 (17.0%)
More than 10 years	170 (26.6%)	46 (27.5%)	26 (26.0%)
Yoga Education in hours			
200 hours	198 (31.1%)	69 (41.3%)	31 (31.0%)
500 hours	123 (19.3%)	26 (15.6%)	21 (21.0%)
More than 500 hours	315 (49.5%)	72 (43.1%)	48 (48.0%)
Place of Teaching^a			
Yoga studio	297 (46.4%)	122 (73.1%)	72 (72.0%)
Yoga school or institute	140 (21.9%)	20 (12.0%)	11 (11.0%)
Private class	377 (58.9%)	86 (51.5%)	46 (46.0%)
Community centre	133 (20.8%)	17 (10.2%)	30 (30.0%)
Gym	94 (14.7%)	42 (25.1%)	26 (26.0%)
Corporate environment	102 (15.9%)	30 (18.0%)	13 (13.0%)
Park	66 (10.3%)	14 (8.4%)	9 (9.0%)
Hospital	37 (5.8%)	2 (1.2%)	9 (9.0%)
Rehabilitation centre	37 (5.8%)	6 (3.6%)	6 (6.0%)
Other	118 (18.4%)	23 (13.8%)	15 (15.0%)

^a – Participants were allowed to select more than one option.

Table 3 - Components of yoga in a class

	Traditional Yoga	Exercise-based (Vinyasa)	Therapy Yoga	P value
Component included in a yoga class				
Yoga poses	632 (98.8%)	164 (98.2%)	99 (99.0%)	p = 0.822
Pranayama (breath techniques)	609 (95.2%) ^a	148 (88.6%) ^b	93 (93.0%)	p = 0.008
Meditation	504 (78.8%)	121 (72.5%)	85 (85.0%)	p = 0.048
Relaxation	577 (90.2%)	134 (80.2%) ^b	96 (96.0%)	p < 0.001
Chanting	437 (68.3%) ^a	71 (42.5%) ^b	43 (43.0%) ^b	p < 0.001

Cleansing	165 (25.8%) ^a	12 (7.2%) ^b	10 (10.0%) ^b	p < 0.001
Lifestyle (Lifestyle & Yama-Niyama)	357 (55.8%)	73 (43.7%) ^b	56 (56.0%)	p = 0.018
Duration % of components in a yoga class				P value
% Duration Yoga poses	50.0% ^c	60.9% ^d	53.9%	p < 0.001
% Duration Breath techniques	16.1% ^c	14.6%	15.3%	p < 0.001
% Duration Meditation	11.7% ^c	8.6% ^d	10.7%	p < 0.001
% Duration Relaxation	15.4% ^c	12.4% ^d	16.7%	p = 0.001
% Duration Chanting	6.8% ^c	3.4%	3.3% ^e	p < 0.001
Selection of components as 'very important'				P value
Yoga poses	427 (86.9%)	117 (92.1%)	68 (86.1%)	p = 0.238
Breath techniques	470 (95.5%)	119 (93.7%)	75 (94.9%)	p = 0.693
Meditation	374 (76.0%)	89 (70.1%)	60 (75.9%)	p = 0.378
Relaxation	451 (91.9%)	114 (89.8%)	75 (94.9%)	p = 0.419
Chanting	254 (53.4%) ^a	25 (20.2%) ^b	22 (31.4%) ^b	p < 0.001

a – Significantly higher after Bonferroni adjusted α

b – Significant lower after Bonferroni adjusted α

c – Significant difference after Bonferroni adjusted α between Traditional and Exercise-based styles

d – Significant difference after Bonferroni adjusted α between Exercise-based and Therapy styles

e – Significant difference after Bonferroni adjusted α between Traditional and Exercise-based styles

Lifestyle and Yama-Niyama component includes diet, social and self-discipline

The various yoga components taught in different types of yoga classes are shown in

Table 3. Nearly all teachers from all categories included physical poses and no

significant differences were observed between the three categories (chi-square $X^2(2,$

$n=907) = 0.393, p=0.822$). Although the chi-square value was significant for meditation,

group differences were not significant after Bonferroni adjustment. However, significant

differences were reported among the three styles in all other components. For

example, a significantly greater percentage of traditional yoga teachers reported

including breath techniques, chanting, and cleansing in classes. Additionally, exercise-

based styles were less likely than traditional and therapy styles to incorporate lifestyle

along with social and self-discipline in the classes.

Teachers of different styles also reported differences in the duration of time allocated to each of the class components (expressed as percentage of total class time, Table 3). For instance, physical poses took up 50.0% of total class time for traditional styles, 60.9% for exercise-based and 53.9% for therapy styles ($p < 0.001$). Conversely, breath techniques, meditation, relaxation and chanting were allocated considerably larger percentages of the class time by teachers of traditional and therapy yoga styles compared to exercise-based styles.

When asked about the importance of including different components in their class, teachers from all three categories selected 'most/very important' options for physical postures ($p = 0.238$), breathing ($p = 0.693$), meditation ($p = 0.378$) and relaxation ($p = 0.419$) (Table 3). However, post hoc analysis revealed differences in chanting with significantly more traditional teachers considering it as 'very important' compared to exercise-based and therapy teachers. Differences were also reported in the number of *Savasana* (a relaxation component) included in a single yoga class. 65.8% of the exercise-based teachers included only one *Savasana* compared to 40.5% of traditional and 44.4% of therapy teachers, while the remaining included more than one *Savasana* in a class.

2.6 Discussion

To our knowledge, this is the first international survey of yoga teachers to describe and compare the components of yoga classes across different styles. Our findings show that traditional and therapy styles include longer duration of breath techniques, meditation and chanting compared to exercise-based styles which include longer duration of physical postures. The practice of different styles is therefore likely to contribute to health outcomes in different ways. For example, for exercise-based yoga styles, physical activity is likely to be the main contributor to health outcomes, while the different compositions of holistic components typically seen in a class of traditional or therapy style may contribute to health outcomes through other mechanisms, which is yet to be examined. In addition, our findings suggested that despite the different time allocations of non-physical components such as breathing, meditation, and relaxation by teachers of different yoga styles, they all perceived these components to be similarly important in their classes. However, chanting was perceived to be more important by traditional styles compared to the therapy and exercise-based styles and the duration of chanting was longer in traditional and therapy classes. These findings indicate that chanting may be an important differentiator between yoga styles and the pattern suggests that there is a mismatch between what yoga teachers perceived to be important in classes and how they actually teach.

A recent survey of yoga practitioners and teachers across all styles in the UK (N=2434) reported that yoga poses comprised 66.6% of yoga practice, followed by breath techniques (13.1%), relaxation (12.0%), meditation (8.6%) and chanting (1.9%).[13]

Similarly, a national survey in Australia (N=3892) found yoga poses take up 61% of the total class with the remainder for relaxation, breath techniques and meditation.[18] Our overall survey findings show smaller proportions of time devoted to yoga poses (52.7%), and more to breath techniques (15.7%), relaxation (14.9%), meditation (11.0%) and chanting (5.7%). However, when examining specific yoga styles, the exercise-based styles in our international survey were very close to overall yoga practice in the UK reported by Cartwright et al. and in Australia by Penman et al.[13], Penman, Cohen [18] This finding likely reflects the predominance of exercise-based styles taught in the UK and Australia and the greater importance given to the physical practice of yoga as part of the exercise culture. However, the pattern reported by Cartwright et al., Penman et al., and this survey is suggestive of the holistic nature of yoga practice as described in ancient yoga texts which goes beyond the physical postures.[13, 18]

It is important to quantify and compare the components across various styles of yoga to understand how yoga practice could contribute to health outcomes through physical component of yoga poses and non-physical component such as breathing and meditation. Although evidence suggests that every style of yoga has health benefits,[16] the specific benefits may differ by activity intensity and components. Most studies measuring energy expenditure through oxygen consumption have categorised most traditional yoga styles (hatha, Iyengar, ashtanga, gentle yoga) as light-intensity PA which is less than 3 metabolic equivalent of task (MET) but exercise-based styles (vinyasa and power yoga) as moderate intensity (3–6 METs).[17, 19] Variations in intensity have been attributed to differences in the selection of yoga poses, the pace,

sequencing and transition between poses.[17] Our data suggest that it is possible that the intensity may very well be influenced by the inclusion of a greater duration of less active components of practice. For example, breath techniques and meditation components of yoga have much lower energy expenditure (1-1.3 METs).[17, 20] Considering the large proportions of class time traditional and therapy yoga teachers reported spending on breath techniques, meditation and relaxation, one may expect that it would be challenging to meet the recommended amount of moderate-to-vigorous intensity aerobic PA solely through practicing these styles. However, considering the beneficial effects of breathing, meditation and chanting on health especially stress management,[9, 11, 12] it is possible that traditional and therapy styles may have a stronger attenuating effect on stress compared to exercise-based styles.

We also found that although a wide spectrum of styles was reported, in almost every response, teachers indicated including multiple components in each class, reflecting the general embrace of holistic wellness practices in yoga teaching. Interestingly, when comparing the original guidelines for styles to the reported descriptions here, we found many differences. For example, exercise-based styles, such as vinyasa or power yoga, are typically described as not including meditation,[21-23] whereas we found that nearly three quarters of the exercise-based teachers reported including meditations. This is likely due to teachers' 'mixing and matching' various principles and components from different styles of yoga. Indeed, three-quarters of the teachers reported teaching multiple yoga styles in this survey.

Similarly, we also observed a discrepancy between what teachers reported to be important for inclusion in classes and what they actually teach. For example, although there was no difference between teachers of different styles in ascribing importance to breath techniques, meditation and relaxation, in a yoga class, exercise-based teachers allocated significantly less time to these components. Many differences may contribute to these results. For example, differences in training received by teachers or preferences of students are likely to influence teachers' choice and confidence to include components in their classes. As we did not record such detailed information, future research is needed to examine the cause of these differences.

Another important difference between styles is the number of *Savasana* (relaxation component) included in a class. For example, in the original guidelines for the vinyasa style (exercise-based), a single *Savasana* is included at the end of the class while most traditional styles include two or more *Savasana* throughout the class.[24] Our data support this pattern, with more exercise-based teachers including only one *Savasana* compared to traditional and therapy teachers.

2.6.1 Strengths and limitations

The key strength of the current study is the large sample of yoga teachers from the eastern and western worlds. This provides ecological validity for the sample across countries and styles of yoga. However, this study was not without limitations. The analysis was based on a convenience sample, indicating that the prevalence and

characteristics of yoga styles taught in our sample may not be generalisable to those of all yoga classes in the world. Our results are only generalisable to English speaking countries given the language of the survey. Therefore, our conclusions may not be applied to much of the global south and the large proportions of non-English speakers in India and Europe. In addition, the organizations contacted for invitation to distribute to members was limited further limiting generalisability. Furthermore, data were self-reported and may be subject to random and systematic errors due to recall and social desirability biases. Finally, the survey is limited in several aspects of detail, including information about training received by teachers, it is likely that the content of teachers own training would influence their delivery of components in their own classes.

2.6.2 Conclusions

Our data from English speaking yoga teachers report important differences between styles of yoga classes in component inclusion and durations, which may have important health implications. We also found that teachers from all styles are integrating traditional yoga practice components such as relaxation, chanting, cleansing, social and self-discipline and lifestyle in their yoga classes irrespective of their yoga style specialisation. This may be due to various additional benefits of these traditional yoga components and a focus on holistic wellness by yoga teachers. Our findings support the description that the practice of yoga is much more than physical poses or breath techniques or meditation in isolation. Further investigation into the independent and combined effects of these components is needed so that we can fully understand and capitalise on the benefits of yoga. Future studies would benefit from a

broader recruitment of non-English speaking yoga teachers as well as therapists. It would also be important to collect more detailed information regarding training received and students being taught to determine the effect on inclusion of different yoga components.

2.7 Acknowledgements

The authors would like to thank all the yoga institutes, studios, teachers for promoting and participating in the survey.

Author Contribution Statement

G.M.: Conceptualization (equal); methodology (equal); investigation (lead); writing - original draft (lead), software (lead), formal analysis (lead). B.N.: Conceptualization (equal); methodology (equal); writing – review and editing (equal); supervision (supporting). D.D.: Conceptualization (equal); methodology (equal); writing – review and editing (equal); supervision (supporting). K.E.: Conceptualization (equal); methodology (equal); investigation (lead); writing – review and editing (equal); supervision (lead). All authors have read and approved the article. All authors had access to all the data and take responsibility for its integrity and the accuracy of the analysis.

Author Disclosure Statement

All authors declare no conflicts of interest, financial or otherwise.

Funding Information

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2.9 Supplementary files

2.9.1 Supplementary file 1

List of Organisations contacted

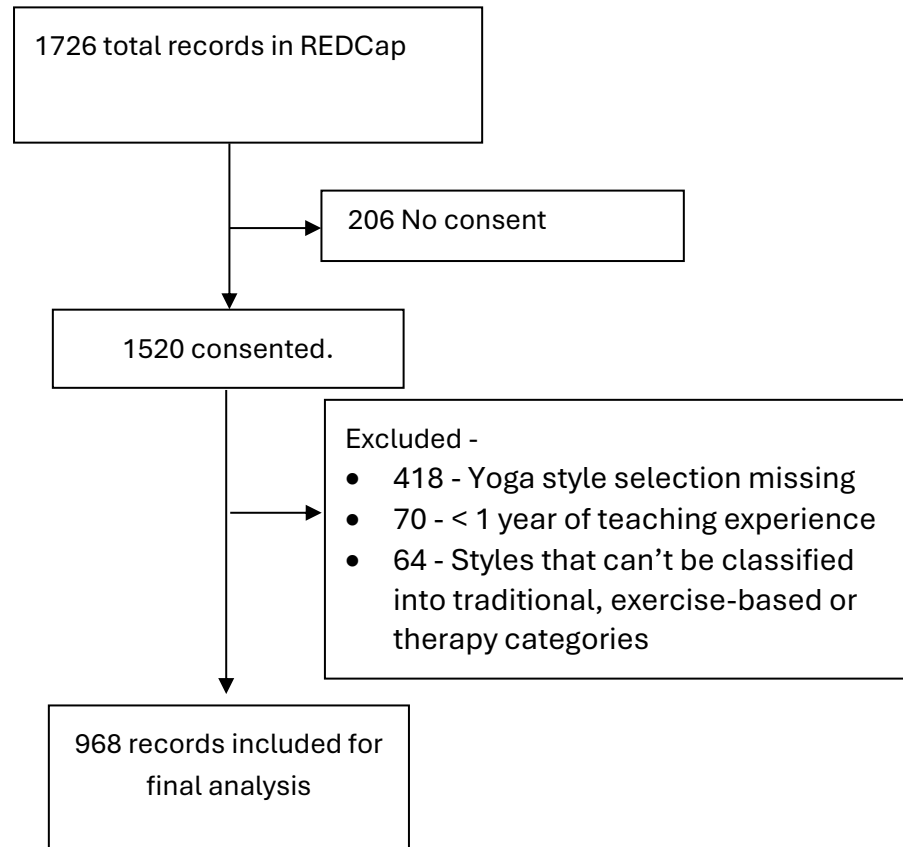
1. Yoga Alliance, USA
2. Kaivalyadhama Yoga Institute, Pune, India
3. Yoga Vidya Gurukul, Nashik India
4. Shri Ambika Yoga Kutir, Mumbai India
5. The Yoga Institute India
6. Yoga Vidya Niketan, Mumbai, India
7. Swami Vivekananda Yoga Anusandhana Samsthana(s-vyasa), Bengaluru, India
8. Morarji Desai National Institute of Yoga, New Delhi, India
9. Sharath yoga centre (Ashtanga Vinyasa), Mysore, India
10. Ramamani Iyengar Memorial Yoga Institute, Pune, India
11. Europe Yoga Alliance

List of Facebook groups contacted

1. Yin community
2. Ashtanga vinyasa sadhna intensive group
3. Yoga Teacher Training Online
4. Power Yoga
5. Yoga Teachers Across the Globe
6. Vinyasa Yoga
7. Iyengar Yoga Practitioners
8. ॐ Yoga de la femme ॐ

2.9.2 Supplementary file 2

Flow Diagram



2.9.3 Supplementary file 3

Yoga teachers/therapists` countries		
	N	%
India	248	25.6%
United States	121	12.5%
Australia	114	11.8%
Singapore	63	6.5%
United Kingdom	60	6.2%
Thailand	54	5.6%
China	33	3.4%
Brazil	26	2.7%
Canada	26	2.7%
South Africa	18	1.9%
France	16	1.7%
Germany	15	1.5%
Switzerland	11	1.1%
Italy	10	1.0%
Spain	10	1.0%
Indonesia	9	0.9%
Malaysia	9	0.9%
Kazakhstan	8	0.8%
Greece	7	0.7%
Norway	7	0.7%
Austria	6	0.6%
Belgium	6	0.6%
Philippines	6	0.6%
Netherlands	5	0.5%
Turkey	5	0.5%
Bulgaria	4	0.4%
Colombia	4	0.4%
Ireland	4	0.4%
Mexico	4	0.4%
Sweden	4	0.4%
United Arab Emirates	4	0.4%
Israel	3	0.3%
Japan	3	0.3%
New Zealand	3	0.3%
Portugal	3	0.3%
Taiwan	3	0.3%
Costa Rica	2	0.2%
Finland	2	0.2%
Mauritius	2	0.2%
Poland	2	0.2%
Qatar	2	0.2%

Slovakia	2	0.2%
Albania	1	0.1%
Azerbaijan	1	0.1%
Bolivia	1	0.1%
Cambodia	1	0.1%
Czech Republic	1	0.1%
Denmark	1	0.1%
Kuwait	1	0.1%
Lithuania	1	0.1%
Luxembourg	1	0.1%
Malta	1	0.1%
Morocco	1	0.1%
Namibia	1	0.1%
North Macedonia	1	0.1%
Oman	1	0.1%
Russia	1	0.1%
Serbia	1	0.1%
Sierra Leone	1	0.1%
Sri Lanka	1	0.1%
Ukraine	1	0.1%
Missing	5	0.5%
Total	968	

2.9.4 Supplementary file 4

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2,3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6,7
Bias	9	Describe any efforts to address potential sources of bias	6,7
Study size	10	Explain how the study size was arrived at	6,7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7

Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	7,8
		(b) Describe any methods used to examine subgroups and interactions	7,8
		(c) Explain how missing data were addressed	NA
		(d) If applicable, describe analytical methods taking account of sampling strategy	NA
		(e) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	8
		(c) Consider use of a flow diagram	Supplementary Data S2
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	Table 2,3
Outcome data	15*	Report numbers of outcome events or summary measures	Table 2,3
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2,3
		(b) Report category boundaries when continuous variables were categorized	NA
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8, 9

Discussion

Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10, 11, 12, 13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13, 14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for exposed and unexposed groups.

NA – Not Applicable

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

Chapter 3. Effect of a single session of yoga and meditation on stress reactivity: A systematic review

3.1 Publication and dissemination

This chapter has been published as Mandlik, G. V., Siopis, G., Nguyen, B., Ding, D., & Edwards, K. M. (2023). Effect of a single session of yoga and meditation on stress reactivity: A systematic review. *Stress and Health*. It is presented here with supporting information placed in the Appendix at the end of the thesis.

3.2 Abstract

Effect of a single session of yoga and meditation on stress reactivity: A systematic review

This systematic review synthesizes the evidence for the effectiveness of a single session of yoga or its components including meditation and breathing techniques in reducing acute stress reactivity in healthy adults. Following the PRISMA guidelines, we searched Medline, EMBASE, Cochrane, CINAHL, and PsycINFO on 30th July 2023 for randomised controlled or crossover trials of yoga components and reporting physiological and/or psychological outcome measure(s) related to stress reactivity. Risk of bias (ROB) was assessed using the Cochrane ROB 2 tool. Data were synthesised narratively. Twenty-one out of 28 eligible studies (n=2,574) relating to 31 interventions (meditation (n=22), breathing (n=4) and yoga (n=5)) reported outcomes in favour of the intervention. Stress reactivity was reported to be reduced by 71% of studies measuring physiological outcomes and 65% of studies measuring psychological outcomes. These studies show that a single session of yoga components is effective in reducing acute stress reactivity in adults and could be

recommended for stress management. Future studies with larger populations and a more equal representation of genders and age groups are warranted.

Keywords

yoga, meditation, pranayama, breathing, stress

3.3 Introduction

The survival benefit of the acute stress response is well established, however repeated and long-term exposure to stressors is associated with various physical and mental health conditions [1]. Chronic exposure to stressors including repeated acute stress responses results in wear and tear of the body systems and organs which is referred to as allostatic load [2]. Acute stress reactivity shows considerable individual differences [3], including sex [4], psychological functioning and genetic variations [5]. Current evidence shows that both exaggerated and attenuated stress reactivity is associated with adverse health outcomes [6]. It has been suggested that when the stress response is adaptive, systems return to baseline faster after the stressor ends. It follows that reducing heightened and prolonged reactivity could be important in reducing the risk of various health conditions. Some behavioural interventions (such as yoga, meditation, exercise, and health behaviours etc.) may have a positive effect in attenuating this stress reactivity [7].

Yoga encompasses a wide range of practices, from philosophical to spiritual but the body-mind practices are the most popular [8], these include components such as physical practices (asana or yoga poses or postures), breathing techniques (pranayama or breath control), relaxation and meditation (dhyana) [9]. In recent years, yoga has grown very rapidly in popularity around the world, for example, in 2017 about 14% of adults in the United States practised yoga and meditation in the last 12 months according to a National Health Interview Survey [10].

Yoga practice has been found to benefit many aspects of physical and mental health especially decreasing the risk factors of various diseases [11, 12]. Often, yoga interventions reported positive outcomes related to stress and may be the attenuation of stress is one of the mechanisms for yoga related health benefits [13]. Moreover, yoga has been shown to be effective in managing stress-related illnesses [14], anxiety and depression [15-17].

Although yoga practice typically includes physical postures, breathing techniques and meditation, these components have also been studied separately for their independent effect on health. For example, the practice of meditation offers many health benefits including improvement in physiological markers of stress [18] and emotional regulation [19]. Similarly, breathing techniques can improve cardiac autonomic functions and reduce stress [12].

Evidence suggests that the mechanism of yoga's effects on stress reduction may include the attenuation of the physiological and psychological responses to stress. Two different pathways have been proposed. First, a top-down neurocognitive model posits that the practice of yoga and meditation may increase emotional regulation and subsequently influence brain and nervous system activities, attenuating the processing of stressful stimuli [20-22]. A second hypothesized mechanism is based on a bottom-up neurophysiological model which suggests that yoga practices increase parasympathetic nervous system (PNS) activity [20, 22, 23], deactivating sympathetic nervous system (SNS)

activity [17, 24, 25] and the hypothalamic-pituitary-adrenal axis (HPA) [17], meaning the same stressful signal elicits an attenuated physiological response. In addition, psychological mechanisms such as mindfulness, interoceptive awareness, spiritual well-being have been found to be associated with attenuating effect of yoga on stress reactivity [13]. These mechanisms have been proposed based on studies of the habitual practice of yoga or its components including meditation, typically from a few weeks to several months.

A number of reviews have evaluated the effectiveness of yoga (1 to 24 weeks) or meditation training (3 to 15 weeks) on stress and have shown significant positive effects of the interventions on psychological [17, 26] and physiological measures of stress [11, 18]. However, it is not clear if these chronic effects of yoga and meditation are an accumulation of short-term effects of each yoga bout, or a gradual change over time, or a combination of both. Understanding this dose response is important to determine mechanisms and inform future interventions. So to understand the mechanisms of the positive effect of yoga and meditation in ameliorating stress reactivity, it is important to study the acute effects of these practices. No systematic review has focused on the effect of yoga components on acute stress reactivity as measured following a single session of practice. The aim of this systematic review is to summarise and synthesize the effects of a single session of yoga or its components including yoga poses, breathing techniques and meditation, on stress reactivity to an acute stress task in healthy adults.

3.4 Methods

3.4.1 Search strategy

The protocol and reporting of this systematic review adhere to the PRISMA guidelines [27]. The databases APA PsychInfo, Cinahl complete, Cochrane Central Register of Controlled Trials, Ovid Embase and Ovid Medline were searched on 30th July 2023 using broad search terms and MeSH terms. Additionally, we searched reference lists of included articles to identify additional studies. The complete search strategy used for the databases is presented in Supplementary file 1. The systematic review methodology was registered in PROSPERO (CRD42020214426) and is available at: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020214426.

3.4.2 Study selection

References of all retrieved studies were imported into ENDNOTE X9 citation management software (Clarivate Analytics, PA, USA). Duplicates were removed and the remaining studies were assessed for eligibility criteria by two researchers (GM and GS). Inclusion criteria were: Participants: adults aged 18 years or above; Intervention: a single session of yoga and/or meditation and exposure to a laboratory stressor (physiological or psychological task which induces acute stress); Comparator: active or passive control. Active controls include other forms of exercise such as walking and passive control refers to physically inactive control conditions such as reading or listening to music; Outcomes: Physiological and psychological markers of stress. Physiological measures include

cardiovascular markers (e.g., heart rate, blood pressure, heart rate variability), inflammatory markers (e.g., interleukin-6, C-reactive protein) or hormones (e.g., cortisol). Psychological measures include self-reported measures related to stress and anxiety. Timeframe: No restriction in regard to the publication year of the study was placed. Searches were conducted on 25th December 2020 and later updated on 7th February 2022. Study design: Randomised controlled trials (RCTs), including pilot, prospective, cluster and crossover RCTs. Other limits: Only studies published in the English language were considered for inclusion.

3.4.3 Data extraction

A data extraction form was developed (GS) based on the guidelines in the 6th version of the Cochrane Handbook for Systematic Reviews of Interventions [28]. The form was piloted on a subsample of the included studies and refined before being used by two authors (GM & BN) to extract the data: publication details (title, journal, year), authors' details (names, affiliations, funding, conflict of interest), study details (year, country, design, purpose, blinding and randomisation method, statistics), participants' characteristics (inclusion criteria, sample size, recruitment process, retention rate, compliance, and demographics i.e. age, sex, race, ethnicity, education and other), intervention (protocol description, stressor, duration, primary and secondary outcome factors), comparison (details of care, other details), results (primary and secondary outcomes and statistical significance), conclusions (considering study limitations).

3.4.4 Data analysis

The revised Cochrane risk-of-bias in randomised trials (ROB 2) tool was used to assess the quality of the studies on aspects of trial design (e.g. random-sequence generation and allocation concealment), trial conduct (e.g. appropriateness of analysis), and trial reporting (e.g. selective outcome reporting), and other sources of bias in accordance with the recommendations of the Cochrane Collaboration [29]. Since the review included both parallel group and crossover RCTs, both ROB 2 tools that correspond to each of these study designs were used. Studies were ranked by two authors (GM and GS) as “low risk”, “some concerns”, or high risk”. Authors resolved discrepancies by discussion.

3.4.5 Data synthesis

The heterogeneity of reported outcomes did not permit for a meta-analysis. Instead, the studies’ findings were presented in a tabular manner and synthesised narratively.

3.5 Results

A total of 5137 records were identified from initial searches and after removing 1,772 duplicates, 3365 abstracts were screened for possible inclusion. Of these, 121 articles were selected for full text screening. Finally, 28 studies meeting the inclusion criteria were selected for qualitative synthesis (Figure 1 – PRISMA 2020 flow diagram). The reasons for exclusion of full-text articles were: more than a single session of intervention (n=25), no relevant outcome (n=16), no laboratory stressor (n=12), not RCT or crossover design (n=13), no relevant population (n=9), conference proceedings or symposium abstract or review protocol (n=8), no relevant intervention (n=8) and no control group (n=2). The details of reasons for exclusion of studies is presented in Supplementary file 2.

3.5.1 Study Characteristics

Study characteristics are summarised in Table 1. Most studies were conducted in the USA (n=17), two studies were from the UK and Canada, and one study each from South Africa, India, China, Germany, Netherlands, Taiwan and Australia. A large majority of studies were parallel arm RCTs (n=25) and three were randomised crossover trials. Most of the articles (n=26) were published in the last 10 years.

Table 3 summarizes the ROB for each individual trial for the outcome. Four RCTs were evaluated as high risk, two of which due to concerns regarding randomization [30, 31] and two missing outcome data [32, 33]. The remainder of the trials were assessed as either low

risk (n=6) or with some concerns (n=16). Two crossover trials were deemed to be low risk while one had some concerns.

Table 1 - Summary of studies included.

Names, (Year) Country	Study design	Sample size	Demographics	Intervention Protocol and duration	Control Condition	Stressor	Physiological Outcomes	Psychological Outcomes
Meditation								
Archary et al., (2021) South Africa	RCT	N=60	Female = 65%, mean age 21.80, SD 6.09; age range 18 to 50	Focused attention meditation (breathing and sounds of ocean waves), 6 min Plant condition (indoor plants in the room), 6 min	Sit quietly (watch a blank computer screen)	Vigilance task		PANAS Dundee Stress State Questionnaire (DSSQ-S)
Azam et al., (2015) Canada	RCT	N=68	Female=43%; mean age for perfectionists 22.05, SD 1.57, and control 20.62, SD 0.82	Mindfulness meditation, 10 min	Audio (information on mindfulness meditation)	Computer-based pattern recognition task	HRV	
Borchardt et al., (2018) USA	RCT	N=107	Female = 56%; mean age 18.94, age range 18 to 22	Focused attention meditation, 20 min	1. Audio book 2 Sit quietly	PASAT	BP HR SC HRV (RMSSD)	PANAS
Carpenter et al., (2019) USA	RCT	N=107	Female = 66%; mean age 19.0, SD 1.4	Mindfulness components (present-moment awareness and nonjudgment), 15 min	Music	CPT Hyperventilation Neutralization task	Tidal volume	SUDS FFMQ Depression, Anxiety, and Stress Scale (DASS)
Carsley et al., (2020) Canada	RCT	N=167	Female =81%; mean age 21.29, SD 4.46	Mindfulness meditation (draw a mandala), 15 min Free drawing, 15 min	Place the numbers, letters etc. in boxes on the page	Wide Range Achievement Test (WRAT-4) (spelling section)		STAI (state) Child and
Crues et al., (2015) USA	RCT	N=123	Female = 65%; mean age 19.08, SD 1.02	Mindfulness meditation, 15-20 min	Relaxation and brief attention	TSST	Cortisol (salivary) Alpha-amylase (salivary)	Acute subjective distress

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Erisman et al., (2010) USA	RCT	N=33	Female = 55%, mean age 24.10, SD 7.28; age range 18 to 50	Mindfulness meditation, 10 min	Educational information	Film clips	SC HR	Difficulties in Emotion Regulation Scale (DERS) PANAS
Goleman et al., (1976) USA	RCT	N=60	Gender not reported; meditators' mean age 25, non-meditators' mean age 23; age range 18 to 31	Transcendental meditation, 20 min	Sit quietly (eyes open) Sit quietly (eyes closed)	Film clip	SC HR	Affect Adjective Check List (AACL) Activity Preference Questionnaire (APQ) STAI
Grant et al., (2013) USA	RCT	N=97	Female = 54%; 95.80% participants between age 18 to 21	Mindfulness component (breathing), 20 min	Audio book	CPT Mirror tracing task (MT)	BP HR	
Hirshberg et al., (2018) USA	RCT	N=166	Female = 61%, mean age 19.29, SD 0.74	Mindfulness component (breath awareness), 12 min Mindfulness component (loving-kindness), 12 min Mindfulness component (gratitude), 12 min	Attention control	CPT		Anxiety sensitivity index Gratitude questionnaire Implicit positive and negative affect task PANAS CPT aversiveness rating
Johnson et al., (2019) USA	RCT	N=75	Female = 79.4%, mean age 21.84, SD 3.48	Mindfulness meditation 5 min	Do nothing control	Speech and Anger recall task	BP	Momentary mood scale
Koerten et al., (2020) USA	RCT	N=120	Female = 74%; mean Age 19.39, SD 2.02	Mindfulness meditation (focus on nonjudgment), 10 min Mindfulness meditation (general), 10 min Progressive muscle relaxation, 10 min	Sit quietly	Cognitive task	HR HRV	
Liu et al., (2013) China	RCT	N=60	Female = 100%; mean age 20.48 years, SD 1.47	Mindfulness meditation, 15 min	Music	CPT	Pain tolerance	

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				Distraction intervention, 15 min			Pain ratings Distress ratings	
Masters et al., (2020) USA	RCT	N=85	Female = 55%; mean age 18.9, SD 1.2	Meditation (secular), 15 min Christian prayer, 15 min	Sit quietly (watching nature landscapes)	Religious views interview	BP HR	PANAS
Mohan et al., (2011) India	RCT	N=32	Female = 0%; mean age 27.3, SD 1.8; age range 23 to 30	Focused attention meditation, 20 min	Sit quietly	Stressful computer game	HR EMG SC QTc/QS2 Cortisol	Acute stress questionnaire
Rausch et al., (2006) USA	RCT	N=405	Female = 71%; mean age 19, SD 3.37; age range 17 to 42	Meditation (mantra), 20 min Progressive muscle relaxation, 20 min	Sit quietly	Four negative affect- and arousal-evoking photographic slides.		STAI Cognitive Anxiety Scale (CAS) Smith Somatic Stress Symptoms Scale-State (SSSSS-S)
Rosenbaum et al., (2020) Germany	RCT	N=67	Female = 72%; mean age mindfulness low rumination 28.6, SD 9.59; mindfulness high rumination 23.2, SD 3.15; instructed thinking low rumination 22.9, SD 3.46; instructed thinking High rumination 22.3, SD 3.46	Mindfulness meditation, 14 trials of 40 sec	Instructed thinking (direct attention to past or future)	Movie clips with strongly negative or neutral valence.	Cortical activation	PANAS
Steffen et al., (2015) USA	RCT	N=62	Female = 50%; mean age mindfulness 19.9, SD 2.0; mean age control 20.6, SD 2.3	Mindfulness meditation, 14.33 min	Audio (related to mindfulness)	PASAT	1.BP 2.HR	STAI (State)
van Hooff et al., (2013) Netherlands	RCT	N=100	Female = 70%; mean age 21.99, SD 5.38	Focused attention meditation (visualisation), 15 min	Audio (related to meditation)	Speech preparation task		SUDS PANAS

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Wilson et al., (2014) UK	RCT	N=80	Female = 60%; mean age 27.12, SD 6.37; age range 18 to 40	Acceptance strategy Mindfulness strategy Suppression strategy Endurance strategy, duration not reported	Audio (content about nature)	Verbal analogy trials	SC	Relaxation and anxiety related adjectives
Breathing								
Chelidoni et al., (2020) UK	RCT	N=75	Female = 64%; mean age 32.32, SD 10.46, age range 18 to 62	Mindfulness meditation (body scan), 5 min Breathing (using BioBase App), 5 min	Sit quietly	Continuous performance task Film clips	HRV	Samn-Perelli Fatigue Checklist Stanford Sleepiness Scale VAS for Moods
Chin et al., (2019) USA	RCT	N=48	Female = 0%; mean age	Breathing, 5 min	Read four adapted articles	Stroop test	HRV	
			Breathing- 29.7	Contraction + relaxation of arm muscles, 5 min				
			Contraction + relaxation - 26.7	Breathing and contraction + relaxation, 5 min				
			Breathing & Contraction + relaxation - 32.3					
			Control - 30.3					
			Age range 18 to 55					
Smith et al., (2017) USA	RCT	N=63	Female = 62%; mean age 20; age range 18 to 23	Breathing, 10 min Progressive muscle relaxation, 10 min	Sit quietly (watch a moving dot on screen)	CPT	ECG HRV	STAI PSS
Yoga								
Benvenuti et al., (2017) Australia	Randomised crossover	N=24	Female = 46%; mean age 22.9, SD 3.5	Yoga (Hatha), 30 min	Video (history of yoga)	PASAT	BP HR Cortisol (Salivary)	Immediate Anxiety Measures Scale (IAMS)
Chu et al., (2023) Taiwan	Randomised crossover	N= 44	Female = 52.3%; mean age = 24.66 SD 3.85 yr	Yoga (Hatha), 30 min	Video (History of Earth)	Stroop task Mental arithmetic task	HR, HRV	

Kiecolt-Glaser et al., (2010) USA	Randomised crossover	N=50	Female = 100%; mean age 41.32, SD 10.33; age range, 30 to 65	Yoga (Iyengar), 85 min	Walking (on treadmill) Neutral video	Stroop test (emotional) CPT Mental arithmetic task	IL-6 TNF- α CRP	Pittsburgh Sleep Quality Index (PSQI) Mood and Anxiety Symptom Questionnaire PANAS
Robinson et al., (2023) USA	RCT	N=97	Female = 65.5%; mean age 19.85, SD = 3.22	Yoga (Hatha)	Nature documentary	TSST	Cortisol (Salivary)	
Wheeler et al., (2019) USA	RCT	N=117	Female = 91%; mean age 19.5	Yoga (poses), 20 min Breathing (deep breathing, nadi shodhan, ujjayi etc.), 20 min Meditation (visualisation), 20 min	Audio (yoga lecture)	TSST	BP HR	PANAS STAI (state)

PASAT-Paced Auditory Serial Addition Test, CPT-Cold pressor task, TSST-Trier social stress test,

BP-Blood pressure, CRP-C-reactive protein, EMG-Electromyography, HR-Heart rate, HRV-Heart rate variability, IL-Interleukin, QTc/QS2-sympathetic reactivity, SC-Skin conductance,

TNF-Tumor necrosis factor, STAI-State trait anxiety inventory, PANAS-Positive and Negative Affect Schedule, PSS-Perceived Stress Scale, FFMQ-Five factor mindfulness questionnaire,

VAS-Visual analog scale, SUDS-Subjective units of distress

Table 2 – Summary of outcome measures and findings

Author	Intervention	Physiological Outcome Measures							Psychological Outcome Measures				
		SBP	DBP	HR	HRV -HF	Cortisol	SC	Other	STAI-S	PANAS +	PANAS -	Other	
Meditation													
Archary et al.	Meditation (FA)											↔	↓ p<0.05 DSSQ-S
Azam et al.	Meditation (MM)				↑ p<0.001								
Borchardt et al.	Meditation (FA)	↔	↔	↔	↔			↓ p<0.01				↔	↔
Carpenter et al.	Meditation (MC)												↔ SUD



Carsley et al.	Meditation (MM)									↓p<0.001
Cruess et al.	Relaxation				↓p<0.05				↔	↓p<0.05
	Meditation				↔				↔	↓p<0.05
									Alfa-Amylase (s)	
Erisman et al.	Meditation (MM)			↔					↔	↓p<0.05
Goleman et al.	Meditation (TM)			↓p<0.01					↓p<0.05	↓p<0.001
Grant et al.	Meditation (MC)	↑p<0.05	↔	↔						
		↔	↔	↔						
Hirshberg et al.	Meditation (MC)									↔
	Meditation (MC)									↔
	Gratitude									↑p<0.05
Johnson et al.	Meditation (MM)	↓p<0.001	↓p<0.001							↔
Koerten et al.	Meditation (MC)			↓p<0.001	↑p<0.001					
	Meditation (MM)			↓p<0.001	↔					
	Relaxation			↔	↔					
Liu et al.	Meditation (MM)								↓p<0.01	↓p<0.05
	Distraction								↓p<0.01	↔
									PT	DT
Masters et al.	Meditation (Secular)	↔	↔	↔						
Mohan et al.	Meditation (BS) (FA)			↓p<0.05		↓p<0.05	↓p<0.05	↓p<0.001	↓p<0.05	↓p<0.01
	Meditation (AS) (FA)			↔		↓p<0.001	↓p<0.001	↓p<0.01	↔	↓p<0.01
									EMG	QTc/QS2
Rausch et al.	Meditation									↓p<0.05
	Relaxation									↓p<0.05
Rosenbaum et al.	Meditation (MM)									↓p<0.001
										EDA
Steffen et al.	Meditation (MM)	↓p<0.001	↓p<0.05							
van Hooff et al.	Meditation (FA)									↑p<0.01
										↓p<0.05
										SUD
Wilson et al.	Acceptance								↓p<0.05	↔
	Meditation (MM)								↔	↔



		Suppression and endurance		↔		↔		Anxiety
Breathing								
Chelidoni et al.	Breathing		↑p=0.01		↑p<0.01 HRV- RMSSD		↑p<0.01 HRV-pNN50	
Chin et al.	Breathing		↔				↔	
	Contraction		↑p<0.001				↓p<0.01	
	Breathing + contraction		↑p<0.001				↓p<0.001 HRV (LF & LF/HF)	
Smith et al.	Breathing		↔				↔	↔
	Relaxation		↔				↔	↔
(PSS)								
Yoga								
Benvenuti et al.	Yoga	↓p<0.05	↓p<0.05		↓p=0.01 (salivary)			
Chu et al.	Yoga			↔	↔			
Kiecolt-Glaser et al.	Yoga vs movement			↓p<0.001			↓p<0.05	↑p<0.001
	Yoga vs video			↓p<0.05			↓p<0.05 TNF-α	↑p<0.001
Robinson et al.	Yoga vs Biofeedback				↔			
	Yoga vs video				↓p=0.01 (Salivary)			
Wheeler et al.	Yoga poses	↔	↔				↔	↔
	Breathing	↔	↔				↔	↔
	Meditation (FA)	↔	↔				↔	↔

↑-Significant increase, ↓- Significant decrease, ↔ - No change, Meditation (MM) - Mindfulness meditation, Meditation (TM) - Transcendental meditation, Meditation (FA) - Focused attention meditation, Meditation (MC) – Mindfulness component, Meditation (BS) - Meditation before stressor, Meditation (AS) - Meditation after stressor
 HR-Heart rate, HRV- Heart rate variability, SBP-Systolic blood pressure, DBP-Diastolic blood pressure, TNF-α - Tumor necrosis factor, QTc/QT2- ,
 ASQ-Acute stress questionnaire, DSSQ-Dundee Stress State Questionnaire, DT-Distress ratings, EDA-Emotional distress and avoidance,

PT-Pain tolerance time, PANAS+)/(–)-Positive affect/Negative affect, PSS-Perceived stress scale, STAI-S-State anxiety, SUD-Subjective units of distress

Table 3 – Risk of bias (ROB2)

RCT's						
Author	D1	D2	D3	D4	D5	Overall
Archary et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Azam et al.	Low risk	Low risk	Low risk	Low risk	Some concerns	Low risk
Borchardt et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Carpenter et al.	Low risk	Some concerns	Some concerns	Some concerns	Low risk	Low risk
Carsley et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Chelidoni et al.	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns
Cruess et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Erisman et al.	Low risk	Low risk	Low risk	Some concerns	Low risk	Some concerns
Goleman et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Grant et al.	Some concerns	Low risk	Some concerns	Low risk	Low risk	High risk
Hirshberg et al.	Some concerns	Low risk	Some concerns	Low risk	Low risk	Some concerns
Johnson et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Koerten et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Liu et al.	Low risk	Low risk	Some concerns	Low risk	Low risk	Some concerns
Masters et al.	Some concerns	Some concerns	High risk	Low risk	Low risk	High risk
Mohan et al.	High risk	Low risk	Low risk	Low risk	Low risk	High risk
Rausch et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Rosenbaum et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Smith et al.	Low risk	Low risk	Some concerns	Low risk	Low risk	Some concerns
Steffen et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
van hooff et al.	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns
Wilson et al.	Low risk	Low risk	Low risk	Some concerns	Some concerns	Some concerns
Chin et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Robinson et al.	Some concerns	Low risk	Some concerns	Low risk	Low risk	Some concerns
Wheeler et al.	Some concerns	Low risk	High risk	Low risk	Low risk	High risk
Crossover trials						
Benvenuti et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk



Chu et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Kiecolt-Glaser et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

D1-Randomisation process, D2-Deviations from the intended interventions,
 D3-Missing outcome data, D4-Measurement of the outcome, D5-Selection of the reported result,
 DS-Bias arising from period and carryover effects

3.5.2 Participant characteristics

A total of 2,574 participants were recruited across all 28 studies. Nine studies had 100 or more participants, 13 studies had 50 to 100 participants and six had 50 or less participants. Most studies had more female than male participants (n=20) and only two studies had more males. Two studies recruited female participants only and two male participants only. One study included equal male and female participants and one more study did not report the gender. Most studies had young adults with a mean age between 18.9 to 27.3 years (n=24) with two studies having participants with a mean age of 30 years or more. Two studies did not report the mean age. Across studies, participants were recruited mostly from universities and colleges (n=22). Eight studies had participants with no or minimal yoga or meditation experience, while seven studies recruited either experienced and /or a mixed population (experienced and naïve). The remaining studies did not report the yoga or meditation experience of the participants.

3.5.3 Intervention

Studies included various yoga components as interventions, mostly meditation (n=22), breathing techniques (n=4) and yoga (n=5). Five studies included multiple components of yoga (yoga poses, breathing, meditation, relaxation) as separate interventions. Of these, two included meditation and relaxation [34, 35], while the other three included meditation and breathing [36], breathing and relaxation [37], and meditation along with yoga poses

and breathing [33]. Meditation studies varied in type and duration. Fourteen studies used meditation based on mindfulness or components of mindfulness (such as awareness of breath and / or body, present moment awareness, loving-kindness meditation) while five other studies included focused attention meditation with focus on breath, body, relaxation or visualisation. Two studies used mantra meditation [35, 38], and Masters, Emerson [32] included secular meditation. Breathing techniques included deep breathing (rate of 5 to 6 breaths per minute) in three studies while the fourth study included various types of breathing (e.g., deep breathing, nadi shodhan or alternate nostril breathing, ujjayi) [33]. Regarding yoga, four studies selected hatha yoga or hatha yoga-based styles [39-42]. One study did not report yoga style [33].

The duration of meditation varied between 5 to 20 minutes, lasting between 15-20 minutes for twelve studies, and less than 12 minutes for nine studies. One study did not report the duration [43]. Three yoga studies were of 30 minutes duration [40-42] while one study was 20 minutes [33], and another study was 85 minutes [39]. The breathing duration was of 5 minutes in two studies [36, 44], 10 minutes in two other studies [37] and 20 minutes in one study [33].

In terms of delivery of interventions, most studies used audio or video recordings (n=15) or self-practice after brief instructions (n=9). In four studies, the intervention was delivered by an instructor. There was substantial variation in control conditions, ranging from listening

to an audio recording (n=9), or music (n=2), watching defined contents (video, images, blank computer screen or a dot) or reading (n=8) to sitting quietly, focusing (n=7), or thinking of a past or future event (n=1) and sorting of numbers or letters (n=1). Two studies included two control conditions [38, 39].

3.5.4 Stressor characteristics

To invoke a stress response in participants, different types of stress tasks were used. Most studies used a single stressor (n=22), but six studies included multiple stressors. Most used stressors were the cold pressor task (CPT) (n=6), mathematical/arithmetic tasks (n=6), film clips or images (n=4), the trier social stress test (TSST) (n=3), Stroop task (n=3) and the remaining stressors are listed in Table 1. The order of intervention and stress task varied across the studies. For the physiological stressors, four out of five studies had the intervention prior to the stress task, and one had both prior to and following the intervention. The order of psychological stressors was mixed with eight studies having it before and eleven after the interventions while four studies had stress task before and after the intervention.

3.5.5 Physiological and psychological outcome measures

Eighteen studies included at least one physiological outcome measure of stress. Heart rate (HR) was the most used measure (n=9) followed by blood pressure (BP) (n=7), heart

rate variability (HRV) (n=7), skin conductance (SC) (n=5), cortisol (n=4), salivary Alfa-amylase (sAA) (n=1), Interleukin (IL-6) (n=1), C-reactive protein (CRP) (n=1), Tumor necrosis factor (TNF- α) (n=1), and sympathetic reactivity (QTc/QS2 ratio) (n=1). Regarding psychological measures, 15 studies included various self-report questionnaires, including: Positive and Negative Affect Schedule (PANAS) (n=7), The State-Trait Anxiety Inventory (STAI) (n=6), Perceived Stress Scale (PSS) (n=1), subjective units of distress (n=1), acute stress questionnaire (n=1), Dundee Stress State Questionnaire (n=1), momentary mood scale (n=1) and self-report relaxation and anxiety scales (n=1). Ten out of 28 studies included both physiological and psychological measures. Thirteen studies used more than one physiological measure, and 11 studies included more than one psychological stress measure.

3.5.6 Study findings

The summary of outcome measures and findings can be found in Table 2. Out of 28 studies included in this review, 21 studies reported statistically significant beneficial effect of yoga or breathing or meditation on stress outcomes. Seventy-seven percent (17 of 22) of meditation, 60% of yoga (3 of 5) and 50% (2 of 4) of breathing interventions reported beneficial effects of yoga-based interventions. Of the 21 studies that used physiological measures, 15 showed statistically significant effects in favour of yoga / meditation / breathing for at least one outcome. All four studies that included cortisol measures showed significant reduction favouring the intervention conditions. Four of five studies

employing SC and four out of seven using HRV found significant results in favour of the intervention. For BP, only three out of seven studies showed significant effect of the intervention, no effect was found by three studies while one study reported a greater rise in SBP compared to the control condition [30] which was contrary to the hypothesis. For HR, three out of nine studies showed significant effect for the intervention and six found no difference. Regarding the psychological measures, 11 out of 17 studies reported statistically significant changes indicative of a beneficial effect of intervention on stress reactivity. For anxiety, four out of six studies reported significant reduction and three out of seven studies had significant changes in positive and/or negative affect in favour of the intervention. Moreover, ten studies included physiological and psychological stress measures, four found notable difference in both measures of stress reactivity [31, 38, 39, 45]. Nine out of 12 (75%) studies having 15 to 20 min meditation practice reported significant effect on stress reactivity in at least one outcome measure and six out of nine (67%) studies with < 12 min practice duration reported favourable outcomes in one of the outcome measures.

For the studies that compared two or more yoga components, results of comparison between the effectiveness of components were mixed. One study found breathing was more effective than meditation [36]. Two studies comparing meditation with relaxation reported both interventions to be effective with one reporting meditation more effective [34] and one reporting relaxation more effective [35]. In contrast, two studies comparing

breathing with relaxation [37] and yoga poses with breathing and meditation [33] found no difference between any of the interventions and control.

3.6 Discussion

To our knowledge, this is the first systematic review to synthesise the acute effects of yoga and meditation on stress reactivity. Overall, the included studies reported beneficial effects of a single session of yoga or its components including meditation, on reducing acute stress reactivity which has implications for physical and mental health. We found more than three quarters of studies reporting reduced acute stress reactivity. In line with the previously hypothesized mechanisms [22], our findings suggest a single session of yoga components leads to deactivation of SNS, HPA axis and activation of PNS which lead to reduced acute stress reactivity.

Elucidating the optimal characteristics of practise of yoga components to maximise its effectiveness is necessary for making most effective recommendations for health benefits. Our analysis therefore examined features including duration of sessions, specificity of action regarding stressor type and the intervention task characteristics as well as the most commonly affected outcome measures.

There is a large variation in recommendations for duration of a single session of meditation practice. For example, mindfulness based stress reduction program as designed by Kabat-Zinn recommends 45 minutes to one hour of meditation every day [46] while transcendental meditation (based on mantra repetition) recommends 15 to 20 minutes twice a day [47-49]. While a positive relationship between meditation time and health

benefits have been established for long-term practice [26], the current review based on a single session (acute effects) found benefits of meditation in ameliorating the stress reactivity irrespective of the duration of meditation. Regarding the duration of yoga, previous reviews of chronic practice have reported significant positive effects where the duration of multiple yoga sessions was between 35 and 90 minutes [17, 50]. Although we included only five studies of yoga, three studies showing beneficial effects used 30 min or more durations while two studies finding no effect were of 30 min and 20 min durations giving partial support to greater efficacy of longer duration practice. In contrast, two out of four breathing interventions of 5 minutes duration reported significant effect, but the longer duration interventions did not find any evidence. The two studies having longer than 5 minutes duration used complex modality in breathing intervention such as nine types of breathing practices or synchronising breath while watching movement on the screen [33, 37]. In contrast, the 5 minutes breathing interventions used simple deep breathing technique [36, 44] and had beneficial effects on stress reactivity. Our findings support previous evidence of usefulness of deep breathing in reducing stress [51].

In the studies included in this review, acute stress was induced using a variety of stress tasks administered at different points in the sequence of the experiment (before the intervention or after the intervention or both). Unsurprisingly, different stress tasks evoke different patterns and magnitudes of responses. For example, a mental arithmetic task vs CPT or cycling produced different SNS receptor activation [52] and the TSST evoked greater HPA axis response compared with CPT [53, 54]. Given this, we considered the effects of

stressors when broadly categorised as physical or psychological stressors [55, 56]. Although the stress reactivity to physical stressors such as CPT can be reduced using multiple session practise of yoga-based interventions [57], the four out of five meditation studies involving physical stressors (CPT) in this review did not report any significant effect [30, 37, 58, 59]. On the contrary, 16 out of 17 studies involving psychological stressors did report beneficial effect of meditation. Protocol differences were reported in studies using different stressor types, but it appears that the timing of the stressor did not affect the intervention effect. All yoga and breathing interventions included psychological stressors with 60% and 50% respectively showing positive effect on response to stressors. These results show the effectiveness of a single session of yoga components in reducing stress reactivity where the stressor was based on psychological (cognitive or emotional or psychosocial or mental) stimuli. Whereas we found little evidence for effect when the stressor was physiological. Together, this evidence points to the top-down neurocognitive model in attenuating stress reactivity after the single session of yoga components. Different meditation techniques were employed in included interventions. A number of these are techniques of meditation described in traditional yoga (for example, mantra meditation) that highlight the importance of uninterrupted sustained attention on a single object [8]. These different types of meditations can be broadly classified as focused attention (focusing on an object in a sustained manner) and open monitoring meditations (nonjudgmental present awareness) [60]. Mindfulness meditation which is a systematic and unified attentional technique rooted in Buddhism and yoga [61] that combines both

focused attention and open monitoring types [60]. In this review, the nine studies that included mindfulness meditation reported positive evidence of reduction in stress reactivity. Similarly, studies using focused attention meditation (e.g., focusing on breath or body scan or relaxation or visualisation) or mantra meditation also reported significant improvement in at least one stress related outcome. The mindfulness meditation typically includes various components such as breathing, body scan, present moment awareness, and loving-kindness meditation [46]. Notably of the five meditation studies that reported no significant effect of intervention in any of the stress measures, four of these used individual components of mindfulness meditation [30, 37, 58, 59] and the fifth one used a secular meditation involving reading of passages and deep reflection [32]. This suggests that traditional meditation techniques are more effective than separated components in providing attenuation of the stress response. A possible explanation is the very developed, logical, methodical and multimodal development of attentional focus in traditional meditations [61] compared to simplified and less progressive process when components are separated.

The three yoga interventions reporting positive effects support the previous findings of beneficial effects of hatha yoga-based styles [62]. Interestingly, these three yoga interventions included breathing and meditation components along with physical postures in the protocol. But the proportions of these components were not specified. Different yoga styles give varying importance to physical postures, breathing and meditation [63].

However, the effects of the contribution of these components on stress reactivity and overall physical and mental health are yet to be evaluated.

The outcome measures we found most consistently attenuated by yoga-based practices were HRV, SC and cortisol. These findings indicate that meditation and yoga interventions can increase PNS activity during stress reactivity (indicated by HRV) [64], decrease stress-induced SNS activity (indicated by SC) [65] and attenuate HPA response (cortisol) [2]. Our synthesis of the findings supports previous evidence of immediate effect of yoga on downregulating HPA axis and SNS [66]. HR and BP outcomes were not consistently affected across studies. It is possible that this inconsistency in BP and HR measures is due to the composite nature of these measures given responses are controlled by many physiological processes including both sympathetic and parasympathetic activity as well as hormonal factors. The hypothesised mechanisms for the effect of yoga components include top-down and bottom-up approach. The effect of yoga interventions on stress reactivity to psychological stressor points to the role of top-down cognitive as well as bottom-up physiological model. While comparing the yoga interventions with meditation practices, such as mindfulness, yoga includes more physical movements, static postures along with conscious breath control and attentional focus which may have a stronger effect on vagus nerve and subsequently on autonomic, emotional and cognitive regulation [21]. However, this review could not compare yoga and meditation interventions due to

small number of yoga studies (n=5), and the outcome measures were not comparable between most of the yoga and meditation studies.

Finally, two studies reporting significant effect of intervention also found differences in stress reactivity between novices and experienced practitioners. The experienced practitioners were quickly habituated to the stressor, had significantly faster stress recovery [38] and less inflammatory response [39].

3.6.1 Strengths and limitations

The strength of this review lies in the use of robust methodologies to synthesise existing evidence, such as those documented by PRISMA and the Cochrane Collaboration. It is worth noting that all studies classified as low risk of bias reported benefits of interventions on stress reactivity, while these benefits were less consistent in studies with some concerns or high risk of bias. However, only 29% of studies were classified as low risk of bias. Searches were not restricted by year of publication. Limitations of this review include the relatively small number of studies with diverse outcome measures. Additionally, most of the studies included a younger population, with greater proportion of female participants, limiting the generalisability of the findings. The variety in intervention protocols, delivery methods and reported outcomes, rendered a meta-analysis of the effect of yoga components in stress reactivity reduction impossible. Finally, this review only included studies published in English.

3.6.2 Conclusion

Considering the important role of stress in development of physical and mental health problems, it is very helpful if simple practices such as yoga and meditation can be recommended for stress management and understanding the effects of a single session will support recommendations as well as understanding of mechanisms. Although this systematic review is based on a small number of studies, we found supporting evidence for a single session of meditation in deactivating HPA axis and SNS activity while increasing PNS activity associated with stress and limited similar evidence for yoga and breathing. These findings support the top-down neurocognitive model and bottom-up neurophysiological model of attenuation of stress especially related to single session of yoga. Future research is needed to understand and quantify the effects of different yoga components and their combinations for various health benefits. More high-quality studies conducted in larger groups which include different age groups are needed. Future research with comparable intervention protocols including duration of yoga components is needed. Additionally, the inclusion of comparable stress tasks and outcome measures will help in developing deeper understanding of the mechanisms of yoga and meditation effects on stress.

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Conflict of interest statement

All authors declare no conflicts of interest, financial or otherwise.

Data availability statement

Template data collection forms, data extracted from included studies, and data used for analyses can all be made available upon request.

Human and animal rights

This article does not contain any studies with human participants or animals performed by any of the authors.

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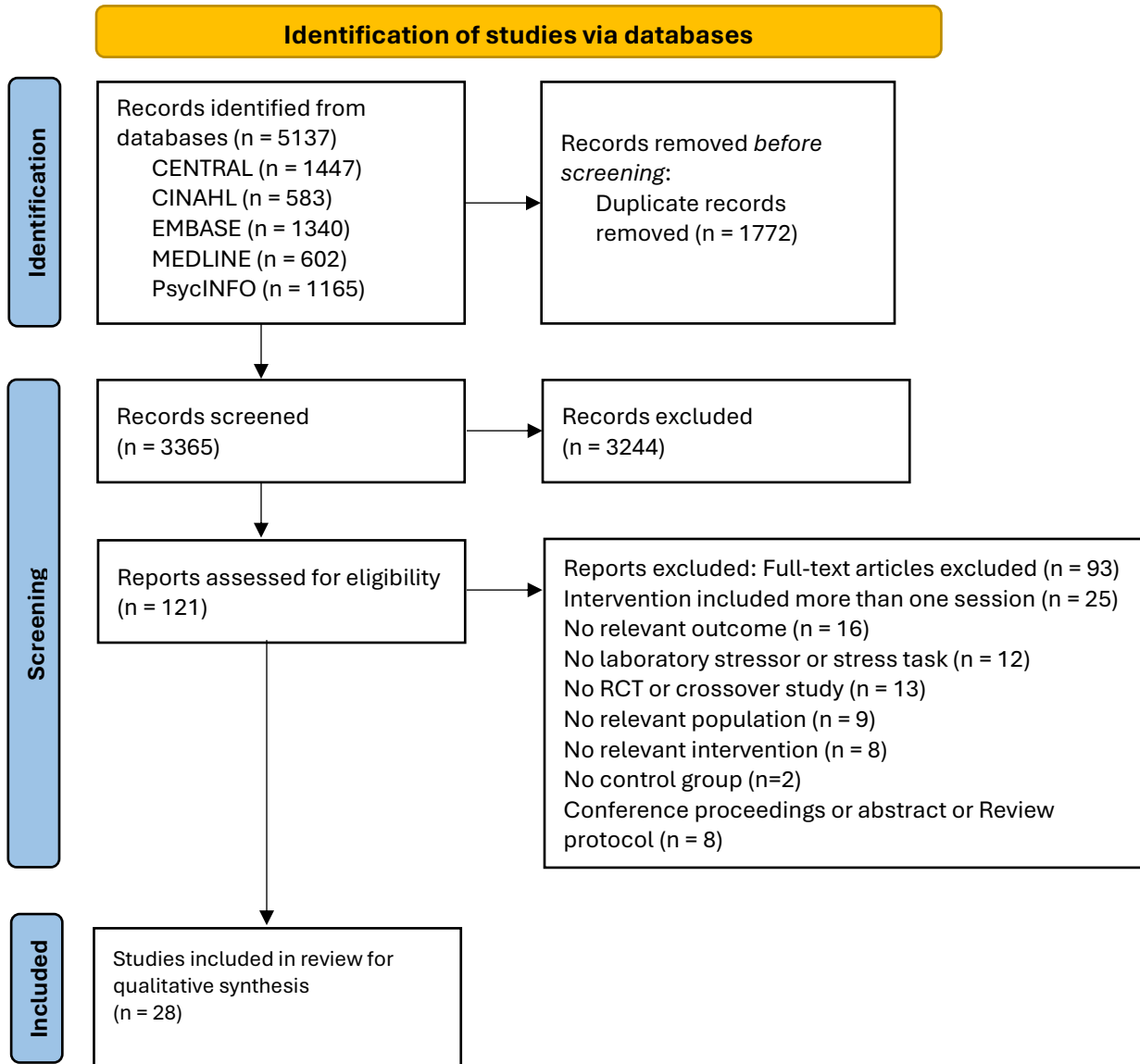
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3.9 Supplementary files and figure

3.9.1 Figure 1 PRISMA 2020 flow diagram



3.9.2 Supplementary file 1 – Database Search Strategies

MEDLINE search strategy

- 1 yoga.mp. or exp Yoga/
- 2 pranayama.mp.
- 3 meditat*.mp.
- 4 mindfulness.mp. or Mindfulness/
- 5 MBSR.mp.
- 6 dhyana.mp.
- 7 yogi*.mp.
- 8 stressor.mp.
- 9 stress.mp.
- 10 task.mp.
- 11 reactivity.mp.
- 12 response.mp.
- 13 reaction.mp.
- 14 acute.mp.
- 15 recovery.mp.
- 16 9 and 10
- 17 9 and 11
- 18 9 and 12
- 19 9 and 13
- 20 9 and 14
- 21 9 and 15
- 22 8 or 16 or 17 or 18 or 19 or 20 or 21
- 23 1 or 2 or 3 or 4 or 5 or 6 or 7
- 24 22 and 23
- 25 limit 24 to (english language and ("young adult (19 to 24 years)" or "adult (19 to 44 years)" or "young adult and adult (19-24 and 19-44)" or "middle age (45 to 64 years)" or "middle aged (45 plus years)" or "all aged (65 and over)" or "aged (80 and over)"))

CINAHL search strategy

- S1 MM "Yoga+" OR "yoga" OR MM "Yoga Pose"
- S2 pranayama
- S3 MM "Mindfulness" OR MM "Meditation Iowa NIC" OR MM "Meditation" OR "meditation"
- S4 yogi*
- S5 mbsr
- S6 dhyana
- S7 stressor
- S8 stress
- S9 task
- S10 reactivity
- S11 response
- S12 reaction
- S13 acute
- S14 S8 AND S9
- S15 S8 AND S10
- S16 S8 AND S11
- S17 S8 AND S12
- S18 S8 AND S13
- S19 recovery
- S20 S8 AND S19
- S21 S1 OR S2 OR S3 OR S4 OR S5 OR S6
- S22 S14 OR S15 OR S16 OR S17 OR S18 OR S20
- S23 S21 AND S22 (Limit to English language and Adults)

EMBASE search strategy

- 1 exp yoga/ or exp iyengar yoga/ or exp hatha yoga/ or exp hot yoga/ or exp yoga nidra/ or yoga.mp.
- 2 pranayama.mp.
- 3 exp mindfulness meditation/ or exp transcendental meditation/ or exp meditation/ or exp open monitoring meditation/ or exp focused attention meditation/ or meditation.mp.
- 4 exp mindfulness meditation/ or exp mindfulness/ or mindfulness.mp.
- 5 MBSR.mp.
- 6 dhyana.mp.

- 7 yogi*.mp.
- 8 stressor.mp.
- 9 acute stress.mp. or exp acute stress/
- 10 stress.mp.
- 11 task.mp.
- 12 reactivity.mp.
- 13 response.mp.
- 14 reaction.mp.
- 15 recovery.mp.
- 16 10 and 11
- 17 10 and 12
- 18 10 and 13
- 19 10 and 14
- 20 10 and 15
- 21 8 or 9 or 16 or 17 or 18 or 19 or 20
- 22 1 or 2 or 3 or 4 or 5 or 6 or 7
- 23 21 and 22
- 24 limit 23 to (english language and (adult <18 to 64 years> or aged <65+ years>))

PscycINFO search strategy

- 1 yoga.mp. or exp Yoga/
- 2 pranayama.mp.
- 3 meditation.mp. or exp Meditation/
- 4 meditat*.mp.
- 5 exp Mindfulness-Based Interventions/ or exp Mindfulness/ or mindfulness.mp.
- 6 MBSR.mp.
- 7 dhyana.mp.
- 8 yogi*.mp.
- 9 stressor.mp.
- 10 stress.mp.
- 11 task.mp.
- 12 reactivity.mp.

- 13 reaction.mp.
- 14 response.mp.
- 15 recovery.mp.
- 16 acute.mp.
- 17 10 and 11
- 18 10 and 12
- 19 10 and 13
- 20 10 and 14
- 21 10 and 15
- 22 10 and 16
- 23 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
- 24 9 or 17 or 18 or 19 or 20 or 21 or 22
- 25 23 and 24
- 26 limit 25 to (english language and ("300 adulthood <age 18 yrs and older>" or 320 young adulthood <age 18 to 29 yrs> or 340 thirties <age 30 to 39 yrs> or 360 middle age <age 40 to 64 yrs> or "380 aged <age 65 yrs and older>" or "390 very old <age 85 yrs and older>"))

Cochrane search strategy

- 1 yoga.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 2 pranayama.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 3 meditat*.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 4 mindfulness.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 5 dhyana.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 6 MBSR.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 7 yogi*.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 8 stressor.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 9 stress.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 10 reactivity.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 11 response.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 12 acute.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 13 task.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 14 reaction.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
- 15 9 and 10

16	9 and 11
17	9 and 12
18	9 and 13
19	9 and 14
20	recovery.mp. [mp=title, original title, abstract, mesh headings, heading words, keyword]
21	9 and 20
22	8 or 15 or 16 or 17 or 18 or 19 or 21
23	1 or 2 or 3 or 4 or 5 or 6 or 7
24	22 and 23
25	limit 24 to ("adult (19 to 44 years)" or "middle age (45 to 64 years)" or "middle aged (45 plus years)" or "all aged (65 and over)" or "aged (80 and over)") [Limit not valid; records were retained]
26	limit 25 to english language

3.9.3 Supplementary file 2 - Excluded full texts with reasons for exclusion

1. (2014). "Correction to Mindfulness-based stress reduction and physiological Activity During Acute Stress: a randomized controlled trial." *Health Psychology* 33(9): 1045.
Reason - Intervention had more than one session
2. (2019). "Mindfulness and cardiovascular health: outcomes, mechanisms & individual differences." *Psychosomatic Medicine* 81(4): A166-A167.
Reason – Symposium abstract
3. Aiello, M. (2018). The impact of brief mindfulness interventions on attentional control in anxious undergraduates: A randomized controlled study, *Dissertation Abstracts International: Section B: The Sciences and Engineering*. Vol.78(7-B(E)),2018, pp
Reason - No stress task
4. Alessi, M. G., et al. (2022). "Trait Mindfulness and Heart Rate Variability Reactivity during a Caffeine Manipulated Emotional Task." *Psychosomatic Medicine* Vol.84(5): A53p.
Reason - No relevant intervention
5. Archer, S. (2015). "BEING MINDFUL AFFECTS BODY'S STRESS RESPONSE." *IDEA Fitness Journal* **12**(1): 69-72.
Reason - No RCT or crossover
6. Azam, M. A., et al. (2016). "Individuals with tension and migraine headaches exhibit increased heart rate variability during post-stress mindfulness meditation practice but a decrease during a post-stress control condition - A randomized, controlled experiment." *International Journal of Psychophysiology* 110: 66-74.
Reason – No relevant population

7. Balasubramanian, S., et al. (2015). "Alterations in salivary proteome following single twenty-minute session of yogic breathing." *Evidence based complementary and alternative medicine*.
Reason – No stress task
8. Baquedano, C., et al. (2017). "Compared to self-immersion, mindful attention reduces salivation and automatic food bias." *Scientific reports* **7**(1): 13839.
Reason – No relevant outcome
9. Bay, E., et al. "Mindfulness-based group therapy vs healthy living intervention: A pilot RCT intervention." *Brain injury* **28**(5-6): 690.
Reason – More than one intervention session
10. Bellinger, D. B., et al. (2015). "Mindfulness, anxiety, and high-stakes mathematics performance in the laboratory and classroom." *Consciousness and Cognition* **37**: 123-132.
Reason – No RCT or crossover
11. Benvenuti, M. J., et al. (2019). "The interaction between trait mindfulness and the effect of a single yoga session on the response to an acute psychological stress." *Brain, Behavior, and Immunity* **76 (Supplement)**: e16.
Reason – conference abstract
12. Bera, T. K., et al. (1998). "Recovery from stress in two different postures and in Shavasana - A yogic relaxation posture." *Indian Journal of Physiology and Pharmacology* **42**(4): 473-478.
Reason - No stress task
13. Bergeron, C. M., et al. (2016). ""Letting go" (implicitly): Priming mindfulness mitigates the effects of a moderate social stressor." *Frontiers in Psychology* Vol 7 2016, ArtID 872 **7**.
Reason - No relevant intervention
14. Borlimi, R., et al. (2019). "An investigation of sequencing effects in combining cognitive questioning and mindful acceptance." *Journal of Rational-Emotive & Cognitive-Behavior Therapy* **37**(3): 284-298.
Reason – No relevant intervention
15. Bradley, B. W. and T. R. McCanne (1981). "Autonomic responses to stress: The effects of progressive relaxation, the relaxation response, and expectancy of relief." *Biofeedback and Self-Regulation* **6**(2): 235-251.
Reason: Intervention had more than one session
16. Budhi, B. R., et al. (2022). "Comparative Cross-sectional Study on Phasic Heart Rate Variability and Working Memory Among Young Adults." *Advances in Mind-Body Medicine* **36**(4): 12-19.
Reason - No relevant intervention
17. Cahn, B. (2022). "P244. Enhanced Frontal Midline Theta (fmTheta) Power After Mindfulness Training in Major Depressive Disorder (MDD) Patients Correlates With Improvements in Mindfulness, Depression, and Perceived Stress." *Biological Psychiatry* **91**(9 Supplement): S186.
Reason - No stress task
18. Colgary, C. D., et al. (2020). "One-Session Mindfulness versus Concentrative Meditation: The Effects of Stress Anticipation." *American Journal of Health Education* **51**(2): 120-128.
Reason – No control group

19. Cavanagh, K., et al. (2013). "A randomised controlled trial of a brief online mindfulness-based intervention." *Behaviour Research and Therapy* 51(9): 573-578.
Reason: Intervention had more than one session
20. Chaix, R., et al. (2020). "Differential DNA methylation in experienced meditators after an intensive day of mindfulness-based practice: Implications for immune-related pathways." *Brain, Behavior, and Immunity* 84: 36-44.
Reason: No stress task
21. Champion, L., et al. (2018). "The efficacy of a brief app-based mindfulness intervention on psychosocial outcomes in healthy adults: a pilot randomised controlled trial." [PLoS ONE \[Electronic Resource\]](#) **13**(12): e0209482.
Reason: Intervention had more than one session
22. Cho, Yoon-Ju., et al. (2020). "Effectiveness of training program combining chakrayoga and meditation." [Journal of complementary and integrative medicine](#) **17**(1).
Reason – Intervention had more than one session
23. Diaz-Silveira, C., et al. (2020). "Mindfulness versus Physical Exercise: effects of Two Recovery Strategies on Mental Health, Stress and Immunoglobulin A during Lunch Breaks. A Randomized Controlled Trial." [International journal of environmental research and public health](#) **17**(8).
Reason – Intervention had more than one session
24. Diaz, N. S. R., et al. (2014). "The role of mindfulness in coping with recollections of acute stressors: A laboratory study." *Psicothema* 26(4): 505-510.
Reason - No relevant intervention
25. Ding, X., et al. (2014). "Modeling emotion-creativity interaction following brief training." [BMC neuroscience](#) **15**(26).
Reason - Intervention had more than one session
26. Dutt, S., et al. (2019). "Healthy and unhealthy eating amongst stressed students: considering the influence of mindfulness on eating choices and consumption." *Health Psychology Report* 7(2): 113-120.
Reason - No relevant outcome
27. Edwards, M. K., et al. (2018). "Effects of acute aerobic exercise or meditation on emotional regulation." *Physiology & Behavior* 186: 16-24.
Reason - No relevant outcome
28. Erisman, S. M. (2011). "Psychosis-proneness, mindfulness, and positive emotional experience: Examining correlational and causal relationships." *Dissertation Abstracts International: Section B: The Sciences and Engineering* 72(2-B): 1162.
Reason - No stress task
29. Feldman, G., et al. (2010). "Differential effects of mindful breathing, progressive muscle relaxation, and loving-kindness meditation on decentering and negative reactions to repetitive thoughts." [Behaviour Research and Therapy](#) **48**(10): 1002-1011.
Reason – No stress task

30. Fennell, A. B., et al. (2016). "A single session of meditation reduces of physiological indices of anger in both experienced and novice meditators." *Consciousness and Cognition: An International Journal* 40: 54-66.

Reason - No RCT or crossover

31. Ferreira-Valente, A., et al. (4077). "Immediate Effects of Hypnosis, Mindfulness Meditation, and Prayer on Cold Pressor Outcomes: a Four-Arm Parallel Experimental Study." *Journal of pain research* 15: 4077-4096.

Reason – No control group

32. Galante, J., et al. (2018). "Effectiveness of providing university students with a mindfulness-based intervention to increase resilience to stress: a pragmatic randomised controlled trial." *Early intervention in psychiatry* 12(96).

Reason: Intervention had more than one session

33. Galante, J., et al. (2017). "A mindfulness-based intervention to increase resilience to stress in university students (the Mindful Student Study): a pragmatic randomised controlled trial." *The lancet public health*(pagination).

Reason: Intervention had more than one session

34. Galante, J., et al. (2020). "Effectiveness of providing university students with a mindfulness-based intervention to increase resilience to stress: 1-year follow-up of a pragmatic randomised controlled trial." *Journal of epidemiology and community health*.

Reason: Intervention had more than one session

35. Gallegos, A. M., et al. (2013). "Toward identifying the effects of the specific components of mindfulness-based stress reduction on biologic and emotional outcomes among older adults." *Journal of alternative and complementary medicine (new york, N.Y.)* 19(10): 787-792.

Reason: Intervention had more than one session

36. Gaylord, C., et al. (1989). "The effects of the transcendental mediation technique and progressive muscle relaxation on EEG coherence, stress reactivity, and mental health in black adults." *International journal of neuroscience* 46(1-2): 77-86.

Reason: Intervention had more than one session

37. Ghosh, P., et al. (2011). "Effects of yoga breathing and meditation on the cardiopulmonary response to sympathetic stimulation in college-aged students: A pilot study." *Physiotherapy* 97(20).

Reason: Intervention had more than one session

38. Goldstein, M. R., et al. (2020). "Improvements in well-being and cardiac metrics of stress following a yogic breathing workshop: randomized controlled trial with active comparison." *Journal of American college health*.

Reason: Intervention had more than one session

39. Gonen, M. L. (2016). "Does the induction of self-compassion buffer negative affect in those exposed to social evaluation?" *Dissertation Abstracts International: Section B: The Sciences and Engineering* 77(1-B(E)): No Pagination Specified.

Reason – No relevant intervention

40. Hall, J. M. (2004). "The Relaxation Response as an inoculation to arousal and a facilitator of decision-making." *Dissertation Abstracts International: Section B: The Sciences and Engineering* 64(7-B): 3524.

Reason – No relevant outcome

41. Hilt, L. M., et al. (2012). "Getting out of rumination: comparison of three brief interventions in a sample of youth." *Journal of Abnormal Child Psychology* 40(7): 1157-1165.

Reason - No relevant population

42. Hoge, E., et al. (2012). "Mindfulness training improves resilience: Reductions in adrenocorticotrophic hormone (ACTH) response to laboratory stress." *Neuropsychopharmacology* 38(2).

Reason - No relevant population

43. Ingold, K. and A. Lueke (2023). "A brief mindfulness intervention reduces the tendency to endorse negative Black stereotypes." *Journal of Applied Social Psychology* 53(2): 112-120.

Reason – No relevant outcome

44. Jin, P. (1992). "Efficacy of Tai Chi, brisk walking, meditation, and reading in reducing mental and emotional stress." *Journal of Psychosomatic Research* 36(4): 361-370.

Reason – Relevant outcome note reported

45. Kazzi, C., et al. (2018). "Effects of instructed meditation augmented by computer-rendered artificial virtual environment on heart rate variability." *Conference proceedings : .. Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual Conference. 2018: 2768-2771.*

Reason - Conference proceeding

46. Keng, S.-L., et al. (2013). "Reappraisal and mindfulness: A comparison of subjective effects and cognitive costs." *Behaviour Research and Therapy* 51(12): 899-904.

reason - No relevant population

47. Lathadevi, G. V., et al. (2012). "Modulation of cardiovascular response after ujjayi pranayama and shavasana training in normal human volunteers." *Journal of clinical and diagnostic research* 6(4 SUPPL. 2): 571-573.

Reason - Intervention had more than one session

48. Kral, Tamni R.A., et al. (2018). "Impact of short- and long-term mindfulness meditation training on amygdala reactivity to emotional stimuli." *NeuroImage* 181(pp 301-313).

Reason – Intervention had more than one session

49. Laurent, H. K., et al. (2015). "Dispositional mindfulness moderates the effect of a brief mindfulness induction on physiological stress responses." *Mindfulness* 6(5): 1192-1200.

Reason - No RCT or crossover

50. Leffler, E., et al. (2016). "The acute impact of relaxation techniques on student psychological and physiological health." *Journal of the American Pharmacists Association Conference: apha2016. Baltimore, MD United States. Conference start: 20160304. Conference end: 20160307. Conference publication:(var.pagings) 56(3): e100-e101.*

Reason - Conference proceeding

51. Lintel, I. A. G. (1980). "Physiological anxiety responses in transcendental meditators and nonmeditators." *Perceptual and Motor Skills* 50(1): 295-300.

Reason - No RCT or crossover

52. Madanmohan, et al. (2002). "Modulation of cold pressor-induced stress by shavasana in normal adult volunteers." *Indian Journal of Physiology and Pharmacology* 46(3): 307-312.

Reason – No RCT or crossover

53. Marr, C., et al. (2021). "Mitigating the negative effects of retrieval stress on memory: An arousal reappraisal intervention." *Memory* 29(3): 330-344.

Reason – No RCT or crossover

54. Novaes, M. M., et al. (2020). "Effects of Yoga Respiratory Practice (Bhastrika pranayama) on Anxiety, Affect, and Brain Functional Connectivity and Activity: a Randomized Controlled Trial." *Frontiers in psychiatry* 11.

Reason - Intervention had more than one session

55. Nyklicek, I., et al. (2013). "Mindfulness-based stress reduction and physiological activity during acute stress: a randomized controlled trial." *Health Psychology* 32(10): 1110-1113.

Reason - Intervention had more than one session

56. Olthuis, J. V., et al. (2011). "Therapist-delivered distance cognitive behavioural therapy for anxiety disorders in adults." *Cochrane Database of Systematic Reviews*(3).

Reason - This is the protocol for a review

57. Pace, T. W., et al. (2009). "Effect of compassion meditation on neuroendocrine, innate immune and behavioral responses to psychosocial stress." *Psychoneuroendocrinology* 34(1): 87-98.

Reason - Intervention had more than one session

58. Pavlov, S. V., et al. (2015). "Impact of long-term meditation practice on cardiovascular reactivity during perception and reappraisal of affective images." *International Journal of Psychophysiology* 95(3): 363-371.

Reason - No RCT or crossover

59. Paul, N. A., et al. (2013). "Psychological and neural mechanisms of trait mindfulness in reducing depression vulnerability." *Social Cognitive and Affective Neuroscience* 8(1): 56-64.

Reason – No RCT or crossover

60. Rodeback, R. E., et al. (2020). "The Association Between Experimentally Induced Stress, Performance Monitoring, and Response Inhibition: An Event-Related Potential (ERP) Analysis." *Frontiers in Human Neuroscience*

Exclude – No stress task

61. Sharma, A., et al. (2015). "The efficacy of a comprehensive yogic intervention on major depression-a randomized pilot study with inflammatory biomarkers." *Neuropsychopharmacology* 40.

Reason – No relevant population

62. Saoji, A., et al. (2017). "Effect of a Single Session of a Yogic Meditation Technique on Cognitive Performance in Medical Students: A Randomized Crossover Trial." *Journal of Religion & Health* 56(1): 141-148.

Reason – No relevant outcome

63. Schlatter, S. S., et al. (2023). "Personality traits influence the psychophysiological anticipatory stress responses and the effectiveness of coping interventions." *International Journal of Psychophysiology* 188(Supplement): 20.

Reason – conference abstract

64. Sevinc, Gunes., et al. (2018). "Common and dissociable neural activity after mindfulness-based stress reduction and relaxation response programs." Psychosomatic Medicine **80**(5): 439-451.
Reason – No stress task
65. Simon, N. M., et al. (2020). "Efficacy of yoga vs cognitive behavioral therapy vs stress education for the treatment of generalized anxiety disorder: a randomized clinical trial." JAMA psychiatry.
Reason – No relevant population
66. Shaabani, F., et al. (2020). "Does a brief mindfulness intervention counteract the detrimental effects of ego depletion in basketball free throw under pressure?" Sport, Exercise, and Performance Psychology **9**(2): 197-215.
Reason - No relevant outcome
67. Sharpe, L., et al. (2013). "A comparison of the effect of mindfulness and relaxation on responses to acute experimental pain." European Journal of Pain (United Kingdom) **17**(5): 742-752.
Reason- No relevant outcome
68. Shires, A., et al. (2019). "The relative efficacy of mindfulness versus distraction: The moderating role of attentional bias." European Journal of Pain (United Kingdom) **23**(4): 727-738.
Reason- No relevant outcome
69. Shuai, R., et al. (2020). "Ultra-brief breath counting (mindfulness) training promotes recovery from stress-induced alcohol-seeking in student drinkers." Addictive Behaviors **102**
Reason- No relevant outcome
70. Solarikova, P. and I. Bartolen (2020). "Higher HRV and lower anxiety in buddhist concentrative and zen-seated meditation in response to acute stress." Activitas Nervosa Superior Rediviva **62**(2): 53-63.
Reason –No RCT or crossover
71. Thomas, K. B. (2016). "The impact of a brief mindfulness exercise on autobiographical memory specificity in trauma-exposed college students." Dissertation Abstracts International: Section B: The Sciences and Engineering **77**(2-B(E)): No Pagination Specified.
Reason - No stress task
72. Twal, W. O., et al. (2016). "Yogic breathing when compared to attention control reduces the levels of pro-inflammatory biomarkers in saliva: a pilot randomized controlled trial." BMC Complementary and Alternative Medicine **16**(294).
Reason - No stress task
73. Tyagi, A., et al. (2014). "An explorative study of metabolic responses to mental stress and yoga practices in yoga practitioners, non-yoga practitioners and individuals with metabolic syndrome." BMC Complementary and Alternative Medicine **14**(1).
Reason – No relevant population
74. Tyagi, A., et al. (2016). "Heart Rate Variability, Flow, Mood and Mental Stress During Yoga Practices in Yoga Practitioners, Non-yoga Practitioners and People with Metabolic Syndrome." Applied psychophysiology and biofeedback **41**(4): 381-393.
Reason – No relevant population

75. Walton, K. G., et al. (2004). "Lowering cortisol and CVD risk in postmenopausal women: A pilot study using the transcendental meditation program." *Annals of the New York Academy of Sciences* 1032: 211-215.

Reason – No RCT or crossover

76. Wang, T., et al. (2019). "Imagining my painful hand is not mine: Self-distancing relieves experimental acute pain induced by a cold pressor task." *The Journal of Pain* 20(3): 358-365.

Reason – No relevant intervention

77. Wielgosz, J., et al. (2022). "Neural Signatures of Pain Modulation in Short-Term and Long-Term Mindfulness Training: A Randomized Active-Control Trial." *American Journal of Psychiatry* 179(10): 758-767.

Reason - Intervention had more than one session

78. Yin, J., et al. (2004). "Inhibitory effects of stress on postprandial gastric myoelectrical activity and vagal tone in healthy subjects." *Neurogastroenterology & Motility* 16(6): 737-744.

Reason – No RCT or crossover

79. (2020). "Gauging the effectiveness of music and yoga for reducing stress among engineering students: an investigation based on Galvanic Skin Response." *Work (Reading, Mass.)* 65(3): 671-678.

Reason – No stress task

80. Canella, R. and C. Gardi (2021). "Mindfulness based stress reduction (MBSR) program leads to a reduction in physiological evaluated stress." *Free Radical Biology and Medicine* 177(Supplement 1): S127.

Reason - Intervention had more than one session

81. Chaplin, T. M., et al. (2021). "Parenting-focused mindfulness intervention reduces stress and improves parenting in highly stressed mothers of adolescents." *Mindfulness* 12(2): 450-462.

Reason - Intervention had more than one session

82. Colgan, D. D., et al. (2020). "Patterns of respiration rate reactivity in response to cognitive stress associated with self-reported wellness and resilience." *Global Advances In Health and Medicine* 9: 86-87.

Reason – No relevant intervention

83. Dang, K., et al. (2021). "Meaning in life and vagally-mediated heart rate variability: Evidence of a quadratic relationship at baseline and vagal reactivity differences." *International Journal of Psychophysiology* 165: 101-111.

Reason – No relevant population (included participants Age 17 to -27 yrs)

84. Firth, A. M., et al. (2019). "Mindfulness and self-efficacy in pain perception, stress and academic performance. The influence of mindfulness on cognitive processes." *Psychology Research and Behavior Management Vol 12 2019, ArtID 565-574* 12.

Reason – No relevant outcome

85. Hase, A., et al. (2021). "Distress and retaliatory aggression in response to witnessing intergroup exclusion are greater on higher levels of collective narcissism." *Psychophysiology* 58(9): e13879.

Reason – No relevant outcome

86. Kaplan, J., et al. (2021). "Mindfulness moderates the relationship between health perception and physiological stress reactivity." *Global Advances In Health and Medicine* 10: 52.

Reason – conference abstract

87. Kirk, U. and J. L. Axelsen (2020). "Heart rate variability is enhanced during mindfulness practice: a randomized controlled trial involving a 10-day online-based mindfulness intervention." PLoS ONE **15**(12): e0243488.

Reason - Intervention had more than one session

88. Kirlic, N., et al. (2020). "Augmented mindfulness training for adolescents with early life stress exposure: fMRI neurofeedback feasibility study." Neuropsychopharmacology **45**: 81.

Reason – conference abstract

89. Manigault, A. W., et al. (2021). "Gender roles are related to cortisol habituation to repeated social evaluative stressors in adults: secondary analyses from a randomized controlled trial." Stress.

Reason - Intervention had more than one session

90. Mengin, A. C., et al. (2021). "Mindfulness Improves Otolaryngology Residents' Performance in a Simulated Bad-News Consultation: a Pilot Study." Journal of surgical education **78**(4): 1357-1365.

Reason – No relevant outcome

91. Merriman, L., et al. (2021). "Effect of a behavioral intervention on anxiety and perceived performance of non-technical skills during surgical simulations." American journal of surgery **222**(2): 329-333.

Reason – Not an acute stress response

92. Goldberg, S. B., et al. (2021). "Brief breath awareness training yields poorer working memory performance in the context of acute stress." Cognition & emotion **35**(5): 1009-1017.

Reason – No relevant outcome

93. Izzetoglu, M., et al. (2020). "Short-term effects of meditation on sustained attention as measured by fNIRS." Brain Sciences **10**(9): 1-16.

Reason – No RCT or crossover

'No Relevant outcome reported' is combined with 'No relevant outcome'

Chapter 4. Is stress reactivity different for traditional yoga and exercise-based yoga? A randomised crossover trial.

4.1 Abstract

Objectives: Yoga has been shown to attenuate the acute stress response. However, styles of yoga differ in their inclusion of class components. The inclusion of components known to attenuate stress responses when used independently (such as meditation and pranayama) may accentuate the stress response attenuation. The present study investigated the effects of traditional yoga (including physical postures and non-physical yoga components of pranayama, meditation and relaxation) and exercise-based yoga (focusing on physical postures only) and control (active and passive) conditions on acute stress reactivity.

Methods: Sixty-eight healthy adults participated in a counterbalanced, randomized-crossover trial, with traditional yoga, exercise-based yoga, active control (walking) and passive control (watching video) interventions. Participants attended the four sessions, each session comprised a baseline, intervention, mental arithmetic stress task and recovery period. Physiological outcome measures included blood pressure (BP), heart rate (HR), heart rate variability (HRV), and galvanic skin response (GSR). Psychological measures included anxiety, and positive and negative affect.

Results: A significant reduction in anxiety post-intervention was reported only in traditional yoga ($p=0.026$). Negative affect was significantly less in traditional yoga compared to video ($p=0.024$) post-intervention and compared to walking ($p=0.035$) and video ($p=0.017$) post-stress. Positive affect in traditional yoga was higher compared to video ($p=0.015$) post-intervention. Traditional yoga was more effective than exercise-based yoga in reducing SNS activation in response to stress (GSR recovery) and

increasing PNS activation (HRV: SDNN ($p=0.018$) post-intervention and HF ($p=0.041$) post-stress) as compared to exercise-based yoga. In contrast, exercise-based yoga resulted in elevated HR and reduced HRV (RMSSD) across intervention and stress which was not seen in any other condition.

Conclusion: A combination of physical (postures) and non-physical components (pranayama, meditation, chanting and relaxation) in traditional yoga style was more effective in attenuating acute stress reactivity compared to exercise-based yoga focused primarily on physical postures. These findings may support a mechanistic understanding of how more holistic yoga practice has greater benefit in stress and subsequently on health.

4.2 Introduction

Stress directly affects physical and mental health through autonomic and neuroendocrine changes and may indirectly contribute to unhealthy lifestyle behaviours (e.g. unhealthy eating) [1]. Excessive, prolonged, and repeated stress reactions can overload physiological response capacity and can lead to dysregulation of stress reactivity[2]. Overload and dysregulated acute stress responses cause wear and tear commonly referred to as ‘allostatic load’ which is associated with the development of various physical health conditions (e.g. obesity, cancer, diabetes, cardiovascular diseases.) and mental health conditions (e.g. depression and anxiety) [3].

Yoga, a globally popular mind-body practice has often been linked to stress reduction. Many systematic reviews have consistently reported that various physiological and psychological markers of stress show improvement with long-term practice of yoga (1 to 24 weeks) [4-7]. Further, the long-term practice of yoga has been shown to attenuate stress reactivity [8]. Even an acute practice of yoga involving just a single session can reduce various stress reactivity markers, which is thought to contribute to the long-term anti-stress effects of yoga practice [9]. The current evidence suggests that mechanisms through which yoga reduces stress reactivity include deactivation of the hypothalamic pituitary axis (HPA) and sympathetic nervous system (SNS) alongside the activation of the parasympathetic nervous system [9].

Yoga can be taught and practiced in many different styles, which can be broadly categorised as traditional yoga (typically identified with closeness of the yoga style to the ancient traditions, e.g., hatha yoga) or exercise-based yoga (identified with the focus of the yoga style on physical exercise, e.g., power yoga) [10]. Studies that have examined the effects of different yoga styles have found all of these styles to be beneficial in reducing stress, measured using various psychological and psychological outcomes [11]. Modern yoga styles such as vinyasa and power yoga are described as forms of physical exercise, with practice focused on physical postures, fitness [12], muscular strength and endurance [13]. It is therefore unsurprising that the effects of physical exercise and yoga poses are comparable in nearly all health-related parameters including stress reactivity [14]. On the other hand, traditional yoga styles, which are more commonly practiced in India, put greater emphasis on non-physical components than modern yoga [12]. A traditional yoga class includes more non-physical components such as chanting, relaxation, pranayama and meditation along with yoga poses, compared to exercise-based modern yoga class which gives greater emphasis on yoga poses and less on other components [10]. These non-physical components (low-intensity activity, 1-1.3 MET) [15, 16], have been independently shown to reduce stress and stress reactivity [17-20]. A traditional style yoga class may have greater effect on stress reactivity given that it includes yoga poses (exercise) in a similar manner to modern styles of yoga, but additionally includes features which also reduce stress reactivity. Given this combination, it is possible that traditional yoga may act through different, or additional mechanisms compared to exercise-based styles, amplifying the combined effects on stress reactivity. In partial support of this, a recent

study comparing a single session of traditional hatha yoga and exercise-based power yoga found that traditional yoga was more effective in improving physiological and psychological markers of stress [13]. Although there is evidence of the longer-term effects of different styles of yoga, the acute effect on stress reactivity has not been examined.

Therefore, this study aimed to compare the effect of traditional yoga and exercise-based yoga on acute stress reactivity using both an active (walking) and a resting control condition. Based on the limited evidence of a reduction in stress reactivity after a single session of yoga, we hypothesized that one single session of yoga would ameliorate physiological reactivity and speed up the recovery from a psychological stressor. Additionally, we hypothesized that traditional yoga would show a greater effect than exercise-based yoga in reducing stress reactivity.

4.3 Material and methods

4.3.1. Participants

We recruited participants through a large yoga institution in India, where a residential yoga program was conducted. This setting allowed us to recruit potential participants who were able to meet the requirement for four visits more easily. This enabled the recruitment of the target sample size but led to a more homogenous sample of experienced yoga practitioners. We recruited mostly experienced yoga practitioners knowing that the results would be not applicable to the inexperienced practitioners. Availability of participants during the residential program at the yoga institute was one the reasons behind this recruitment strategy. In addition, experienced practitioners allowed us to remove the novelty of yoga interventions and increased the possibility of more accurate practice of yoga components by participants which increased the reliability of the findings. Participants were recruited via advertisements on the social media handles of the Yoga Vidya Gurukul Institute, India. Participants filled in their contact details and provided informed consent via an online survey designed using the secure, web-based Research Electronic Data Capture (REDCap) application. The inclusion criteria were: aged ≥ 18 years; a minimum of two yoga sessions completed in the previous month without injury or adverse effect; not suffering from any immune, cardiovascular, metabolic or kidney disease/disorder; no current illness or infection; not using any prescribed medication (excluding the contraceptive pill); no pregnancy or suspected pregnancy; and non-smoker. Eligibility criteria also included the screening participants for exercise risk factors measured using the Physical Activity Readiness Questionnaire (PAR-Q) [21]. The study was approved by The University of Sydney

Human Research Ethics Committee (HREC 2022/185). All study data was collected between October 2022 and March 2023 at the Yoga Vidya Gurukul institute, Maharashtra, India.

4.3.2 Study design and procedures

The design of the study was a randomised crossover trial with all participants completing four sessions, each including one 60-minute intervention: traditional yoga, exercise-based yoga, interval walking (active control) and watching a video (passive control). A computer-generated randomisation algorithm (Balanced Latin-square design) was used for counterbalancing the order of interventions. Following participant consent, the allocation sequence, prepared by the chief investigator (KE) was revealed to the researcher. The assistant who was conducting the experiment and participants were blinded to the sequence order. Only the intervention of the day was informed to the assistant. Participants were informed about the intervention they would be receiving on the day of their session, just before starting the procedure by the assistant. The sessions were separated by a minimum of a 24 hr washout period between them to account for hypotensive effects following acute exercise which can last for 4 to 16 hours [22].

The candidate was not the yoga teacher. The sessions were not live streamed, instead a recorded video was played for each participant in the same hall on different days. As the entire experiment was conducted in a yoga institute in India, the recording was played in the hall of the institute.

Participants were asked to abstain from vigorous exercise for at least 24 hours, alcohol for 12 hours, caffeine for 2 hours, and food for 1 hour before starting each session. On arrival participants filled in a demographic questionnaire, which included questions related to yoga, meditation experience and preferred yoga styles. Yoga styles were later on categorised into four categories including traditional yoga, therapy yoga, exercise-based yoga and mixed styles (a combination of traditional and exercise-based yoga). Participants completed a 10-minute baseline period and measures of physiological outcomes of heart rate (HR), galvanic skin response (GSR), heart rate variability (HRV), and blood pressure (BP), and psychological outcomes using the State and Trait Anxiety Inventory (STAI) questionnaire [23] and Positive and Negative Affect Schedule (PANAS) [24] were recorded. Following the baseline period, participants completed one of the four interventions (60 mins) as per their assigned randomisation order. After the intervention, measures of HR, GSR, HRV, BP, STAI and PANAS were repeated during a 10 min break. Participants were then asked to complete a mental arithmetic stress task (Paced Auditory Serial Addition Test (PASAT) – 8-minute version) [25]. BP, STAI and PANAS were measured immediately after the PASAT and again after 15 minutes of seated recovery. GSR was recorded in the last minute of the stress task, after 5-14 minutes of recovery, while HR and HRV were recorded for the last 4 minutes of the stress task, 2- 6 minutes of recovery and 11-15 minutes of the recovery.

Figure 1 – Outline of the session including intervention, stress task and measurements.

4.3.3. Study interventions

Yoga interventions (traditional and exercise-based)

Traditional and exercise-based yoga interventions were performed using recorded instructional videos. Both videos were recorded by the same experienced yoga instructor to control for teaching style. In addition, another yoga instructor was present during the class to supervise and assist participants.

The traditional yoga intervention was comprised of Omkar meditation, followed by warmups, yoga poses, Savasana and pranayama. Participants performed a variety of traditional yoga poses involving forward bends, backbends, twists and stretches, held for 30-120 seconds steadily and comfortably accompanied by instructions for relaxation, focus on body parts and breath. Savasana (a relaxation pose) was added 2 times in the entire session of 60 minutes. To maximise the effect of pranayama practice, we included 4 pranayama techniques as described in the traditional ancient text of hatha yoga in a short period of 6 minutes. Pranayama included slow breathing techniques (for example, alternate nostril breathing, Bhramari, Ujjayi) and fast breathing techniques (kapalbhati and fast breathing). The evidence suggests that alternate nostril breathing, Bhramari and Ujjayi may increase PNS activity [26-29] and practice of Kapalbhathi and fast breathing may enhance SNS activity [28, 30]. The details of the traditional yoga class are given in Supplementary file 1 at the end of this chapter.

Exercise-based yoga included physical yoga poses only, which were held for up to 10 seconds. The sequence of yoga poses was taught in a flow that was comparable to physical strength exercises reflecting the design of exercise-based yoga styles such as Western adaptations of Ashtanga vinyasa [12]. The yoga poses in this program were

continuous without any breaks or relaxation in between but finished with a short Savasana. Besides some sitting and supine positions, most yoga poses were in a standing position. The instructions of practice were focused on asking the participants to do their best in performing various yoga poses. The details of the exercise-based yoga class are given in Supplementary file 1 at the end of this chapter. We did not include pranayama and meditation in the exercise-based protocol to magnify the difference between styles. The original vinyasa class guidelines were followed [31]. Finally, this design was to compare traditional yoga that included 70% of physical (yoga poses) and 30% of non-physical components (pranayama, meditation, relaxation) with the exercise-based yoga which included 5% relaxation and the remaining 95% yoga poses.

Low-intensity exercise (walking) intervention (active control)

Given the established effects of exercise on stress reactivity, we included an active control group. Participants completed 60 minutes of low-intensity interval walking at 40-45% of heart rate reserve (HRR). This intensity level was selected to compare the effects of low-intensity exercise to yoga since most styles of yoga have been shown to represent low-intensity physical activity [32-34]. Participants alternated between 3 minutes of low intensity walking and 3 minutes of very slow walking on an indoor treadmill for the 60 minute duration.

Passive control

Participants watched a non-yoga educational video on English grammar (BBC Learning English) that lasted 60 minutes. The video was played in the same room where participants completed other interventions. Participants were instructed to remain seated in a relaxed position for the entire duration of the video. Participants were instructed to not sleep during the intervention.

4.3.4. Stress task

A visual version of the PASAT was used to induce a stress response [35]. During the test, single-digit numbers were presented sequentially on a computer screen and participants were instructed to add the last two digits and say the answer loudly. The 8-minute version consisted of four 2-minute periods, where successively the time interval between the number of presentations decreased. For a wrong or missed answer the participant was given unpleasant feedback by announcement of the word 'wrong' loudly, increasing the stress experience through social evaluation [36].

4.3.5. Outcome measures

Physiological measures of stress

Blood pressure was recorded using a manual sphygmomanometer and brachial cuff around the non-dominant arm (Diamond BPMR120 Deluxe). Beat-to-beat HR was recorded using a chest strap Polar H10 heart rate monitor. HR and HRV were evaluated in 4-minute epochs through the Elite HRV mobile app and analysed using Kubios HRV software (version 3.5.0). GSR was manually recorded by Shimmer3 GSR unit and analysed by Consensus software application.

Autonomic activity was analysed using HRV and GSR measures. HRV measurements which included the time domain measures (SDNN, RMSSD) and frequency domain measures (LF, HF) were analysed. SDNN, RMSSD, and HF parameters have been closely related to parasympathetic cardiac control with higher values of SDNN, RMSSD and HF are indicative of higher parasympathetic activity while LF parameter is modulated by parasympathetic as well sympathetic activity [37, 38]. GSR measurement is directly related to SNS activity [39].

Psychological measures of stress

The state form of STAI was used to measure state anxiety. State anxiety represents transitory emotional states (i.e., how one feels at the moment) and has been shown to reliably measure psychological stress [23]. The STAI consists of a 20-item scale with answers scored on a 4-point Likert scale. Participants rated how closely each item described their present self, ranging from 1 (not at all) to 4 (very much). The PANAS scale which measures positive affect (PA), and negative affect (NA) was administered. NA is related to subjective distress and unpleasurable engagement while PA represents pleasurable engagement and a lower value is strongly correlated to depression [40].

4.3.6 Statistical analysis

To assess for normality of variance, the Kolmogorov-Smirnov test was used to determine if the data followed a normal distribution and log transformations were

performed where the data was not normally distributed (for STAI, PANAS-P, PANAS-N, DBP, SBP, GSR, RMSSD, LF, HF). Outliers were removed (for STAI-2.38%, PANAS-N-3.86%, PANAS-P-1.47%, HR-1.76%, DBP-1.47%, SBP-1.47%, GSR-16.32%, SDNN-15.81%, RMSSD-4.26%, LF-10.44%, HF-8.16%) before employing linear mixed models to analyse the between-groups and within-subject changes in each variable (HR, BP, HRV, GSR, STAI, PANAS). We employed mixed models to account for outliers and missing data. Outcome variables were assessed with fixed effects of intervention, time, and intervention \times time. To establish the carry-over effect and sequence order effect, the sequence variable was added to the model as fixed effect. Significant effects were examined using post-hoc tests with Bonferroni correction as an adjustment for multiple comparisons. Data are reported as mean (standard deviation). A p-value less than 0.05 was considered significant. Partial eta squared (η^2) was reported as a measure of effect size. All analyses were performed using SPSS (version 28.0).

Sample size calculations were based on an anticipated effect size of 0.3 and an $\alpha=0.05$, with four interventions and four or five repeated measure time points. This effect size was chosen based on a similar study examining the effect of Western yoga on responses to acute psychological stress [41]. We calculated a required sample size of $N=44$ participants for the study. Assuming a 20% dropout rate, we planned to recruit 53 participants. However, due to technical problems in GSR readings we recruited more participants ($N=68$).

4.4 Results

4.4.1 Demographics, effects of interventions and time

Participants' demographic characteristics along with yoga experience and style of yoga practice are presented in Table 1. A total of sixty-eight healthy adults ($n = 48$ female) participated in the current study (mean age: 38.9 ± 11.55 years, body mass index: 22.4 ± 3.08 kg/m²). There were no dropouts. All participants except one had 6 months or more experience of yoga practice. Eighty-five percent of participants practiced yoga sessions more than twice a week. Sixty-two percent of participants reported practising more than one hour of meditation a week. Majority of participants (70.6%) reported traditional yoga (for example, hatha yoga, Patanjali's ashtanga yoga) as their preferred style of practice. All participants completed all interventions. However, due to technical problems with sensors, GSR and HRV data for 4 participants data could not be retrieved from the sensors.

Analyses show significant effects of time and intervention for all outcome measures, with the exception of low frequency HRV for time effects and SBP for intervention effect. The time x intervention interaction did not reach significance for any outcome measure but approached significance for anxiety. All statistics for effects are summarised in Table 2. Post hoc test results indicating the differences found over time and between interventions are found in the relevant figures. All effect sizes (partial eta squared) were small (< 0.06). Carry-over and sequence order effect as analysed using linear mixed model was not significant for any of the outcome measures ($p > 0.05$).

Table 1 – Demographics and yoga experience of participants

Variable	Categories	Mean (SD)
Age (years)		38.91±11.55
Weight (kg)		61.21±9.42
Height (cm)		165.29±8.80
BMI (kg/m ²)		22.35±3.08
Sex		n (%)
	Male	20 (29.4%)
	Female	48 (70.6%)
Ethnicity		
	White	22 (32.4%)
	South Asians	28 (41.2%)
	Others	5 (7.5%)
	Missing	13 (19.1%)
No of yoga sessions in a week		
	Twice a week or less	10 (14.7%)
	More than twice a week	58 (85.3%)
Yoga Experience		
	0-2 years	16 (23.5%)
	2-5 years	23 (33.8%)
	5-10 years	10 (14.7%)
	More than 10 years	19 (27.9%)
Preferred Yoga styles		
	Traditional	48 (70.6%)
	Exercise-based	7 (10.3%)
	Mixed	13 (19.1%)
Meditation duration per week		
	No	20 (29.4%)
	< 1 hour	6 (8.8%)
	1-2 hours	19 (27.9%)
	3 or more hours	23 (33.8%)

Data are expressed as mean±SD or number (percent) accordingly. BMI-Body mass index

Table 2 – Effects of interventions on outcome variables across time points

Outcome	Time	p value	η_p^2	Intervention	p value	η_p^2	Time X Intervention	p value	η_p^2
Anxiety (STAI)	F (3, 1062) = 5.055	0.002 *	0.014	F (3, 1062) = 19.209	< 0.001 *	0.051	F (9, 1062) = 1.824	0.060 *	0.015
Positive affect (PANAS-P)	F (3, 1072) = 5.478	< 0.001 *	0.015	F (3, 1072) = 19.209	0.004 *	0.051	F (9, 1072) = 0.802	0.614	0.007
Negative affect (PANAS-N)	F (3, 1046) = 4.346	0.005 *	0.012	F (3, 1046) = 7.031	< 0.001 *	0.020	F (9, 1046) = 0.676	0.731	0.006
Heart Rate	F (4, 1336) = 9.510	< 0.001 *	0.028	F (3, 1336) = 10.630	< 0.001 *	0.023	F (12, 1336) = 1.053	0.397	0.009
Systolic Blood Pressure	F (3, 1057) = 3.949	0.008 *	0.011	F (3, 1072) = 1.296	0.275	0.004	F (9, 1072) = 0.344	0.960	0.003
Diastolic Blood Pressure	F (3, 1057) = 3.591	0.013 *	0.010	F (3, 1072) = 2.852	0.036 *	0.008	F (9, 1072) = 0.229	0.990	0.002
Galvanic Skin Resistance	F (4, 1138) = 24.002	< 0.001 *	0.078	F (3, 1138) = 3.806	0.010 *	0.010	F (12, 1138) = 0.310	0.988	0.003
HRV (SDNN)	F (4, 1145) = 2.496	0.041 *	0.009	F (3, 1145) = 4.368	0.005 *	0.011	F (12, 1145) = 1.093	0.362	0.011
HRV (RMSSD)	F (4, 1302) = 5.251	< 0.001 *	0.016	F (3, 1302) = 7.962	< 0.001 *	0.018	F (12, 1145) = 0.750	0.702	0.008
HRV (LF)	F (4, 1218) = 1.792	0.128	0.006	F (3, 1218) = 3.071	0.027 *	0.008	F (12, 1218) = 1.120	0.339	0.011
HRV (HF)	F (4, 1249) = 2.300	0.057 *	0.007	F (3, 1249) = 4.896	0.002 *	0.012	F (12, 1249) = 1.267	0.232	0.012

SDNN, RMSSD - HRV time domain measures, LF, HF - HRV frequency domain measures * Significant fixed effect

4.4.2 Psychological outcomes

Psychological outcomes are displayed in Figure 1.

Figure 1A presents geometric means of state anxiety scores across all timepoints for all interventions. The traditional yoga intervention reduced anxiety immediately post-intervention and at this point, anxiety was significantly lower than for exercise yoga and video conditions. Only the exercise yoga and video conditions showed greater anxiety post-stress compared to baseline, but anxiety improved for both these interventions from post-stress to recovery. As expected, anxiety increased for all interventions from post-intervention to post-stress.

Figure 1B and 1C respectively show the geometric means of positive affect and negative affect scores across all timepoints for all interventions. Positive affect was reduced post-stress compared to baseline in the exercise yoga and video conditions and was significantly greater in the traditional yoga condition immediately post-intervention than the video condition. Conversely, negative affect was greater post-intervention in the video control compared to traditional yoga, this effect was also found post-stress with a smaller effect for the traditional yoga condition than both video and walking conditions, and at recovery where it remained lower in traditional yoga compared to the video condition.

Figure 1 Geometric means of Anxiety (state), PANAS (P) and PANAS (N)

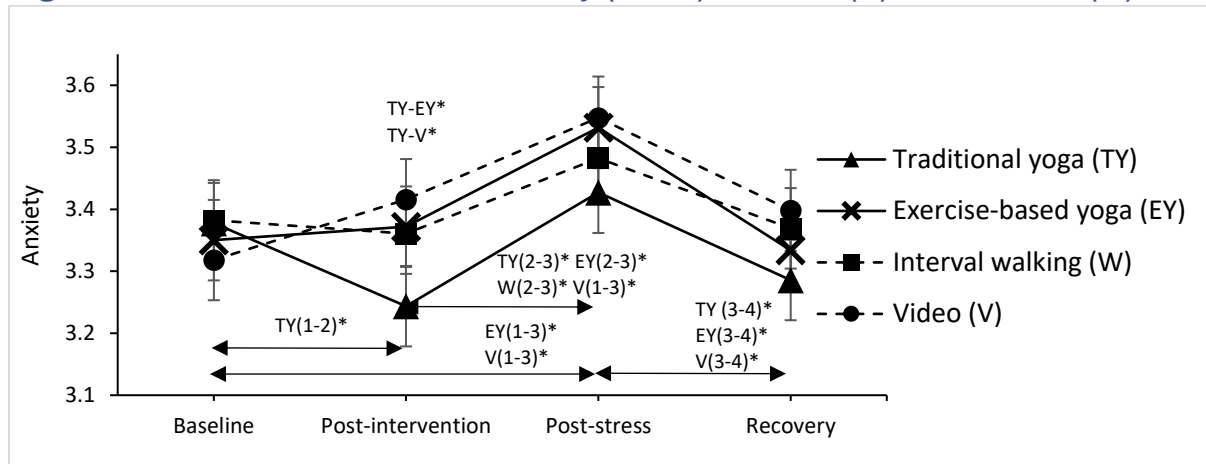


Figure 1A Geometric means of Anxiety (state) and Error bars (95% Confidence Interval) (1-2)- baseline–post intervention, (1-3)- baseline-post stress, (2-3) post intervention to-post-stress, (3-4)-post stress-recovery. p-values TY-EY*-p=0.037, TY-V*-p<0.001, TY(1-2)*-p=0.026, EY(1-3)*-p<0.001, V(1-3)*-p<0.001, TY(2-3)*-p<0.001, EY(2-3)*-p=0.004, W(2-3)*-p=0.064, V(2-3)*-p=0.033, TY(3-4) – p=0.016, EY(3-4)*-p<0.001, V(3-4)*-p=0.010

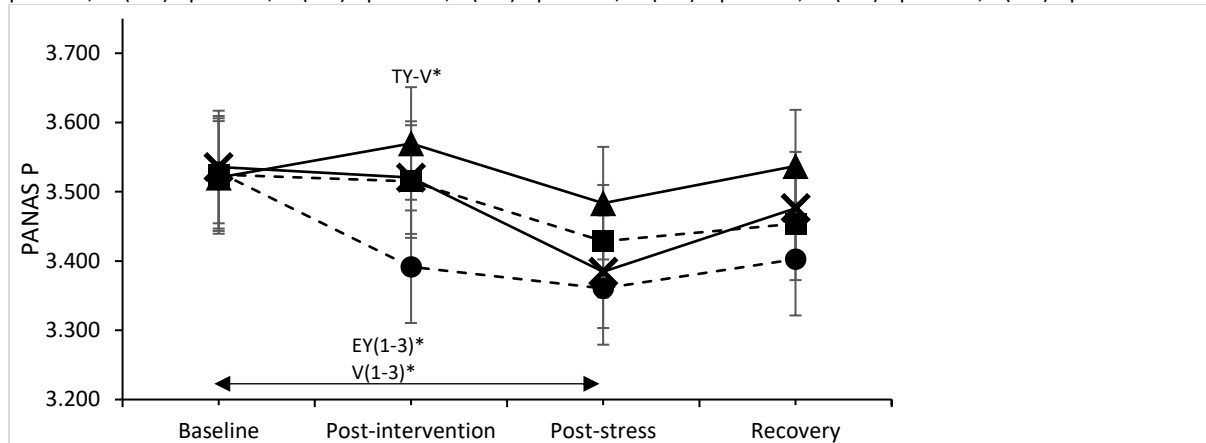


Figure 1B Geometric means of PANAS P and Error bars (95% Confidence Interval) (1-3)-difference between baseline-post stress. p-values TY-V*-p=0.015, V(1-3)*-p=0.026, EY(1-3)*-p=0.060

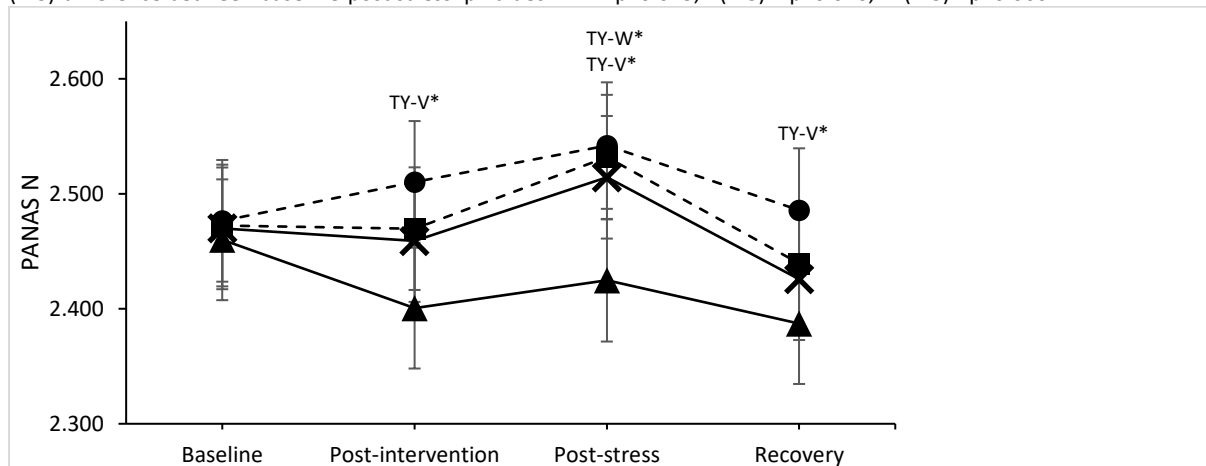


Figure 1C Geometric means of PANAS N and Error bars (95% Confidence Interval) p-values TY-V*(PI)-p=0.024, TY-W*-p=0.035, TY-V*(PS)-p=0.017, TY-V*(R)-p=0.061

4.4.3 Physiological outcomes

HR was unchanged across time points in both traditional yoga and video conditions, while in the exercise yoga condition, HR increased from baseline to post-stress and decreased from post-stress to 15-minute recovery. In the video condition, it decreased from post-stress to recovery and was also lower at 15-minute recovery compared to baseline. Neither systolic blood pressure (SBP) nor diastolic blood pressure (DBP) showed any differences across time or condition. GSR was reduced at 15-minute recovery compared to baseline in both exercise yoga and walking conditions. All data is displayed for HR, SBP, DSP and GSR in Figure 2.

Figure 2 - Means of HR, Geometric means for DBP, SBP and GSR, between group differences and within group differences for interventions.

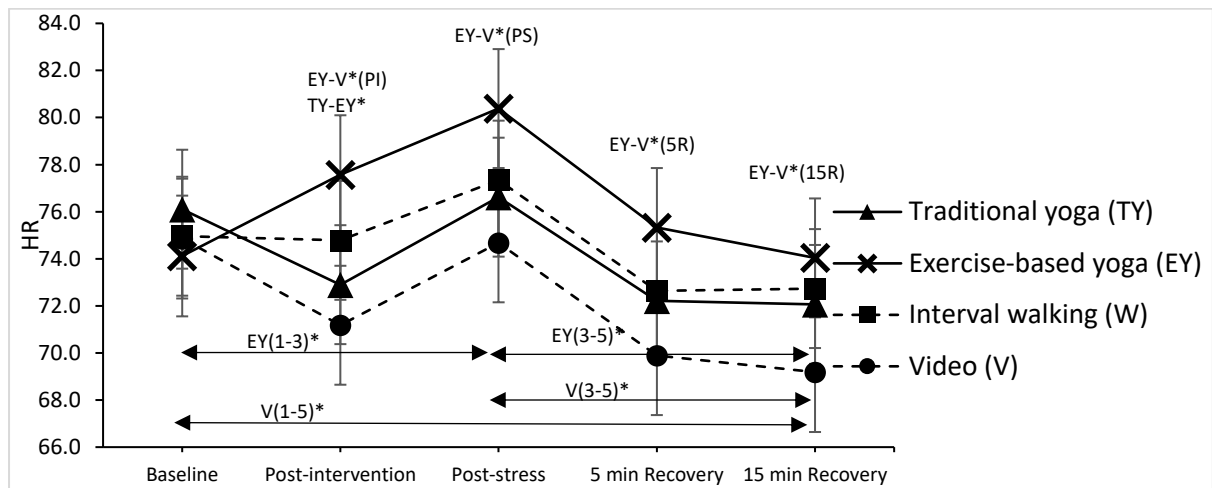


Figure 2A HR Means and Error bars (95% Confidence Interval)

(1-3)-difference between baseline – post stress, (3-5)-difference between post stress - 15 mins recovery, (1-5)-difference between baseline to 15 min recovery, p-values EY-V*(PI)-p=0.003, TY-EY*-p=0.063, EY-V*(PS)-p=0.011, EY-V*(5R)-p=0.017, EY-V*(15R)-p=0.048, EY(1-3)*-p=0.007, EY(3-5)*-p=0.005, V(1-5)*-p=0.020, V(3-5)*-p=0.027

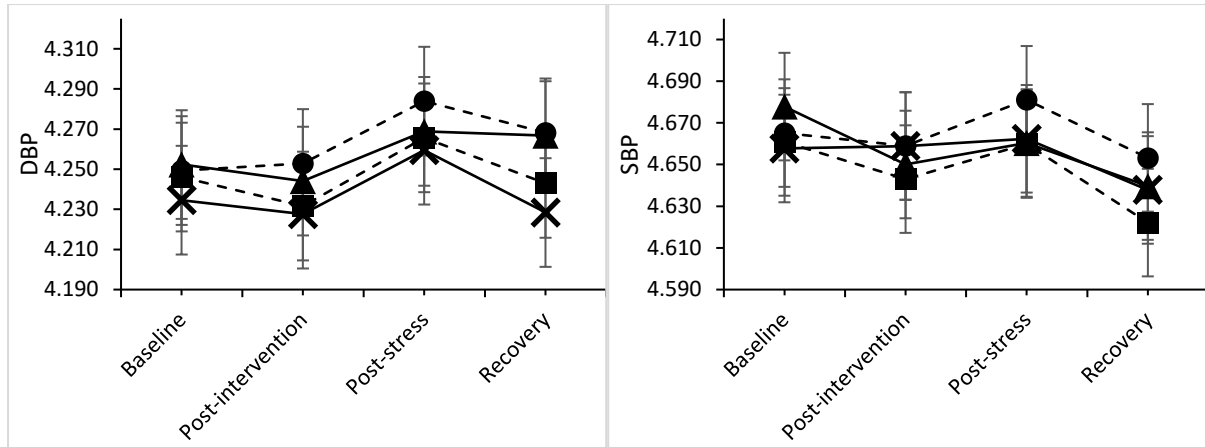


Figure 2B Geometric means of DBP & SBP and Error bars (95% Confidence Interval)

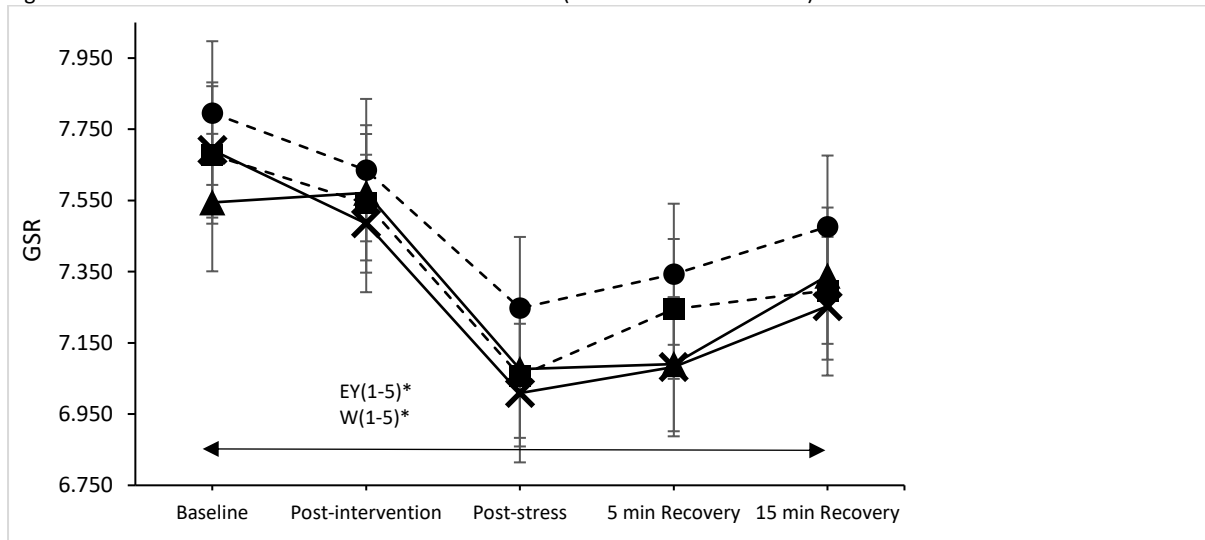


Figure 2C Geometric means of GSR and Error bars (95% Confidence Interval)
 (1-5)-difference between baseline – 15 mins recovery, p-values EY(1-5)*-p=0.016, W(1-5)*-p=0.066

In the HRV outcome variables (Figure 3), SDNN was greater after the traditional yoga intervention than the exercise yoga intervention. RMSSD decreased in the exercise yoga condition post-stress compared to baseline and increased from post-stress to 15 min recovery. At post-stress, RMSSD was lower in the exercise yoga condition compared to video, and this effect was also seen at 5-minute recovery. HF was lower in the exercise yoga condition compared to the video condition at post-intervention, while at post-stress it was lower than the traditional yoga condition. LF HRV in the video condition was lower at baseline than at both post-stress and 15-minute recovery.

Figure 3 - Means of SDNN, Geometric means for RMSSD, LF & HF, between group differences and within group differences for interventions.

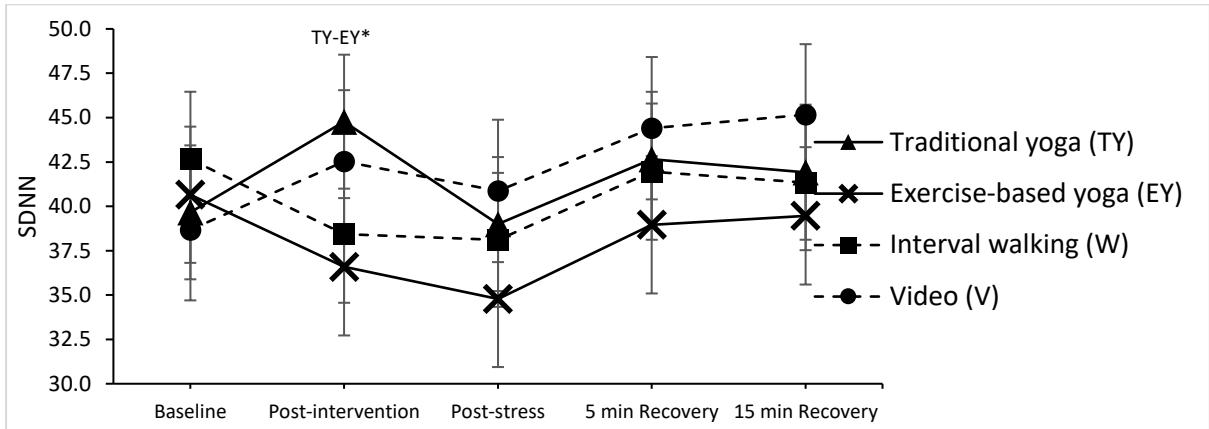


Figure 3A SDNN Means and Error bars (95% Confidence Interval)
 TY-EY*-p=0.018.

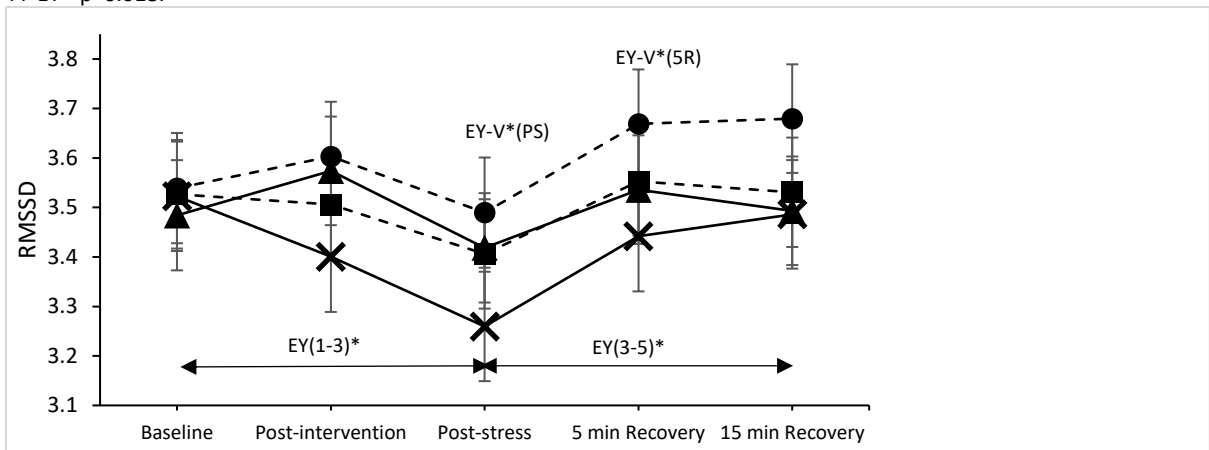


Figure 3B RMSSD Geometric Means and Error bars (95% Confidence Interval)
 (1-3)-difference between baseline – post stress, (3-5)-difference between post stress - 15 mins recovery, p-values EY-V*(5R)-p=0.025, EY-V*(5R)-p=0.026, EY(1-3)*-p=0.010, EY(3-5)*-p=0.044.

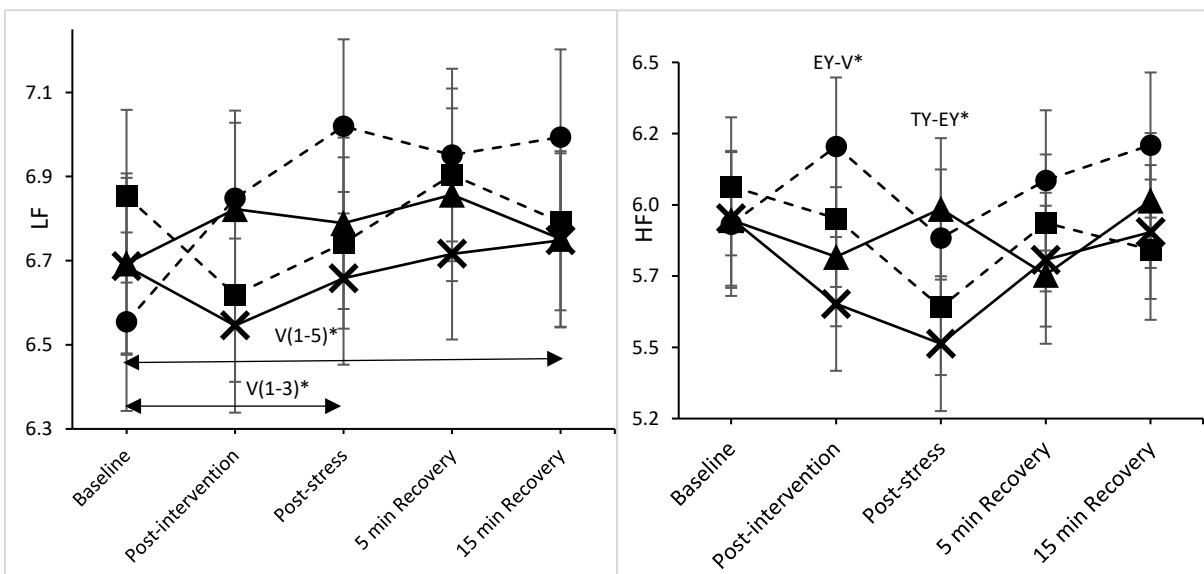


Figure 3C LF & HF Geometric means and Error bars (95% Confidence Interval)
 (1-3)-difference between baseline – post stress, (1-5)-difference between baseline to 15 min recovery, p-values V(1-3)*-
 $p=0.022$, V(1-5)*- $p=0.039$, EY-V*- $p=0.008$, TY-EY*- $p=0.041$.

4.5 Discussion

This is the first study to compare the effects of different yoga styles on the acute stress response. Overall, our findings indicate that a single session of traditional yoga may better ameliorate stress reactivity compared with exercise-based yoga, active (walking) and passive (video) control conditions. Although not every comparison showed statistical significance, the pattern of differences, including those reaching significance was that traditional yoga lowered anxiety and negative affect post-intervention and resulted in higher positive affect post-intervention and post-stress. Furthermore, we found that traditional yoga was more effective than exercise-based yoga in reducing SNS activation (evidenced by post-stress recovery of GSR) and increasing PNS activation (indicated by the greater values for SDNN and HF post-intervention / post-stress). In contrast, exercise-based yoga resulted in elevated HR and reduced HRV (RMSSD) across intervention and stress which was not seen in any other condition.

Our findings highlight the effectiveness of traditional yoga in reducing an acute stress response to a psychological stressor as measured by state anxiety. In this study, anxiety was reduced after the traditional yoga intervention and reported post-stress anxiety was not different to baseline while it was increased compared to baseline in both exercise-based yoga and video conditions. Interestingly, anxiety was lowest for traditional yoga as compared to all interventions at all time points except baseline. A

similar reduction in anxiety was reported after a single session of meditative yoga (comparable to traditional yoga) by Marshall and colleagues who compared the effects to exercise-based power yoga but did not include a stress task [13]. State anxiety as measured by STAI is often associated with emotion regulation, default mode network (DMN), [42] and amygdala functioning [43]. Reduction of state anxiety after traditional yoga supports the previous evidence of yoga's positive effect on DMN by decreasing its activity [44], increasing emotion regulation [45] and deactivation of the amygdala [43]. There is compelling evidence of improvement in positive affect as a result of long-term yoga practice [46]. Even a single yoga session has been shown to increase positive affect [47]. However, the evidence for a reduction in negative affect is mixed for the long-term practice of yoga [46]. The current study found a greater positive effect for traditional yoga compared to all other interventions at all time points except baseline. For exercise-based yoga and video control conditions, positive affect was reduced post-stress. Similarly, negative affect was lower for traditional yoga compared to both control conditions post-intervention, post-stress and through recovery.

The results relating to physiological measures of GSR suggest that traditional yoga may ameliorate SNS activation in response to stress. In both exercise yoga and walking conditions (although this did not quite reach significance), GSR was decreased across the session compared to baseline while the change in GSR was not significant in the traditional yoga or video conditions. Earlier studies have shown that a single-session practice of traditional yoga components such as meditation, and breathing increases GSR [48, 49]. In the current study, meditation and breathing components were included

in traditional yoga but not in the exercise-based yoga protocol, which may explain higher SNS activity in exercise-based yoga compared to traditional yoga. The video condition similarly to traditional yoga, showed no difference in GSR between baseline to 15 minutes recovery. However, the baseline GSR for video condition was higher than all other conditions (non-significant) which may have reduced the significance of any GSR increases during that intervention.

This study demonstrated that traditional yoga increased PNS activity compared to exercise-based yoga as indicated by HRV parameters: SDNN post-intervention and HF post stress were both greater in the traditional yoga condition compared to exercise-based yoga. A prior study which used a gentle yoga session similarly found increased SDNN following the practice [50], but they also reported that the HF parameter decreased after practice [50]. As both SDNN and HF parameters are associated with PNS activity, we suggest our parallel findings for these parameters is the more likely hypothesised effect. Our findings of lower PNS activity in exercise-based yoga (lower SDNN and lower HF values) are consistent with a study that evaluated a single session effect of vinyasa, an exercise-based yoga style [51]. In addition, lower values of RMSSD reported in the current study only in exercise-based yoga also point out to lower PNS activity.

In the current methods, traditional yoga and exercise-based yoga protocols had key differences, particularly related to the components included and the practice of yoga postures. One of the important differences between yoga styles is regarding yoga

poses. Our exercise-based yoga included mostly standing poses with no specific instructions for relaxation during the practice while a majority of poses in sitting, supine and prone positions was included for traditional yoga. A previous study found that standing poses evoke higher BP and HR response in comparison to sitting, supine and prone positions [52]. We also found partial support for higher HR during exercise-based sessions compared to traditional yoga post-intervention ($p=0.063$). Another difference between the exercise-based and traditional yoga poses was the time for which poses were held. In exercise-based yoga, poses are practiced one after another in a flow without static hold of postures effectively reducing the duration of the poses held. This pattern of changing poses often results in greater HR responses, which is reflected in the classification of exercise-based yoga styles as moderate to vigorous intensity physical activity [53]. On the other hand, due to long duration holding of the yoga poses and lower HR responses, traditional yoga has been classified as light-intensity physical activity [53]. Our results are consistent with this pattern, although we did not find any differences in the BP responses between yoga styles, greater HR was observed for exercise-based yoga compared to video control at all time points except baseline.

Our Exercise-based yoga intervention did not include non-physical components such as relaxation, pranayama, meditation and chanting. Research suggests that even a single session of independent practice involving these elements can be beneficial in mitigating the stress response [9]. Our findings indeed support the significance of non-physical components when included in yoga practice in attenuating the stress response as evidenced by traditional yoga's greater effectiveness compared to

exercise-based yoga in improving both psychological and physiological stress markers. In the current study, the traditional yoga condition also had lower negative affect and better recovery of GSR as compared to the walking condition indicating traditional yoga's effectiveness compared to non-yoga physical activity of a similar level of intensity. A similar findings were reported by a RCT, Cramer and colleagues found yoga intervention only consisting of non-physical components (breathing, meditation and relaxation) was more effective than intervention that included yoga postures along with non-physical components in reducing SBP [54]. In conclusion, our data aligns with prior evidence suggesting the superiority of traditional yoga interventions over other forms of physical activity in improving stress-related outcomes [14]. This further underscores the notion that yoga's benefits extend beyond purely physical activities [46].

4.5.1 Strengths and limitations

The strength of the current study was in its crossover design which accounted for individual differences that might influence the outcomes. Inclusion of both psychological and physiological outcome measures helped identify the mechanisms of yoga's effect on acute stress reactivity. The study was conducted in an institute where participants were attending the same residential program and were following the same routine. This helped in minimising various confounding factors.

The current study was not without limitations. The sample was a convenience sample of participants recruited at a yoga institute. About 32% of participants were white and

41% were South Asians (from India). Nearly all participants had more than six months of yoga experience and were practicing yoga regularly (more than twice a week). Likewise, nearly two thirds of participants meditated for more than an hour per week. Furthermore, most of our participants (70.6%) preferred practising traditional yoga and only 10.3% preferred practising exercise-based yoga. Therefore, they may have responded to traditional yoga more favourably because it was their preferred style, although our inclusion of both self-report and objective physiological measures fortify our findings. The stress task used here, the PASAT is prone to practice effect, with subsequent exposures eliciting reduced responses [25] and in the current study PASAT was used four times for each participant, resulting in averaged responses that are considerably smaller than found in single exposures.

4.5.2 Conclusion

Traditional yoga incorporating both physical postures and non-physical yoga components may be better at improving psychological outcomes (anxiety, affect) and physiological outcomes (GSR, HRV) as compared to exercise-based yoga focused primarily on physical postures. Further, traditional yoga was superior to similar intensity PA like walking as evidenced by lower negative affect and complete GSR recovery in traditional yoga condition. These findings suggests that the inclusion of non-physical components (pranayama, meditation, chanting and relaxation), their duration, as well as the selection of yoga poses may significantly influence the effectiveness of yoga in modulating the stress reactivity. Specific component selection (within or

between yoga styles) is therefore an important factor in the likely effectiveness of a particular yoga style in stress management. Future studies could further differentiate between different types of pranayama and meditation for their differential effect on stress response. More high-quality studies involving clinical populations across diverse age groups, balanced gender representation, naïve and experienced yoga participants are needed to fully elucidate the nuanced efficacy of yoga styles and the components within on physical and mental health.

4.6 References

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4.7 Supplementary file 1

Traditional yoga protocol (60 minutes)

Traditional Yoga Session		Total 60 mins
Omkar chanting + Meditation		4
Warmups		8
Tree pose, bent tree pose, twist 6 rounds each		
Sun salutations 6 rounds		
Shavasana		4
Supine Position Yoga poses		12
Pawanmuktasana (gas release pose)		
Side twist		
kandharasana (bridge pose)		
Anantasana (side bend)		
Prone Position Yoga poses		7
Cobra pose		
Bow pose		
Locust pose		
Vajrasana Yoga Mudra		
Sitting Position Yoga poses		10
Forward bend		
Camel pose		
Half spinal twist		
Shavasana		4
Pranayama		8
Fast breathing/Kapalbhati		
Alternate nostril breathing		
Ujjayi + Bhramari pranayama		
Omkar chanting + Meditation		3

Exercise-based yoga protocol (60 minutes)

Exercise Yoga Session	60 min
Omkar	1
Sun salutations A series + B series (3 rounds)	10
Standing poses	22
Standing Forward bend (hold 5 breaths)	
Standing Forward bend (hold 5 breaths)	
Vinyasa 1 round (Plank + Chaturang + Cobra + Downward dog + Forward bend)	
Trikonasana (Triangle Pose)	
Parshva Trikonasana (Reverse Triangle Pose)	
Utthit Parsva Konasana (Triangle Variation Pose)	
Parshva Trikonasana Variation (Reverse Triangle Variation Pose)	
Prasarit Padottanasana Variation 1,2 & 3 (Forward bend with legs apart)	
Parsvottanasana (Forward bend with legs apart)	
Utthit Hasta Padangushtasana (Balance on one leg)	
Ardha Padma baddhotasana (Half Lotus Forward bend) Left + Right side + Vinyasa 1 round	
Utkatasana (Chair Pose)	
Veerbhadrasana variation 1 + variation 2 (Warrior Pose 1 & 2) (Left + Right side) + Vinyasa 1 round	
Sitting Position Yoga Poses	18
Paschimottanasana (Forward Bend) + Vinyasa 1 round	
Purvattanasana (Back Bend Planck) + Vinyasa 1 round	
Ardha Paschimottanasana (Half Forward Bend) Left + Right side + Vinyasa 1 round	
Ardha Baddha Padma Paschimottanasana (Half Lotus Forward Bend) Left + Right side + Vinyasa 1 round	
Vajra Ardha Paschimottanasana (Half Thunderbolt Forward Bend) + Vinyasa 1 round	
Navasana (Boat Pose) + Vinyasa 1 round	
Kurmasana (Tortoise Pose) + Vinyasa 1 round	
Ugrasana (Forward Bend with legs apart)	
Utthit Ugrasana (Balancing Forward Bend)	
Supine Position Yoga Poses	6
Chakrasana (Wheel Pose)	
Sarvangasana (Shoulder Stand)	
Halasana (Plough pose)	
Karnapeedasana (Plough with folded knees)	
Vistrut Pada Halasana (Spread Legs Plough Pose) + Vinyasa 1 round	
Shavasana	2
Omkar	1

Chapter 5. Discussion and conclusion

The practice of yoga includes a combination of multi-modal components, which holds potential to improve health, and particularly ameliorate stress and related diseases. This thesis endeavoured to investigate the effect of yoga on stress, specifically examining its impact on acute stress reactivity. Firstly, I explored the differences in inclusion of yoga components between various yoga styles practiced around the world (Chapter 2), compared and analysed differences in acute stress responses of these yoga components (Chapter 3), and explored the differences in acute stress reactivity between traditional and exercise-based yoga styles (Chapter 4). The main findings are summarised below and is followed by a discussion of yoga's comparison with exercise, various components (yoga poses, breathing, meditation), mechanisms of yoga's effect, highlighting the significance and novelty of the findings, strengths, limitations of the studies and finally the conclusion.

5.1 Summary of main findings

Yoga encompasses various styles, many of which have demonstrated benefits in stress management when examined separately. However, although ancient texts describe some differences in styles, modern western yoga styles have evolved dramatically from eastern traditional styles over the years. There was a gap in the lack of quantified description of different styles of yoga classes taught worldwide and their components. Hence, the first study (Chapter 2), conducted as an online survey, aimed to determine specific component differences among globally practiced yoga styles. Results revealed notable differences in yoga styles, attributable to the inclusion of non-physical components (such as *pranayama*, meditation, relaxation, and chanting), the duration of

these components and the importance given to these components. Across teachers of all styles, yoga teachers attributed similar, high importance to these non-physical components along with physical yoga poses, reflecting that all yoga is viewed as a holistic practice. We note that this attribute may be a differentiator between yoga and other structured exercise. We classified different yoga styles into “traditional yoga” (categorised by the style’s adherence to ancient texts or traditions), “exercise-based yoga” (where the style focussed on physical exercise), and “therapy yoga” (categorised by the gentle or restorative styles with therapy objective). We found that exercise-based yoga styles included more physical postures over non-physical components compared to traditional and therapy yoga styles. However, despite this different emphasis, all styles included several yoga components, both non-physical and postures, irrespective of their background.

After establishing that ‘not all yoga is the same’, this thesis then considered the effects of separate yoga components on stress responses. The literature strongly supports an acute effect of exercise on attenuating stress responses [1, 2], therefore we designed a review to examine the evidence for separate effects of non-physical components of yoga. In Chapter 3, our systematic review investigated and compared the separate effects of meditation and breathing on the responses to an acute stress task. We also included studies that had included a combined yoga session (postures, breathing and meditation) to provide a full comparison. The findings of this review support the role of non-physical components of yoga in ameliorating acute stress reactivity when assessed in isolation. Indeed, 77% of studies of meditation found positive effects in

reducing stress responses, compared to 60% of yoga interventions and 50% of breathing interventions.

The culmination of this thesis was the randomised crossover trial in Chapter 4, which assessed the effect of two yoga styles, 'traditional' and 'exercise-based' on stress reactivity. We included both an exercise control (light intensity physical activity (walking)) and passive control (resting and watching a video) tasks. The findings were in line with our hypothesis that a single session of traditional yoga was superior in mitigating the acute stress response compared to exercise-based yoga, active (walking) and passive (video) control conditions. Greater inclusion of non-physical components, along with their duration, and methodology of yoga poses may significantly impact the efficacy of yoga sessions in acutely modulating stress reactivity. These findings support existing evidence of the superiority of yoga interventions over physical activity in reducing stress reactivity [3, 4]. The observed greater benefits of yoga over exercise could be due to the addition of these non-physical components which may act via different mechanisms such as deactivation of the hypothalamic-pituitary-adrenal axis (HPA), sympathetic nervous system (SNS) and activation of the parasympathetic nervous system (PNS) or other pathways, and that may provide an additive effect.

5.2 Comparison between yoga and exercise

5.2.1 Energy cost of different styles and components of yoga

Yoga is often considered as a form of exercise or physical activity. However, there is an ongoing debate among researchers whether to term yoga as an exercise form [5]. Some reviews have pointed at the inclusion and importance of yoga's non-physical components as part of the reason for excluding yoga from exercise classification [5]. However, when simply considering the energy cost, rate of oxygen uptake or metabolic intensity of different yoga styles and components, yoga styles have mostly been classified as light intensity physical activity (PA), with a few styles classified as moderate and vigorous intensity PA [6-8]. Notably, yoga styles (such as vinyasa and power) which include more standing poses, sun salutations along with fast transitions between poses in the flow have greater energy cost in the range of moderate intensity (3-6 MET's) [6, 9]. Conversely, the styles incorporating more poses in sitting, supine, prone positions and inversions have lower energy cost, in the light intensity range (1-3 MET's) [6, 8]. Similarly, the non-physical components when examined separately show metabolic equivalents close to that of resting (1 MET): *pranayama* (1-1.3 MET), meditation (1 MET), and savasana (1 MET) [6]. In our online survey, the styles classified as traditional (Hatha, Patanjali's Ashtanga, etc.) and therapy styles (Restorative, Gentle, etc.) are classified as light intensity PA (1-3 METs) while exercise-based styles (power, vinyasa, etc.) are classified as moderate intensity PA (3-6 METs) [7, 8].

5.2.2 Energy cost of traditional vs exercise-based yoga

In the RCT described in Chapter 4, we did not explicitly measure the metabolic intensity of the tasks. However, it is likely that the traditional yoga protocol was light intensity overall: it included sun salutations (5 mins), yoga poses (37 mins of poses in sitting and supine poses, backbends in prone and inversions), om chanting meditation (6 mins), *pranayama* (6 mins), and relaxation (6 mins of savasana). In contrast, the exercise-based yoga protocol included longer sun salutations (10 mins), a flow sequence of standing (23 mins) and sitting poses (24 mins) followed by a short relaxation (3 mins of savasana) which was likely of higher intensity than the traditional yoga session. It is likely that our RCT was in line with previous intensity classifications of traditional and exercise-based yoga styles [8], and our heart rate (HR) data support this. After the end of the 60 min yoga session, HR was significantly higher post exercise-based yoga (mean HR 77.6 SD 12.5 bpm), compared to post traditional yoga (mean HR 72.9 SD 9.9 bpm).

5.2.3 Comparing yoga interventions with exercise

Given the well-established effects of exercise on stress, stress reactivity and health, and the similar effects of yoga (as described in Chapter 1), it is important to consider the comparison between exercise and yoga. Many reviews comparing yoga interventions with exercise have found yoga at least equal or superior to exercise in various health related outcomes. Two reviews comparing physical therapy exercise and yoga on pain and disability for chronic low back pain found no difference between them [10, 11]. In another review studying cancer related fatigue, yoga had the greatest effect compared to other exercise interventions [12]. Noetel and colleagues found yoga to be equally beneficial to other form of exercises as a treatment for depression but reported

that yoga and strength training were better tolerated compared to other exercises [13]. Ross and colleagues systematic review compared long-term practice of yoga with exercise and found yoga as an equivalent or superior intervention to exercise in enhancing various health parameters (such as HRV, cortisol, blood glucose levels, oxidative stress markers etc.) across both healthy and clinical populations [3]. Of the 12 yoga interventions included in this review, seven used styles with multiple components (poses, breathing and meditation). Similarly, a systematic review and meta-analysis comparing yoga and exercise for type II diabetes also found that yoga interventions were more effective in improving fasting, postprandial blood glucose, HbA1c and body mass index as compared to exercise [4]. Seven out of the eight yoga interventions in this review employed multiple components of yoga (poses, breathing and meditation). Given that when considering exercise, typically a dose-response relationship is found with greater effects associated with higher intensities, the evidence that a low intensity activity such as yoga, can outperform higher intensity exercise supports the notion discussed in this thesis that the non-physical components provided an enhancing additive.

In our findings in Chapter 4, traditional yoga (likely light intensity activity) was superior to the higher intensity activity of exercise-based yoga in psychological (anxiety, positive affect, negative affect) and physiological measures (HRV and GSR) of stress reactivity. Further, traditional yoga was superior to light intensity walking in psychological (negative affect) and physiological (GSR) outcomes of stress reactivity. Traditional yoga was also superior to the video condition in psychological outcomes (anxiety, positive

and negative affect) and physiological (HRV) outcomes. We suggest that the explanation for the superior efficacy of traditional yoga may lie in its emphasis on non-physical components and breathing instructions in yoga poses. Both of these factors were absent in exercise-based yoga, walking and video condition.

The complete recovery of the galvanic skin response (GSR) after stress, found only after the traditional yoga intervention, suggested a stronger deactivation of the SNS compared to both exercise-based yoga and walking. Interestingly, no differences were reported in GSR recovery between traditional yoga and video interventions. However, a different SNS marker, the LF parameter of HRV [14], was significantly higher in video post-stress and at recovery. These differences in findings likely reflect the small effect size of changes observed resulting in different statistical findings. The directional pattern, overall, is as hypothesised with SNS activity post stress attenuated by exercise (walking and exercise-based yoga) and further by traditional yoga.

Other outcomes in our RCT found mixed effects of interventions. Walking was more effective in attenuating anxiety and improving positive affect post-stress as compared to exercise-based yoga and video where anxiety increased, and positive affect decreased post-stress. These findings are contrary to our hypothesis that exercise-based yoga would be better at reducing stress-related parameters compared to both control conditions. Previous evidence has found that a short bout of light intensity walking can induce higher positive affect [15], and some evidence suggests that higher intensity PA may result in lower positive affect than light and moderate intensity PA [15,

16]. Our exercise-based yoga intervention had higher intensity than walking (as indicated by HR), which may have caused the differences in affect between these interventions.

5.3 Effects of different yoga components on acute stress reactivity

In chapter 3 we explored the evidence for the effects of different yoga components on stress reactivity. Much of the evidence was related to meditation, with a small number of studies examining *pranayama* (breathing) and a few studies that used a combined yoga session. Most yoga studies that found a beneficial effect on stress reactivity, included one or more non-physical component (breathing, meditation, relaxation) along with postures in the intervention. We found that independent practice of at least 30 minutes of yoga (combination of components), or 5 minutes of *pranayama* or 6 minutes of meditation can reduce stress reactivity. Given this finding of reduced stress reactivity after a single session of meditation, or *pranayama* stand-alone practice, this adds evidence for the importance of these non-physical yoga components in reducing stress reactivity and cement the case for their inclusion in a yoga class.

5.3.1 Yoga poses

Although modern practice of yoga often considers the physical practice of yoga poses as similar to exercise and stretching, the traditional approach to the practice of yoga poses, emphasizes the development of body awareness, focus on breathing, relaxation, and concentration in yoga postures health benefits and to prepare the body-mind for meditation [17]. Interestingly, some of the scientific findings support the importance of this traditional approach. Current research suggests that the benefits of yoga stem primarily from three key factors: a focus on breath, the cultivation of

mindfulness incorporating both body awareness and interoceptive awareness (IA), and enhanced attentional focus during practice [18].

Growing evidence suggests that mindfulness can be cultivated using yoga-based practices [19]. IA is an essential aspect of developing mindfulness. A popular Mindfulness-Based Stress Reduction (MBSR) program has specifically included yoga poses (from hatha yoga) to cultivate body awareness [20]. Although, increased body awareness is often observed in various mental disorders such as anxiety, panic disorder and depression, other research in IA have discovered its beneficial role related to increased emotional and behavioural regulation [19].

The role of physical postures in promoting relaxation is another important part of stress management applications of yoga. Streeter and colleagues proposed a vagal-GABA theory suggesting that specific yoga poses (backbends, inversions and savasana) and breathing can stimulate vagal nerve afferents, and in turn increasing the PNS and brain GABA activity [21]. Research evidence supports that both acute and chronic practice involving yoga poses can improve GABA activity, which can improve mood and reduce anxiety [22, 23]. Notably, these studies by Streeter and colleagues, employed Iyengar yoga (derived from hatha yoga), a style which focuses on alignment in the posture while holding yoga poses for longer duration (up to several minutes) [24]. In our RCT, traditional yoga and exercise-based yoga both included many similar yoga postures with the difference in duration for which the poses were held, and instructions given during the practice. The HRV parameters of SDNN and HF were higher in traditional

yoga post-intervention and post-stress respectively in traditional yoga as compared to exercise-based yoga. Higher values of SDNN and HF suggest higher PNS activity in traditional yoga over exercise-based yoga. These findings support the proposal that the practice of yoga postures is different than stretching and exercise in terms of its longer duration hold and attentional focus (breath, body and relaxation) involved, and this can be an important differentiator between yoga poses and exercise in activating PNS and GABA responses.

5.3.2 *Pranayama* or breathing techniques

Breathing is unsurprisingly present in all components of a yoga practice, as well as the separate breathing techniques of *pranayama*, focus on breathing is an explicit part of asana practice and meditations. In traditional texts, *pranayama* or yoga breathing are described as having the potential to heal all physical and mental health disorders [25]. Breathing is controlled by voluntary and involuntary mechanisms. The voluntary yogic breathing techniques offer a unique and potent tool to modulate autonomic nervous system activation, which over time may alter the resting balance of SNS and PNS [26] and results in increased GABA activity, which is associated with reductions in anxiety, depression, and other stress-related disorders [27].

Evidence suggests that voluntary breathing modifications can acutely alter emotional states and influence well-being [18]. This voluntary control and attention to breathing both in *pranayama* and while performing yoga poses enhances cortical synchronization, alertness and executive functioning [18]. Disengagement from

distractions and attention on the object of focus (for example, breathing) constitutes a top-down strategy. This approach reduces negative cognitive appraisals, rumination and ultimately leads to a reframing of the stress perception and mitigating the stress response [28]. Emerging evidence suggests a link between parasympathetic activity, CNS activity associated with emotional regulation and psychological well-being during the *pranayama* practice [29]. Furthermore, regular long term *pranayama* practice (consisting of various slow and fast breathing techniques) results in slowing of the breath and making it rhythmic which enhances vagal tone (increasing HRV), which can result in attenuation of HPA activity in response to a stressor suggesting bottom-up model influencing effect on stress [18, 27].

In our systematic review (Chapter 3), out of three studies examining independent *pranayama* practice, two studies showed increased HRV parameters even after 5 minutes of a single *pranayama* session. The findings in our RCT (Chapter 4) that HRV indices were lower after exercise-based yoga and higher after traditional yoga, may in part be due to the differences in breathing within the sessions. The traditional yoga session incorporated 6 minutes of *pranayama* and specific instructions for focusing on breath during asana practice, while the exercise-based yoga session included no explicit *pranayama* and lacked these instructions during asanas, simply guiding participants in holding poses for designated counts. It is likely that focusing on breath during the practice could contribute to the effect of traditional yoga, particularly on the PNS activity markers.

Pranayama is an umbrella term involving voluntary control of breathing and includes different breathing practices, from hyperventilation to hypoventilation, creating a sound while breathing, inhaling through mouth and even holding the breath [30]. Some research has examined the effects of different types of *pranayama* on physical and mental health, particularly in relation to stress management. A commonly practiced technique of alternate nostril breathing (slow breathing technique with focus on abdominal breathing) has been associated with neurocognitive benefits such as increased concentration, spatial memory [31], vagal tone resulting in increased PNS activity [18], better muscular relaxation, alert but relaxed state of neuromuscular system [32], and decreased HR, BP, perceived stress [33]. A review examining the effect of Bhramari *pranayama* (exhalation with humming sound) concluded that it increases PNS activity, evidenced by reductions in BP, HR and an increase in gamma waves in an electroencephalogram (EEG) [34]. Ujjayi, a combination of slow breathing and contraction of glottis while making a hissing sound, has been found to increase PNS activity by stimulating vagal afferents in the glottis, lungs, pharynx, and abdominal area as evidenced by increased HRV [35, 36]. In contrast, Bhastrika and Kapalbhati (hyperventilation techniques) stimulate SNS activity similar to that of physical exercise [35, 37]. In our RCT, the *pranayama* practice included alternate nostril breathing, Bhramari, Ujjayi and Kapalbhati techniques. Although we cannot separate the effects of these *pranayama* types, our overall findings suggest a beneficial role of all these types of *pranayama* in attenuating acute stress reactivity as evidenced by increase in HRV parameters (such as HF and SDNN suggesting activation of PNS) and higher GSR (suggesting deactivation of SNS).

Regarding the duration of *pranayama* practice, a survey by Cartwright and colleagues reported an average of 13.1% class time [38] and another survey by Penman and colleagues found 9.1% of the class time was dedicated to *pranayama* [39]. In our survey, we found 16.1% of the class time was for *pranayama* practice in traditional yoga styles. In our RCT (Chapter 4), the traditional yoga session included 10% of the class time (6 minutes) for *pranayama* practice consisting of several types; Kapalbhathi (hyperventilation technique) (2 minutes), alternate nostril breath (2 minutes), Ujjayi and Bhramari *pranayama* (2 minutes), while the exercise-based yoga did not include *pranayama* practice. Overall effect of the traditional yoga session was superior to the exercise-based yoga session, suggesting effectiveness of the combination of breathing practices included in traditional yoga session. It is worth noting that the proportion of *pranayama* in our RCT was perhaps even lower than other traditional styles of yoga practice, leaving remaining questions on the dose-response relationship to be explored.

5.3.3 Meditation

Meditation practices are typically categorized into three primary types. Open monitoring (OM), also known as mindfulness-based meditation, cultivates a non-reactive awareness of the present moment to moment experience. Focused attention (FA) meditation involves intentional and continued focus on a specific object, with the effort to redirect the attention back to the object whenever the mind wanders. Finally, automatic self-transcending (AST) meditation employs a mantra, which the meditator can attend to effortlessly without needing focused attention [40]. Pascoe and

colleagues concluded that all three types of meditation reduce physiological markers of stress such as BP, HR, cortisol, C-reactive protein, and tumor necrosis factor-alpha in a number of diverse populations [40]. In our systematic review in Chapter 3, we found similar evidence with acute benefits related to stress reactivity with all three types of meditation included. In line with our RCT findings, a recent study compared addition of meditation to Hatha yoga and reported that inclusion of meditation increased positive affect and reduced negative affect compared to only Hatha yoga practice [41]. The traditional yoga session in our RCT included 6 minutes of mantra meditation, given the effects we reported in Chapter 3, it is likely that the inclusion of meditation may have been part of the amplification of the effect of that yoga style in ameliorating the stress response.

5.4 Strengths and limitations

5.4.1 Methodological strengths

Our survey is the first international yoga teachers' survey with large number of participants from eastern and western world representing 64 countries and teaching >22 yoga styles. This sample size and geographic diversity provides ecological validity to the survey results.

The systematic review is the first review to provide comparative analysis of yoga components for their acute effect on stress reactivity. The findings highlight the role that non-physical components can play in stress reactivity reduction.

Although our survey reported inclusion of non-physical components in exercise-based styles, we did not include *pranayama* and meditation in the exercise-based protocol we designed in our RCT as we chose design to magnify the difference between styles. We followed the original class guidelines for an Vinyasa class as designed by style's founder Pattabhi Jois [42]. This exclusion allowed us to compare the effect of traditional yoga which included 70% of physical (yoga poses) and 30% of non-physical components (*pranayama*, meditation, relaxation) whereas the exercise-based class only included 5% relaxation and the remaining 95% yoga poses. Due to the inclusion of light intensity walking as a control condition, we were able to compare the effects of traditional yoga with matched intensity exercise. This comparison further allowed us to understand differences between traditional yoga practice, exercise-based yoga practice and exercise alone.

Our RCT was conducted in a yoga institute where participants were attending a residential yoga program which allowed us to control many extraneous factors such as daily routine, stressors, food, and the environment. Inclusion of both psychological measures of stress (STAI and PANAS) and physiological measures of stress (HR, BP, GSR and HRV) made it possible to understand the different mechanisms through which yoga components work on stress reactivity. Although our sample contained participants with ethnic diversity (White, Hispanic, Black, Asian etc.), the sample was more homogenous in other ways.

5.4.2 Methodological limitations

Evidence suggests that experienced yoga practitioners react differently to negative emotional stimuli and may be better at applying executive strategies to control and reduce impact of such negative emotions [43]. A study by Kiecolt-Glaser and colleagues found that experienced yoga practitioners had lower autonomic and inflammatory responses to a stressor as compared to inexperienced practitioners [44]. In our RCT, almost all participants were experienced yoga practitioners and therefore their responses to interventions and stress task may have been influenced by their yoga experience. The participants were healthy adults, predominantly females (70.6%), which further limits the generalisability of our findings. The results may not be applicable to clinical populations. Within our RCT, most of the participants (70.6%) preferred traditional yoga style over exercise-based yoga style. This style preference may have introduced bias into self-reported anxiety and affect measures.

The participants were students in a yoga institute attending a traditional yoga program that promoted yoga lifestyle practices including following a plant-based diet, practice of meditation, chanting, and behavioural modifications of *yama-niyama* (social and self-discipline). The yoga institute is located in peaceful natural surroundings. All these factors which provided a controlled environment for the participants may have influenced the results, and it remains to be seen if the same can be replicated in everyday life surrounded by various stressors.

The survey (Chapter 2) also had some limitations:

- a) The recruitment resulted in a larger proportion of participants from yoga centres in India. In India, through popular yoga institutes, it was possible to reach large number of yoga teachers easily and that was reflected in more participants from India completing the survey than any other country. Due to cultural factors (e.g. the predominant teaching of traditional styles of yoga taught at institutes in India), the data were weighted toward traditional yoga teachings due to the recruitment bias to India.
- b) It is possible that the typical class setting of a yoga teacher might account for some of the discrepancies between teacher rating of different components and time spent on them in class (e.g. a traditional yoga teacher gives more importance to non-physical components like pranayama, meditation etc. but while teaching in gyms less time is spent on these non-physical components and more time is spent for physical poses).

- c) Only some of the questionnaire data was reported here that was related to the research question. Other survey data are not analysed. Other data included for example, sequence of yoga class, including various yoga poses, breathing techniques and types of meditations. In future this data can be used for descriptive work on the typical composition of yoga classes of different styles.

The small number of studies of yoga (N=5) and breathing (N=4) that were included in the systematic review (Chapter 3) resulted in many limitations including limited statistical power, reduced heterogeneity and generalisability, increased risk of bias and finally making it difficult to draw definitive conclusions. Overall, the results need to be evaluated with caution especially for yoga and breathing interventions.

5.5 Clinical applications

5.5.1 Traditional yoga as light intensity PA

Given that traditional yoga is considered to be a light intensity PA, it does not contribute to meeting the WHO PA recommendation of 150 minutes per week of moderate intensity PA. However, some evidence has emerged suggesting that >150 min per week of light intensity PA can improve cardiometabolic health (reduction in adiposity, improvement in BP and lipidaemia) and mortality risk [45, 46], and yoga has been shown to be more effective than matched PA for many health indicators [3]. Taken together, it is possible that traditional yoga practice may bring stress-related physical and mental health benefits even outside of meeting WHO PA intensity recommendations.

5.5.2 Choosing right style of yoga

Choosing the right yoga style for optimum health benefits is an important decision. Yoga styles have differences in terms of intensity, gentle to vigorous movements, fitness to spiritual focus and as described here, differences in inclusion of components [47]. Selection of traditional yoga styles or similar styles that include non-physical components of *pranayama* (e.g. alternate nostril breathing, Bhramari, Ujjayi, Kapalbhathi), meditation (e.g. mindfulness-based meditations, mantra, breathing focused), relaxation (savasana, yoga nidra), and Om chanting may be more effective in reducing stress reactivity and subsequently, stress-related illness, than exercise-based yoga styles primarily focused on physical component of postures and movements.

Medical professionals may recommend these traditional styles for clinical populations suffering from various stress-related physical and mental health conditions.

Although non-physical yoga components are comparable to sedentary activity (1-1.3 MET) in PA intensity [7], their practice can reduce stress reactivity significantly making a strong case for their inclusion into yoga practice or even standalone practice for reducing stress-related disease.

Based on the traditional yoga protocol in our RCT, we found that 30% of the class time for combined practice of *pranayama*, relaxation, meditation and chanting for effectively reducing acute stress response. We included 6 mins of *pranayama*, 6 mins of meditation which is in line with our systematic review finding that 6 mins of meditation and 5 mins of *pranayama* was sufficient to ameliorate stress responses. Therefore, we suggest that further research examine these recommended parameters for class components, and practitioners use this as a starting point for their teaching planning.

5.5.3 Injuries and yoga styles

Some reviews have found that yoga practice can cause injuries. One in five practitioners have reported some form of acute injury due to yoga practice. Often exercise-based yoga styles (power yoga, ashtanga vinyasa) are associated with a higher number of injuries compared to traditional yoga styles [48, 49]. If selecting exercise-based yoga styles, it is recommended that participants and practitioners conduct appropriate screening and refer to health professionals as appropriate.

5.5.4 Implications of shorter duration yoga practices in daily life

The findings of the systematic review suggesting benefits of shorter durations of yoga (30 minutes), breathing techniques (5 minutes), and meditation (6 minutes) practices could be very relevant in today's fast paced world. These shorter duration practices can be easily integrated in daily life and can offer accessibility, efficiency, and a range of physical and mental health benefits. With the help of technology, these shorter duration programs can be made easily accessible to everyone and certainly offer great hope especially for handling the stress related health problems.

5.6 Directions for future research

5.6.1 Exploring the philosophical and spiritual practices of yoga

Although our RCT version of a traditional yoga practice incorporated several key yoga components, including postures (*asanas*), breathing exercises (*pranayama*), meditation, chanting, and relaxation techniques, it was a limited single design. A nuanced examination of non-physical yoga components, especially considering the diverse range of *pranayama* practices, types of meditation, chanting practices, and relaxation methods is warranted. Interestingly, Smith and colleagues reported that anxiety and stress reduction benefits of yoga can be amplified by incorporating lifestyle, philosophical and spiritual yoga components such as *yama* and *niyama* [50]. Most ancient texts of yoga have given great importance to the control of sensory desires and attachments identifying them as the reasons for stress and have recommended practice of *yama* and *niyama* [25, 51, 52]. Future research could include explicit exploration of these spiritual and philosophical practices on stress and stress reactivity.

5.6.2 Dose of yoga interventions

Another important consideration for future research is the dose of the yoga interventions. The ancient traditions of yoga recommend regularity, sincerity and long-term practice to achieve the benefits of yoga practices [52]. Yoga should be made an inseparable part of daily lifestyle [51]. However, there is a large variation in the length and duration of yoga interventions (single session to few years) in different studies [53].

Most of the research studying the long-term effects of yoga have included yoga interventions of 60 to 90 minutes twice or three times a week and lasting generally for 4 to 8 weeks [54-56] which should be considered as a low dose [57]. A RCT studying high dose (3 sessions of 90 minutes and 4 home practice sessions of 30 minutes each per week) vs low dose (2 sessions of 90 minutes and 3 home practice sessions of 30 minutes each per week) reported significantly more participants in high dose group with reduced depressive symptoms as compared to low dose group [58]. However, both groups in this study showed significant reduction in depressive symptoms but more participants in low dose group had less depression scores (cut off score of ≤ 10 indicating minimal depression) [58]. Another study compared mental health status using General Health Questionnaire (GHQ28) between daily practice group (yoga more than 3 times a week) vs non-daily practice group (yoga 2 times or less in a week). The daily practice group had significant improvement in their mental health status after 3 months but no differences were found in the non-daily group [59]. Very high dose of yoga (80 minutes session two times a day) for six months also reduced stress reactivity to a physical stressor [60]. It is therefore important to establish a comparison to a higher dose of yoga practice as recommended by ancient texts and scientific evidence (daily 60-90 minutes) to more completely understand the dose-response relationship between yoga and stress and stress reactivity.

5.6.3 Time of yoga practice

All ancient traditions have recommended morning time just before sunrise to derive the maximum benefits of yoga practice [17]. Regarding PA, the evidence for effect of time of

practice is inconclusive with some studies favouring morning and evening time [61]. Brooker and colleagues did not find difference between morning and evening PA for cardiometabolic risk factors, but evening PA achieved meaningful weight loss and improvement in VO₂peak [62]. Another study reported beneficial effects of morning PA compared to evening PA for improving glycemic control in patients with Type1 diabetes [63]. However, no yoga studies have examined the time of the yoga practice in any intervention. Even in our own RCT, we conducted the experiment at different times for participants according to convenience. Future studies can examine whether yoga provides differential effects based on the time of practice.

5.6.4 Other considerations

Future studies can focus on more balanced gender participation, including different age groups, active and passive control groups, clinical populations, and larger sample sizes. Also, studies may include blinding the participants and researchers to improve the quality of studies. Although it is very difficult to blind the participants and researchers to the interventions, blinding them to the purpose of the study, randomisation, order of intervention and an independent researcher conducting data analysis can reduce the participant bias and researcher bias.

5.7 Conclusion

Yoga has become a popular, multifaceted part of preventive healthcare and alternative and complementary medicine. This holistic practice of yoga involves many diverse

components. This thesis found that the majority of yoga styles practiced around the world, include these diverse components, highlighting yoga's broader role as a philosophy of life.

This thesis also demonstrated that modern yoga classes, as taught around the world, include variations in terms of components included in the class and their duration. We classified modern yoga styles into traditional styles (those include a higher percentage of non-physical components of *pranayama*, meditation, relaxation and chanting), exercise-based styles (focused more on physical components of yoga postures) and therapy styles (the gentle or restorative forms practiced as therapy) and defined the differences between these in typical component inclusion.

We demonstrated that non-physical components are effective in attenuating the acute stress response. Even a short single session practice of these components can reduce the acute stress response. Consequently, we suggest that traditional yoga styles including more of these non-physical components are more effective in reducing stress reactivity than exercise-based yoga styles which focus primarily on the physical component of postures. Collectively, these findings suggest that traditional yoga is more effective in deactivating SNS and activating PNS compared to exercise-based yoga.

Due to inclusion of these non-physical components, traditional yoga is often a light intensity PA while exercise-based yoga is moderate intensity PA. Despite these intensity

differences, traditional yoga seems more effective than moderate intensity exercise-based yoga and light intensity walking PA in ameliorating the acute stress reactivity. This suggests that the intensity dose-response relationship of exercise with stress reactivity should be viewed differently in the context of yoga due to effects of non-physical components.

Our findings support yoga's influence on the brain and its functions bringing psychological changes (top-down model) as well as influencing biological mechanisms (bottom-up model). In conclusion, we found support for the top-down neurocognitive model as well as the bottom-up neurophysiological model as potential mechanisms underlying yoga's therapeutic effects.

5.8 Reflexion on PhD journey

Initial challenges

The PhD journey was a great learning experience for me. However, the start of this PhD journey presented challenges. My first supervisor did not want to continue with my PhD subject as she thought that the direction is changing. It was unexpected for me, but Dr Kate (current supervisor) offered to take over providing me a great relief. Dr Nicola who was the coordinator at that time also provided her great support and helped me get over this challenge easily. I remembered the yoga wisdom which says that there is a positivity hidden in every apparently negative event. This helped me deal with the stress. Now I feel that this change happened for good as the changed direction proved more meaningful in relation to the findings of this thesis.

COVID - 19

Then entered COVID-19, unfortunately I got stuck in India and my family was in Australia. This was initially stressful, as it resulted in emotional stress, but I used this time for my own learning and discipline. This period also delayed the data collection of my RCT. But through the regular guidance of my supervisors, I was able to write chapter 1, chapter 2 and chapter 3 partly of my thesis during this period. Many events switched to online mode during this period which again helped me stay focused on the PhD. I also attended an online conference SYR 2020 arranged by the International Association of Yoga Therapists and presented the survey abstract which was awarded Swami Kuvalyananda Research Abstract Award for Excellence and Innovation in Yoga Research.

Writing challenges

Writing the manuscripts also presented various challenges. I had no previous experience with academic writing, so I used to make a lot of mistakes. Sometimes it was frustrating to rewrite everything as my supervisors used to suggest a lot of improvements. Later I started realising that this rewriting is very beneficial to my learning. So now I see many positive outcomes out of this effort. Now I want to thank my supervisors for this. In ashtanga yoga, a principle is given to counter the stressful thoughts. The principle is 'If you are not happy with someone then try and analyse the situation from the other person's perspective'. I used this to understand why my supervisors give me so many corrections, and this exploration made me realize that my supervisors had to go through this same work many times and it must be frustrating for

them as well, but they all want me to improve so they are spending so much time on this. This changed my perspective of looking at the corrections.

Ethics approval, data collection was all time consuming, and I felt that this is not a very fruitful use of time but as always, we learn from every experience. I learnt a lot of patience and ability to smile. I think this is very important as smiling is moving away from stress.

In my last progress evaluation meeting, the evaluators expressed doubt if I will be able to complete the remaining part of the thesis in a short period of time. It was very frustrating for me to hear that. But I took this as a challenge and my supervisor Dr Kate expressed her confidence in my ability to complete it. This was extremely important for me. At that point, I decided whatever happens, I will complete the thesis as I didn't want to disappoint my supervisor. I received great help from Dr Nicola who trusted me and provided me with this opportunity. I am happy that I could do this together with my supervisor.

Cultural factors

We decided to conduct the RCT in India at a yoga institute as it was very difficult to recruit participants in Australia and my RCT required every participant to visit lab 4 times on 4 different days. The requirement of number of participants was around 68 so it was very difficult to conduct a total of 272 testing sessions. At the yoga institute, facilitated by the residential programs, meant participants did not have to travel far to take part in the study and had time to complete the visits. This is reflected in the fact that all participants completed all four sessions. The yoga institute provided me the opportunity to conduct the study which was completed in 3 months. But the cultural

factors may have played a role in influencing the results as the institute in India was focused on teaching traditional yoga.

I come from India and have a background in yoga. I have been teaching yoga to people from all over the world since 2003. I have seen some clear differences in the western and Indian views of yoga practices. From the western perspective yoga is often seen as an alternative to physical exercise and is especially it is suitable for women. However, the Indian view is that yoga is more of a spiritual practice concerned with lifestyle changes and a way to connect with the divine energy. The teachings of western teachers naturally focus more muscles, joints, cardio fitness aspects while practicing yoga and Indian teachers aim to deepen their spirituality through yoga practices.

Conclusion

The system of yoga always generated a lot of interest and curiosity in me, and I wanted to find out myself formal evidence for whether yoga techniques can be effective in managing modern life stress. The University of Sydney and my supervisors presented this opportunity to me, and I feel very content to complete my research and add to the body of evidence.

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Appendix 1 - Not All Yoga Styles Are the Same: An International Survey on Characteristics of Yoga Classes

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ORIGINAL ARTICLE

Not All Yoga Styles Are the Same: An International Survey on Characteristics of Yoga Classes

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Abstract

Objectives: Yoga is a multicomponent activity that has been associated with many health benefits. Different yoga styles contain different combinations and durations of components (e.g., postures, breathing, meditation, relaxation, and chanting). A better description and quantification of yoga components within different styles are important in understanding how different yoga styles contribute to health outcomes. This survey aims to understand the general characteristics and components taught in different yoga styles.

Design: An online international survey was sent to yoga teachers (18+ years with >1 year teaching experience) using snowball recruitment. Survey questions included demographic and professional characteristics of participants, specialized yoga style, and details of components typically taught in the class. The analysis included descriptive statistics and a comparison between teachers of traditional versus exercise-based versus therapy styles using w^2 and Kruskal–Wallis tests.

Results: Nine hundred and sixty-eight yoga teachers (76.8% female, mean age 43.8–11.1 years) from 64 countries participated in the survey. When grouped according to primary yoga style taught, 70.6% of participants taught traditional (e.g., hatha or ashtanga), 18.4% exercise-based (e.g., vinyasa or power), and 11.0% therapy (e.g., restorative or gentle) styles. Nearly all teachers included physical postures, but breath techniques, chanting, and cleansing were included by significantly more traditional teachers (95.2%, 68.3%, 25.8%, respectively) compared with exercise-based (88.6%, 42.5%, 7.2%) and therapy teachers (93.0%, 43.0%, 10.0%). Variations were reported in the time allocated to each of these class components. Physical postures took up 50.0% of total class time for traditional styles, 60.9% for exercise-based, and 53.9% for therapy styles ($p < 0.001$). Conversely, breath techniques, meditation, relaxation, and chanting took significantly more of the class time for traditional and therapy compared with exercise-based styles. However, teachers from all styles regarded yoga poses, breathing, meditation, and relaxation as equally important in the yoga class.

Conclusions: Exercise-based yoga styles unsurprisingly dedicate more time to physical postures and less time to nonphysical components than traditional and therapy yoga styles. However, all yoga teachers report valuing and including multiple components of yoga practice regardless of the primary style of teaching, which is reflective of the holistic nature of yoga practice. Further research into the benefits of the specific component combinations in different yoga styles is needed to better understand the full potential of yoga practice for health.

Keywords: yoga styles, pranayama, meditation, relaxation, breathing, yoga poses

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NOT ALL YOGA STYLES ARE THE SAME

Introduction

Yoga, a multicomponent practice, is growing rapidly in popularity worldwide.^{1,2} According to a National Health Interview Survey conducted in the United States in 2017, yoga was the most commonly used complementary health approach with 14.3% of American adults practicing it at least once in the prior 12 months.³ Widely considered as a type of physical activity (PA) due to its physical components, yoga has been shown to convey similar or greater benefit than various types of PA on health parameters such as blood glucose, lipids, cortisol, heart rate variability, and oxidative stress.⁴

Besides the physical postures (*Asana*), yoga also consists of different practice components, such as breath techniques (*Pranayama*), meditation (*Dhyana*), relaxation, social and self-discipline (*Yama-niyama*), chanting (*Mantra*), and cleansing and lifestyle (e.g., diet).⁵ These different components contribute differently to health. For example, the physical components of yoga improve balance, muscle strength, aerobic PA, gait, coordination, and physical function.⁶ Breath techniques improve cardiorespiratory parameters,⁷ reduce stress, and improve general wellbeing,⁸ while meditation has been found to reduce stress reactivity and inflammation,⁹ and increase emotional balance and wellbeing.¹⁰ In addition, the relaxation practice of *Savasana* was found to be effective in reducing stress,¹¹ and *Om* chanting resulted in the deactivation of the limbic system suggestive of an important role in stress management.¹²

Moreover, yoga practitioners often report healthier lifestyle choices (such as vegetarian dietary choice) compared with the general population.¹³ This suggests that yoga contributes to health through different mechanisms,¹⁴ and it is important to differentiate between the components in various yoga styles to understand the contributions of style-specific combinations to health.

Yoga styles vary from gentle to vigorous, and from exercise-based to spiritually focused. Having moved away from eastern traditional styles as described in ancient yoga texts, western yoga styles tend to focus more on physical poses for fitness and exercise over other components such as breath techniques,¹⁵ meditation, and relaxation, which is less holistic than the traditional styles.¹⁶ Also, the different yoga styles vary in the intensity of PA (e.g., light, moderate, or vigorous), which depends on the duration of the postures, the speed of the sequence of postures, and types of poses (e.g., standing or balancing).¹⁷

Considering the ubiquity and diverse range of yoga styles and the inclusion of different components, it is important yet challenging to quantify yoga practice for the examination of its health benefits at the population level, particularly in terms of its PA components. Without a better description of yoga components within styles, understanding the contribution of yoga to physical and mental health through PA as well as other components is limited. Based on an online survey, our study is the first international study to describe the general characteristics of different styles of yoga classes taught around the world, including inclusion and duration of components.

Methods

Study design and recruitment

Between February and August 2020, we conducted a cross-sectional survey using an online questionnaire. Parti-

cipants were recruited using snowball sampling. An invitation to participate (including the survey link) was emailed to yoga institutes, studios, and associations (Supplementary Data S1), with a request for distributing the questionnaire link to associated yoga experts/teachers. Social media posts, including the survey link, were distributed on platforms such as WhatsApp and Facebook, targeting various yoga teachers' groups (Supplementary Data S1). For this anonymous survey, all the participants provided online informed consent. The data were collected using the secure web-based Research Electronic Data Capture (REDCap) application. The study was approved by the University of Sydney Human Ethics Committee (HREC 2020/007). The study was reported using STROBE checklist (STROBE checklist cross-sectional).

Participants

Yoga teachers 18 years of age and above who had at least 1 year of teaching experience in any style, and had access to the internet, were eligible to participate in the survey.

Measurement

The online survey included the following questions regarding the participants and the classes they "typically" teach.

Participants' characteristics. Participants were asked to provide information about their yoga certification/training, teaching experience (e.g., years of teaching), yoga training in hours, country of residence, and place of teaching (e.g., yoga studio, gym, park).

Style of teaching. Participants were asked to report the yoga styles they typically taught and if reporting more than one, identify their primary teaching style. The primary reported style was used to group teachers into three overarching styles: "traditional yoga" (characterized by the proximity of the yoga style to its lineage based on ancient texts or traditions), "exercise-based yoga" (characterized by the focus of the yoga style on physical exercise), "therapy yoga" (characterized by the gentle or restorative forms and the closeness of such type of yoga to therapy) or "unspecified" (for the styles that we could not include in the above three categories). Examples of specific styles in each category are provided in Table 1.

Yoga class characteristics. Participants were asked to describe the details of each class component (physical poses, breath techniques, meditation, relaxation (including the number of *Savasana* included in a class), chanting, cleansing, lifestyle, social, and self-discipline), such as duration and percentage of class time allocated to each of these components in a "typical" class they taught. Additionally, participants were asked to rate the importance of each of the following components (i.e., physical poses, breath techniques, meditation, relaxation, and chanting) that they use in their yoga class using a 5-point Likert scale ranging from "not important" to "most important." These response options were further combined as "most/very important" versus "not/less/somewhat important."

Table 1. Yoga Style Categories

<i>Style categories</i>	<i>Selected styles by participants</i>
Traditional yoga	Traditional, Hatha, Ashtanga, Sivananda, Satyananda, Integral, Iyengar, Kripalu
Exercise-based yoga (Vinyasa)	Power, Vinyasa, Ashtanga Vinyasa, Anusara, Jivamukti, Bikram, Hot, Aerial
Yoga therapy	Restorative, Prenatal, Chair, Gentle, Yin
Unspecified	All other styles not mentioned above

Statistical analysis

Data were extracted from REDCap and analyzed using SPSS version 25 (IBM Corp.). Participants were included in the analysis if they provided complete data on the three main questions related to the yoga style they teach, and the components included in their yoga class. Descriptive statistics for participants' demographic and professional characteristics were computed for the three different yoga style categories (traditional yoga, exercise-based yoga, and therapy yoga). Differences in yoga styles with regard to selection and relative importance of components were analyzed using χ^2 tests for these categorical variables with a Bonferroni adjustment for *post hoc* analysis. Kruskal–Wallis test was performed to assess differences between the duration of the components among different yoga styles with a Bonferroni adjustment for pair-wise comparison. In a question asking respondents about the percentage of time allocated to the different yoga components in their class, the responses were adjusted to 100% if the sum of percentages was below/above 100%.

Results

Yoga teachers from 64 countries (Supplementary Data S3) teaching over 60 different yoga styles participated in the survey. A total of 968 yoga teachers (76.8% female, mean age: 43.8 – 11.1 years) were included in the final analysis (Supplementary Data S2). When grouped according to their reported primary style of teaching, 70.6% of teachers reported typically using traditional yoga styles, 18.4% exercise-based yoga styles, and 11.0% therapy yoga styles (Table 2). However, in our sample, 72.2% of teachers reported teaching more than one style of yoga. Over a quarter of responses were from India (25.6%), followed by the United States (12.5%), Australia (11.8%), Singapore (6.5%), and the United Kingdom (U.K.) (6.2%). Demographic and professional characteristics of yoga teachers in the traditional yoga, exercise-based, and therapy yoga categories are presented in Table 2. Participants' reported yoga teaching experience ranged from 1 to 3 years (30.2%) to over 10 years (27.0%). Just under half of the participants had >500 h of yoga training (48.2%). Teachers reported a wide range of teaching locations.

Table 2. Demographic and Professional Characteristics of Yoga Teachers

	<i>Traditional yoga</i>	<i>Exercise-based (Vinyasa)</i>	<i>Therapy yoga</i>
Total	<i>n</i> = 640	<i>n</i> = 167	<i>n</i> = 100
Male	174 (27.2%)	24 (14.4%)	11 (11.0%)
Female	465 (72.7%)	143 (85.6%)	89 (89.0%)
Other	1 (0.2%)	0 (0.0%)	0 (0.0%)
Mean age (years) and SD	43.9 (–11.2)	41.6 (–9.8)	46.9 (–12.3)
Teaching experience			
1–3 years	210 (32.8%)	43 (25.7%)	30 (30.0%)
4–6 years	153 (23.9%)	49 (29.3%)	27 (27.0%)
7–10 years	107 (16.7%)	29 (17.4%)	17 (17.0%)
More than 10 years	170 (26.6%)	46 (27.5%)	26 (26.0%)
Yoga education in hours			
200	198 (31.1%)	69 (41.3%)	31 (31.0%)
500	123 (19.3%)	26 (15.6%)	21 (21.0%)
More than 500	315 (49.5%)	72 (43.1%)	48 (48.0%)
Place of teaching ^a			
Yoga studio	297 (46.4%)	122 (73.1%)	72 (72.0%)
Yoga school or institute	140 (21.9%)	20 (12.0%)	11 (11.0%)
Private class	377 (58.9%)	86 (51.5%)	46 (46.0%)
Community center	133 (20.8%)	17 (10.2%)	30 (30.0%)
Gym	94 (14.7%)	42 (25.1%)	26 (26.0%)
Corporate environment	102 (15.9%)	30 (18.0%)	13 (13.0%)
Park	66 (10.3%)	14 (8.4%)	9 (9.0%)
Hospital	37 (5.8%)	2 (1.2%)	9 (9.0%)
Rehabilitation center	37 (5.8%)	6 (3.6%)	6 (6.0%)
Other	118 (18.4%)	23 (13.8%)	15 (15.0%)

^aParticipants were allowed to select more than one option. SD, standard deviation.

Table 3. Components of Yoga in a Class

	<i>Traditional yoga</i>	<i>Exercise-based (Vinyasa)</i>	<i>Therapy yoga</i>	<i>P</i>
Component included in a yoga class				
Yoga poses	632 (98.8%)	164 (98.2%)	99 (99.0%)	0.822
Pranayama (breath techniques)	609 (95.2%) ^a	148 (88.6%) ^b	93 (93.0%)	0.008
Meditation	504 (78.8%)	121 (72.5%)	85 (85.0%)	0.048
Relaxation	577 (90.2%)	134 (80.2%) ^b	96 (96.0%)	<0.001
Chanting	437 (68.3%) ^a	71 (42.5%) ^b	43 (43.0%) ^b	<0.001
Cleansing	165 (25.8%) ^a	12 (7.2%) ^b	10 (10.0%) ^b	<0.001
Lifestyle (Lifestyle and Yama-Niyama)	357 (55.8%)	73 (43.7%) ^b	56 (56.0%)	0.018
Duration % of components in a yoga class				
% Duration yoga poses	50.0% ^c	60.9% ^d	53.9%	<0.001
% Duration breath techniques	16.1% ^c	14.6%	15.3%	<0.001
% Duration meditation	11.7% ^c	8.6% ^d	10.7%	<0.001
% Duration relaxation	15.4% ^c	12.4% ^d	16.7%	0.001
% Duration chanting	6.8% ^c	3.4%	3.3% ^e	<0.001
Selection of components as “very important”				
Yoga poses	427 (86.9%)	117 (92.1%)	68 (86.1%)	0.238
Breath techniques	470 (95.5%)	119 (93.7%)	75 (94.9%)	0.693
Meditation	374 (76.0%)	89 (70.1%)	60 (75.9%)	0.378
Relaxation	451 (91.9%)	114 (89.8%)	75 (94.9%)	0.419
Chanting	254 (53.4%) ^a	25 (20.2%) ^b	22 (31.4%) ^b	<0.001

Lifestyle and Yama-Niyama component includes diet, social and self-discipline.

^aSignificantly higher after Bonferroni adjusted a.

^bSignificant lower after Bonferroni adjusted a.

^cSignificant difference after Bonferroni adjusted a between traditional and exercise-based styles.

^dSignificant difference after Bonferroni adjusted a between exercise-based and therapy styles.

^eSignificant difference after Bonferroni adjusted a between traditional and exercise-based styles.

The various yoga components taught in different types of yoga classes are shown in Table 3. Nearly all teachers from all categories included physical poses and no significant differences were observed between the three categories ($w^2 [2, n = 907] = 0.393, p = 0.822$). Although the w^2 value was significant for meditation, group differences were not significant after Bonferroni adjustment. However, significant differences were reported among the three styles in all other components.

For example, a significantly greater percentage of traditional yoga teachers reported including breath techniques, chanting, and cleansing in classes. Additionally, exercise-based styles were less likely than traditional and therapy styles to incorporate lifestyle along with social and self-discipline in the classes.

Teachers of different styles also reported differences in the duration of time allocated to each of the class components (expressed as percentage of total class time, Table 3). For instance, physical poses took up 50.0% of total class time for traditional styles, 60.9% for exercise-based, and 53.9% for therapy styles ($p < 0.001$). Conversely, breath techniques, meditation, relaxation, and chanting were allocated considerably larger percentages of the class time by teachers of traditional and therapy yoga styles compared with exercise-based styles.

When asked about the importance of including different components in their class, teachers from all three categories selected “most/very important” options for physical postures ($p = 0.238$), breathing ($p = 0.693$), meditation ($p = 0.378$), and relaxation ($p = 0.419$) (Table 3). However, *post hoc* analysis revealed differences in chanting with significantly more traditional teachers considering it as “very important” compared with exercise-based and therapy teachers. Differences were also reported in the number of *Savasana* (a relaxation component) included in a single

yoga class. Around 65.8% of the exercise-based teachers included only one *Savasana* compared with 40.5% of traditional and 44.4% of therapy teachers, whereas the remaining included more than one *Savasana* in a class.

Discussion

To our knowledge, this is the first international survey of yoga teachers to describe and compare the components of yoga classes across different styles. Our findings show that traditional and therapy styles include longer duration of breath techniques, meditation, and chanting compared with exercise-based styles, which include longer duration of physical postures. The practice of different styles is therefore likely to contribute to health outcomes in different ways. For example, for exercise-based yoga styles, PA is likely to be the main contributor to health outcomes, while the different compositions of holistic components typically seen in a class of traditional or therapy style may contribute to health outcomes through other mechanisms, which is yet to be examined. In addition, our findings suggested that despite the different time allocations of nonphysical components such as breathing, meditation, and relaxation by teachers of different yoga styles, they all perceived these components to be similarly important in their classes.

However, chanting was perceived to be more important by traditional styles compared with the therapy- and exercise-based styles and the duration of chanting was longer in traditional and therapy classes. These findings indicate that chanting may be an important differentiator between yoga styles and the pattern suggests that there is a mismatch between what yoga teachers perceived to be important in classes and how they actually teach.

A recent survey of yoga practitioners and teachers across all styles in the U.K. ($N = 2434$) reported that yoga poses comprised 66.6% of yoga practice, followed by breath techniques (13.1%), relaxation (12.0%), meditation (8.6%), and chanting (1.9%).¹³ Similarly, a national survey in Australia ($N = 3892$) found yoga poses take up 61% of the total class with the remainder for relaxation, breath techniques, and meditation.¹⁸ Our overall survey findings show smaller proportions of time devoted to yoga poses (52.7%), and more to breath techniques (15.7%), relaxation (14.9%), meditation (11.0%), and chanting (5.7%). However, when examining specific yoga styles, the exercise-based styles in our international survey were very close to overall yoga practice in the U.K. reported by Cartwright et al. and in Australia by Penman et al.^{13,18} This finding likely reflects the predominance of exercise-based styles taught in the U.K. and Australia and the greater importance given to the physical practice of yoga as part of the exercise culture. However, the pattern reported by Cartwright et al., Penman et al., and this survey is suggestive of the holistic nature of yoga practice as described in ancient yoga texts, which goes beyond the physical postures.^{13,18}

It is important to quantify and compare the components across various styles of yoga to understand how yoga practice could contribute to health outcomes through physical component of yoga poses and nonphysical component such as breathing and meditation. Although evidence suggests that every style of yoga has health benefits,¹⁶ the specific benefits may differ by activity intensity and components. Most studies measuring energy expenditure through oxygen consumption have categorized most traditional yoga styles (hatha, Iyengar, ashtanga, gentle yoga) as light-intensity PA which is less than 3 metabolic equivalents of task (MET), but exercise-based styles (vinyasa and power yoga) as moderate intensity (three to six METs).^{17,19} Variations in intensity have been attributed to differences in the selection of yoga poses, the pace, sequencing, and transition between poses.¹⁷ Our data suggest that it is possible that the intensity may very well be influenced by the inclusion of a greater duration of less active components of practice. For example, breath techniques and meditation components of yoga have much lower energy expenditure (1–1.3 METs).^{17,20}

Considering the large proportions of class time traditional and therapy yoga teachers reported spending on breath techniques, meditation, and relaxation, one may expect that it would be challenging to meet the recommended amount of moderate-to-vigorous-intensity aerobic PA solely through practicing these styles. However, considering the beneficial effects of breathing, meditation, and chanting on health especially stress management,^{9,11,12} it is possible that traditional and therapy styles may have a stronger attenuating effect on stress compared with exercise-based styles.

We also found that although a wide spectrum of styles was reported, in almost every response, teachers indicated including multiple components in each class, reflecting the general embrace of holistic wellness practices in yoga teaching. Interestingly, when comparing the original guidelines for styles to the reported descriptions in this study, we found many differences. For example, exercise-based styles, such as vinyasa or power yoga, are typically described as not including meditation,^{21–23} whereas we found that nearly three quarters of the exercise-based teachers reported including meditations. This is likely due to teachers' "mixing

and matching" various principles and components from different styles of yoga. Indeed, three-quarters of the teachers reported teaching multiple yoga styles in this survey.

Similarly, we also observed a discrepancy between what teachers reported to be important for inclusion in classes and what they actually teach. For example, although there was no difference between teachers of different styles in ascribing importance to breath techniques, meditation, and relaxation, in a yoga class, exercise-based teachers allocated significantly less time to these components. Many differences may contribute to these results. For example, differences in training received by teachers or preferences of students are likely to influence teachers' choice and confidence to include components in their classes. As we did not record such detailed information, future research is needed to examine the cause of these differences.

Another important difference between styles is the number of *Savasana* (relaxation component) included in a class. For example, in the original guidelines for the vinyasa style (exercise-based), a single *Savasana* is included at the end of the class while most traditional styles include two or more *Savasana* throughout the class.²⁴ Our data support this pattern, with more exercise-based teachers including only one *Savasana* compared with traditional and therapy teachers.

Strengths and limitations

The key strength of the current study is the large sample of yoga teachers from the eastern and western worlds. This provides ecological validity for the sample across countries and styles of yoga. However, this study was not without limitations. The analysis was based on a convenience sample, indicating that the prevalence and characteristics of yoga styles taught in our sample may not be generalizable to those of all yoga classes in the world. Our results are only generalizable to English-speaking countries given the language of the survey. Therefore, our conclusions may not be applied to much of the global south and the large proportions of non-English speakers in India and Europe. In addition, the organizations contacted for invitation to distribute to members was limited further limiting generalizability. Furthermore, data were self-reported and may be subject to random and systematic errors due to recall and social desirability biases. Finally, the survey is limited in several aspects of detail, including information about training received by teachers, it is likely that the content of teachers' own training would influence their delivery of components in their own classes.

Conclusions

Our data from English-speaking yoga teachers report important differences between styles of yoga classes in component inclusion and durations, which may have important health implications. We also found that teachers from all styles are integrating traditional yoga practice components, such as relaxation, chanting, cleansing, social and self-discipline, and lifestyle in their yoga classes irrespective of their yoga style specialization. This may be due to various additional benefits of these traditional yoga components and a focus on holistic wellness by yoga teachers. Our findings support the description that the practice of yoga is much more than physical poses or breath

NOT ALL YOGA STYLES ARE THE SAME

techniques or meditation in isolation. Further investigation into the independent and combined effects of these components is needed so that we can fully understand and capitalize on the benefits of yoga. Future studies would benefit from a broader recruitment of non-English-speaking yoga teachers as well as therapists. It would also be important to collect more detailed information regarding training received and students being taught to determine the effect on inclusion of different yoga components.

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Authors' Contributions

G.M.: Conceptualization (equal); methodology (equal); investigation (lead); writing—original draft (lead), software (lead), and formal analysis (lead). B.N.: Conceptualization (equal); methodology (equal); writing—review and editing (equal); and supervision (supporting). D.D.: Conceptualization (equal); methodology (equal); writing—review and editing (equal); and supervision (supporting). K.E.: Conceptualization (equal); methodology (equal); investigation (lead); writing—review and editing (equal); and supervision (lead). All authors have read and approved the article. All authors had access to all the data and take responsibility for its integrity and the accuracy of the analysis.

Author Disclosure Statement

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Supplementary Material

Supplementary Data S1
Supplementary Data S2
Supplementary Data S3
STROBE_checklist_cross-sectional.docx

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Appendix 2 - Survey Of Components In A Yoga Class

Survey of components in a yoga class

Survey to understand your teaching style and the components of your yoga class.

Participant Information Statement

(Please read the statement carefully.)

(1) What is this study about?

You have been invited to take part in this survey as you are a yoga teacher. This study aims to understand different components of a yoga class. A typical yoga class contains components such as yoga poses, pranayama, relaxation and meditation. However, different yoga styles have very different composition of the class. One of the main goals of this study to understand the typical structure of the yoga class. Additionally, this survey aims to understand the differences between yoga styles, and to determine common yoga practices used in Western style and traditional style yoga classes. This Participant Information Statement tells you about the research study. Knowing what is involved will help you decide if you want to take part in the research. Please read this sheet carefully and ask questions about anything that you want to know more about or do not understand.

(2) Who is running the study?

The study is being carried out by Dr Kate Edwards, Senior Lecturer in Exercise Physiology, The University of Sydney; Associate Professor Melody Ding, Dr Binh Nguyen and Mr Gandhar Mandlik, doctoral candidate at the University of Sydney, under the supervision of Dr Kate Edwards.

(3) What will the study involve for me?

If you agree to take part, you will complete a short questionnaire about your yoga teaching background, your experience of yoga teaching, and details of your yoga class. Furthermore, you will be asked about the details of a yoga class such as duration, contents, sequence, nature of the yoga practices and intensity of the practices. Furthermore, this survey aims to explore different types of yoga poses used in the yoga classes, minimum and maximum duration of practice, type of instructions given by yoga instructors, different breathing techniques used, relaxation methods, and details of meditation.

(4) How much of my time will the study take?

This online survey will take about 10 to 15 minutes for you to complete.

(5) Who can take part in the study?

Adults (at least 18 years old) who (1) are yoga teachers and/or yoga experts; (2) have taught yoga for at least one year.

(6) Do I have to be in the study? Can I withdraw from the study once I've started?

Being in this study is completely voluntary and you do not have to take part. Your decision whether to participate will not affect your current or future relationship with the researchers or anyone else at the University of Sydney.

Submitting your completed questionnaire is an indication of your consent to participate in the study. You can withdraw your responses any time before you have submitted the questionnaire. Once you have submitted it, your responses cannot be withdrawn because they are anonymous and therefore we will not be able to tell which one is yours.

(7) Are there any risks or costs associated with being in the study?

Aside from giving up your time, we do not expect that there will be any risks or costs associated with taking part in this study.

(8) Are there any benefits associated with being in the study?

We cannot guarantee that you will receive any direct benefits from being in the study. However, this study has the potential to improve our understanding of different styles of yoga, different components used in yoga session and other details of yoga sessions, which may help standardise the yoga class. Your participation will contribute to the understanding of various styles yoga teachers use all over the world. Your responses will be evaluated and synthesized to create more effective yoga class design especially useful for stress management. This is the first survey of its kind to attempt standardisation of yoga class.

(9) What will happen to information about me that is collected during the study?

By providing your consent, you are agreeing to us collecting personal information about you for the purposes of this research study. Your information will only be used for the purposes outlined in this Participant Information Statement, unless you consent otherwise.

Your information will be stored securely, and your identity/information will be kept strictly confidential, except as required by law. Study findings may be published, but you will not be individually identifiable in these publications. We will keep the information we collect for this study, and we may use it in future projects. By providing your consent you are allowing us to use your information in future projects. We don't know at this stage what these other projects will involve. We will seek ethical approval before using the information in these future projects.

Data will be retained for 5 years and then destroyed according to University protocol.

(10) Can I tell other people about the study?

Yes, you are welcome to tell other people about the study.

(11) What if I would like further information about the study?

When you have read this information, a study team member will be available to discuss it with you further and answer any questions you may have. If you would like to know more at any stage during the study, please feel free to email the study team at gman2104@uni.sydney.edu.au or call Gandhar Mandlik on +61 451069173 or +91 9420484010

(12) Will I be told the results of the study?

You have a right to receive findings of this survey. You can tell us that you wish to receive findings of this survey by ticking the relevant box in the survey. The findings will be in the form of summary and conclusion. You will receive these findings after the study is finished.

(13) What if I have a complaint or any concerns about the study?

Research involving humans in Australia is reviewed by an independent group of people called a Human Research Ethics Committee (HREC). The ethical aspects of this study have been approved by the HREC of the University of Sydney [2019/711]. As part of this process, we have agreed to carry out the study according to the National Statement on Ethical Conduct in Human Research (2007). This statement has been developed to protect people who agree to take part in research studies.

If you are concerned about the way this study is being conducted or you wish to make a complaint to someone independent from the study, please contact the university using the details outlined below. Please quote the study title and protocol number.

The Manager, Ethics Administration, University of Sydney: Telephone: +61 2 8627 8176 Email: ro.humanethics@sydney.edu.au Fax: +61 2 8627 8177 (Facsimile)

To continue you must provide your consent to participate. By giving your consent to take part in this study you are telling us that you

- Have read the Participant Information Statement above and understand what you have read.
- Voluntarily agree to take part in the research study as outlined in the Participant Information Sheet.
- Agree to the use of your personal information as described in the Participant Information Statement.

- Yes, I consent
 No, I don't consent

Your background as a yoga teacher

Sex

- Male
 Female
 Other

Age

Country where you teach yoga classes

- Afghanistan
- Albania
- Algeria
- Andorra
- Angola
- Antigua and Barbuda
- Argentina
- Armenia
- Australia
- Austria
- Azerbaijan
- Bahamas
- Bahrain
- Bangladesh
- Barbados
- Belarus
- Belgium
- Belize
- Benin
- Bhutan
- Bolivia
- Bosnia and Herzegovina
- Botswana
- Brazil
- Brunei
- Bulgaria
- Burkina Faso
- Burundi
- Cabo Verde
- Cambodia
- Cameroon
- Canada
- Central African Republic
- Chad
- Chile
- China
- Colombia
- Comoros
- Congo
- Costa Rica
- Côte d'Ivoire
- Croatia
- Cuba
- Cyprus
- Czech Republic
- Denmark
- Djibouti
- Dominica
- Dominican Republic
- East Timor
- Ecuador
- Egypt
- El Salvador
- Equatorial Guinea
- Eritrea
- Estonia
- Eswatini
- Ethiopia
- Fiji
- Finland
- France
- Gabon
- Gambia
- Georgia
- Germany
- Ghana
- Greece
- Grenada
- Guatemala

- Guinea
- Guinea Bissau
- Guyana
- Haiti
- Honduras
- Hungary
- Iceland
- India
- Indonesia
- Iran
- Iraq
- Ireland
- Israel
- Italy
- Jamaica
- Japan
- Jordan
- Kazakhstan
- Kenya
- Kiribati
- Korea North
- Korea South
- Kosovo
- Kuwait
- Kyrgyzstan
- Laos
- Latvia
- Lebanon
- Lesotho
- Liberia
- Libya
- Liechtenstein
- Lithuania
- Luxembourg
- Madagascar
- Malawi
- Malaysia
- Maldives
- Mali
- Malta
- Marshall Islands
- Mauritania
- Mauritius
- Mexico
- Micronesia
- Moldova
- Monaco
- Mongolia
- Montenegro
- Morocco
- Mozambique
- Myanmar (Burma)
- Namibia
- Nauru
- Nepal
- Netherlands
- New Zealand
- Nicaragua
- Niger
- Nigeria
- North Macedonia
- Norway
- Oman
- Pakistan
- Palau
- Panama
- Papua New Guinea
- Paraguay
- Peru
- Philippines
- Poland

- Portugal
- Qatar
- Romania
- Russia
- Rwanda
- Saint Kitts and Nevis
- Saint Lucia
- Saint Vincent and the Grenadines
- Samoa
- San Marino
- Sao Tome and Principe
- Saudi Arabia
- Senegal
- Serbia
- Seychelles
- Sierra Leone
- Singapore
- Slovakia
- Slovenia
- Solomon Islands
- Somalia
- South Africa
- Spain
- Sri Lanka
- Sudan
- Sudan South
- Suriname
- Sweden
- Switzerland
- Syria
- Taiwan
- Tajikistan
- Tanzania
- Thailand
- Togo
- Tonga
- Trinidad and Tobago
- Tunisia
- Turkey
- Turkmenistan
- Tuvalu
- Uganda
- Ukraine
- United Arab Emirates
- United Kingdom
- United States
- Uruguay
- Uzbekistan
- Vanuatu
- Vatican City
- Venezuela
- Vietnam
- Yemen
- Zambia
- Zimbabwe

Your yoga education - how many hours of yoga training have you completed?

- 200 hours
- 500 hours
- more than 500 hours

Is your yoga certification recognised by a government or government recognised organisation?

- Yes
- No

Please tell us the name of your certification provider.

How many years have you been teaching yoga?

- Less than 1 year
- 1-3 years
- 4-6 years
- 7-10 years
- More than 10 years

Where do you teach yoga classes most often?

- Yoga Studio
- Yoga school or institute
- Private class
- Community centre
- Gym
- Corporate environment
- Park
- Hospital
- Rehabilitation Centre
- Other, please specify

Please specify "Other"

How many classes do you usually teach in a week?

What styles of yoga do you teach?

- Traditional Yoga
- Hatha yoga
- Ashtanga yoga
- Ashtanga Vinyasa yoga
- Iyengar yoga
- Kundalini yoga
- Power yoga
- Bikram yoga
- Sivananda yoga
- Satyananda yoga
- Vinyasa yoga
- Restorative yoga
- Yin yoga
- Other, please specify

Please specify "Other"

Of these which style do you consider your specialisation?

- Traditional Yoga
- Hatha yoga
- Ashtanga yoga
- Ashtanga Vinyasa yoga
- Iyengar yoga
- Kundalini yoga
- Power yoga
- Bikram yoga
- Sivananda yoga
- Satyananda yoga
- Vinyasa yoga
- Restorative yoga
- Yin yoga
- Other, please specify

Please specify "Other"

Considering your main style of yoga, what components do you include in your regular yoga class?

- Yoga poses (Asana)
 - Breathing (Pranayama)
 - Meditation (e.g. breath awareness, chakra visualisation etc.)
 - Relaxation (Yoga nidra, Shavasana, child's pose etc.)
 - Chanting (Mantra such as Om, Positive resolve etc.)
 - Cleansing (such as neti)
 - Yama and Niyama (non violence, austerities such as fasting, silence etc.)
 - Lifestyle modifications
 - Other, please specify
-

Please specify "Other"

25% complete

Details of Yoga components (yoga poses, pranayama, meditation, relaxation and chanting):
Considering your specialisation in the style of yoga, please answer the following questions.
(For example, if you are teaching ashtanga vinyasa as your main style of teaching then considering ashtanga vinyasa, please answer the following questions.)

What do you emphasise in teaching a yoga pose?

- Steady and comfortable pose
- Moving with ease,
- Alignment and body awareness
- Linking breaths to movement
- Strengthening and Stretching
- A good physical workout
- Gentle and relaxing
- Other, please specify

Please specify "Other"

What yoga poses do you regularly use in your classes?
(Please select multiple choices.)

- Gentle movements for joints
- Sun salutations
- Dynamic flow of poses (Vinyasa flow)
- Standing poses
- Balancing poses (arm balances)
- Poses in supine position
- Poses in prone position
- Poses in seated position
- Back bends
- Forward bends
- Inversions
- Twists
- Core strengthening poses
- Shavasana and other relaxing poses
- Other, please specify

Please specify "Other"

How long do you ask students to hold a yoga pose?
(Please write average number of breaths while holding a yoga pose.)

- 1-3 breaths 4-7 breaths
- more than 8 breaths

What is the average duration of a yoga pose in your class?
(Please write the time duration in seconds and minutes.)

- up to 30 seconds 30 seconds-1 minute
- 2-5 minutes more than 5 minute

What type of instructions do you give to your students in a yoga pose?

- Focus on body parts, joints and muscles
- Breathing awareness
- Deepening the yoga pose
- Stretch more, bend more etc.
- Relaxation instructions
- Other, please specify

Please specify "Other"

What percentage of your class is focused on yoga poses? (min 0 to max 100)

What pranayama practices do you regularly use in your classes?

- Slow breathing
- Abdominal breathing
- Deep breathing
- Alternate nostril breathing
- Anuloma viloma
- Ujjayi
- Bhramari
- Kapalbhata
- Bhastrika
- Fast breathing
- Sheetalī or Sitkari
- Kumbhaka (retention of breath)
- Other

Please specify "Other"

What percentage of your class is focused on pranayama? (min 0 to max 100)

How long is pranayama or yoga breathing practice in your class?

- up to 5 min
- 6-10 min
- 11-15 min
- more than 15 min

50% complete

How many times do you typically include shavasana (corpse pose) in a class?

- 0-1
- 2-3
- 4-5
- more than 5

What percentage of your class is focused on relaxation? (min 0 and max 100)

How long is the duration of relaxation or shavasana in your classes?

- Less than 5 min
- 5-10 min
- 11-20 min
- 21-30 min
- More than 30 min

What types of meditation do you regularly use in your classes?

- Mindfulness
- MBSR (Mindfulness-based stress reduction)
- Vipassana
- Breath awareness meditation
- Kundalini meditation
- Chakra meditation
- Om meditation
- Mantra chanting meditation
- Transcendental meditation
- Loving kindness meditation
- Sound meditation
- Other

Please specify "Other"

What percentage of your class is focused on meditation? (min 0 and max 100)

How long is the meditation practice that you use in your classes?

- up to 5 min
- 6-10 min
- 11-15 min
- 16-20 min
- 20-30 min
- more than 30 min

Do you typically include chanting in your classes?

- Yes
- No

Which chants do you typically include in your yoga classes?

- Om chanting
- Mantras (in Sanskrit)
- Positive resolves
- Chakra related mantras
- Other

Please specify "Other"

What percentage of your class is focused on chanting?
(min 0 and max 100)

We are interested in the sequence of yoga components used in classes. Please use the list below to allocate a commonly used sequence of various practices in your classes. (you can select a practice more than once).

	Start	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	End
1 Sun salutations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2 Warm ups for joints	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3 Vinyasa flow	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4 Standing poses	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5 Forward bends and back bends	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6 Side bends and twists	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7 Inversions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8 Balancing poses	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9 Relaxing poses	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10 Pranayama	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11 Meditation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12 Chanting	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

If you would prefer to provide an alternative sequence using yoga components other than stated above, please do so here.

Are there any related practices other than yoga poses, pranayama, relaxation and meditation that you teach in your class? Please list here.

75% complete

Details of your Yoga class

How often do you design a class to suit individual needs?

- Never
- Occasionally
- Sometimes
- Often
- Usually
- Always

What is the typical duration of your yoga class?

- Less than 15 min
- 16-30 min
- 31-45 min
- 46-60 min
- 61-75 min
- 76-90 min
- More than 90 min

Please rate the importance of yoga components that you use in your yoga class.

	Most important	Very important	Somewhat important	Less important	Not important
1 Yoga poses	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2 Pranayama or Breathing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3 Meditation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4 Relaxation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5 Chanting or Om	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6 Other (cleansing, austerities, Yama, Niyama)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

It is often cited that people practise yoga to help cope with stress. In your opinion, are there particular symptoms of stress that are reduced by the practise of Yoga?

In your opinion, does a single session of yoga impart benefits to stress related symptoms?

- Yes
- No
- Can't say

Which, if any, of the following benefits are commonly seen after practise of a single session of yoga?

- Calmness of mind
- Focus and concentration
- Energetic feeling
- Better sleep
- Feeling of happiness
- Increased self confidence
- Increased self esteem
- Reduced muscle and joint pain
- Healing of health condition
- Other

Please specify "Other"

Do you think that a single yoga session is associated with any of the following psychological/physiological improvements?

	Strongly agree	Somewhat agree	Neutral	Somewhat disagree	Strongly disagree
1 Overall improvement in psychological symptoms related to stress	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2 Decrease in anger, irritability, anxiety, worries, fear, depression, sadness etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3 Improvement in concentration	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4 Overall improvement in physiological symptoms of stress	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5 Muscular tension, back pain, neck pain, headache	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6 Stomach and gut problems, acidity, heart burn, diarrhoea, constipation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7 High BP, Heart related problems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8 Sleep problems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

100% complete

Thank you for completing the survey, we welcome participation of other yoga teachers. Please feel free to forward the link below to your friends who are yoga teachers.
 Survey link: [Yoga Components Survey](#)
 Please feel free to contact Gandhar Mandlik with any questions.
 T: +61 451069173 E: gman2104@uni.sydney.edu.au

If you would like to receive the summary and conclusion of the survey, please provide an email address where we can send the summary when available. _____

Appendix 3 - Effect of a single session of yoga and meditation on stress reactivity-A systematic review

Effect of a single session of yoga and meditation on stress reactivity: A systematic review

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Abstract

This systematic review synthesises the evidence for the effectiveness of a single session of yoga or its components including meditation and breathing techniques in reducing acute stress reactivity in healthy adults. Following the PRISMA guidelines, we searched Medline, EMBASE, Cochrane, CINAHL, and PsycINFO on 30th July 2023 for randomised controlled or crossover trials of yoga components and reporting physiological and/or psychological outcome measure(s) related to stress reactivity. Risk of bias (ROB) was assessed using the Cochrane ROB 2 tool. Data were synthesised narratively. Twenty-one out of 28 eligible studies ($n = 2574$) relating to 31 interventions (meditation [$n = 22$], breathing [$n = 4$] and yoga [$n = 5$]) reported outcomes in favour of the intervention. Stress reactivity was reported to be reduced by 71% of studies measuring physiological outcomes and 65% of studies measuring psychological outcomes. These studies show that a single session of yoga components is effective in reducing acute stress reactivity in adults and could be recommended for stress management. Future studies with larger populations and a more equal representation of genders and age groups are warranted.

KEYWORDS

breathing, meditation, pranayama, stress, yoga

1 | INTRODUCTION

The survival benefit of the acute stress response is well established, however repeated and long-term exposure to stressors is associated with various physical and mental health conditions (Agorastos & Chrousos, 2022). Chronic exposure to stressors including repeated acute stress responses results in wear and tear of the body systems and organs which is referred to as allostatic load (McEwen, 2008). Acute stress reactivity shows considerable individual differences (Boyce & Ellis, 2005), including sex (Bangasser et al., 2019),

psychological functioning and genetic variations (Gunnar & Herrera, 2013). Current evidence shows that both exaggerated and attenuated stress reactivity is associated with adverse health outcomes (O'Connor et al., 2021). It has been suggested that when the stress response is adaptive, systems return to baseline faster after the stressor ends. It follows that reducing heightened and prolonged reactivity could be important in reducing the risk of various health conditions. Some behavioural interventions (such as yoga, meditation, exercise, and health behaviours etc.) may have a positive effect in attenuating this stress reactivity (Kiecolt-Glaser et al., 2020).

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Yoga encompasses a wide range of practices, from philosophical to spiritual but the body-mind practices are the most popular (Eliade, 2009), these include components such as physical practices (asana or yoga poses or postures), breathing techniques (pranayama or breath control), relaxation and meditation (dhyana) (Cartwright et al., 2020). In recent years, yoga has grown very rapidly in popularity around the world, for example, in 2017 about 14% of adults in the United States practised yoga and meditation in the last 12 months according to a National Health Interview Survey (Clarke et al., 2018).

Yoga practice has been found to benefit many aspects of physical and mental health especially decreasing the risk factors of various diseases (Cramer, Lauche, Haller, et al., 2014; Innes & Selfe, 2016). Often, yoga interventions reported positive outcomes related to stress and may be the attenuation of stress is one of the mechanisms for yoga related health benefits (Park et al., 2021). Moreover, yoga has been shown to be effective in managing stress-related illnesses (Riley & Park, 2015), anxiety and depression (Kirkwood et al., 2005; Pascoe & Bauer, 2015; Pilkington et al., 2005).

Although yoga practice typically includes physical postures, breathing techniques and meditation, these components have also been studied separately for their independent effect on health. For example, the practice of meditation offers many health benefits including improvement in physiological markers of stress (Heckenberg et al., 2018) and emotional regulation (Gotink et al., 2016). Similarly, breathing techniques can improve cardiac autonomic functions and reduce stress (Innes & Selfe, 2016).

Evidence suggests that the mechanism of yoga's effects on stress reduction may include the attenuation of the physiological and psychological responses to stress. Two different pathways have been proposed. First, a top-down neurocognitive model posits that the practice of yoga and meditation may increase emotional regulation and subsequently influence brain and nervous system activities, attenuating the processing of stressful stimuli (Gard et al., 2014; Kinser et al., 2012; Schmalzl et al., 2015). A second hypothesised mechanism is based on a bottom-up neurophysiological model which suggests that yoga practices increase parasympathetic nervous system (PNS) activity (Gard et al., 2014; Kinser et al., 2012; Streeter et al., 2012), deactivating sympathetic nervous system (SNS) activity (Pascoe & Bauer, 2015; Riley, 2004; Salmon et al., 2009) and the hypothalamic-pituitary-adrenal axis (HPA) (Pascoe & Bauer, 2015), meaning the same stressful signal elicits an attenuated physiological response. In addition, psychological mechanisms such as mindfulness, interoceptive awareness, spiritual well-being have been found to be associated with attenuating effect of yoga on stress reactivity (Park et al., 2021). These mechanisms have been proposed based on studies of the habitual practice of yoga or its components including meditation, typically from a few weeks to several months.

A number of reviews have evaluated the effectiveness of yoga (1-24 weeks) or meditation training (3-15 weeks) on stress and have shown significant positive effects of the interventions on psychological (Goyal et al., 2014; Pascoe & Bauer, 2015) and physiological measures of stress (Cramer, Lauche, Haller, et al., 2014; Heckenberg

et al., 2018). However, it is not clear if these chronic effects of yoga and meditation are an accumulation of short-term effects of each yoga bout, or a gradual change over time, or a combination of both. Understanding this dose response is important to determine mechanisms and inform future interventions. So to understand the mechanisms of the positive effect of yoga and meditation in ameliorating stress reactivity, it is important to study the acute effects of these practices. No systematic review has focused on the effect of yoga components on acute stress reactivity as measured following a single session of practice.

The aim of this systematic review is to summarise and synthesise the effects of a single session of yoga or its components including yoga poses, breathing techniques and meditation, on stress reactivity to an acute stress task in healthy adults.

2 | METHODS

2.1 | Search strategy

The protocol and reporting of this systematic review adhere to the PRISMA guidelines (Page et al., 2021). The databases APA PsychInfo, Cinahl complete, Cochrane Central Register of Controlled Trials, Ovid Embase and Ovid Medline were searched on 30th July 2023 using broad search terms and MeSH terms. Additionally, we searched reference lists of included articles to identify additional studies. The complete search strategy used for the databases is presented in Appendix A1. The systematic review methodology was registered in PROSPERO (CRD42020214426) and is available at: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020214426.

2.2 | Study selection

References of all retrieved studies were imported into ENDNOTE X9 citation management software (Clarivate Analytics, PA, USA). Duplicates were removed and the remaining studies were assessed for eligibility criteria by two researchers (Gandhar V. Mandlik and George Siopis). Inclusion criteria were: *Participants*: adults aged 18 years or above; *Intervention*: a single session of yoga and/or meditation and exposure to a laboratory stressor (physiological or psychological task which induces acute stress); *Comparator*: active or passive control. Active controls include other forms of exercise such as walking and passive control refers to physically inactive control conditions such as reading or listening to music; *Outcomes*: Physiological and psychological markers of stress. Physiological measures include cardiovascular markers (e.g., heart rate, blood pressure, heart rate variability), inflammatory markers (e.g., interleukin-6, C-reactive protein) or hormones (e.g., cortisol). Psychological measures include self-reported measures related to stress and anxiety. *Timeframe*: No restriction in regard to the publication year of the study was placed. Searches were conducted on 25th December 2020 and later updated on 7th February 2022. *Study*

design: Randomised controlled trials (RCTs), including pilot, prospective, cluster and crossover RCTs. *Other limits*: Only studies published in the English language were considered for inclusion.

2.3 | Data extraction

A data extraction form was developed (George Siopis) based on the guidelines in the sixth version of the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2019). The form was piloted on a subsample of the included studies and refined before being used by two authors (Gandhar V. Mandlik and Binh Nguyen) to extract the data: publication details (title, journal, year), authors' details (names, affiliations, funding, conflict of interest), study details (year, country, design, purpose, blinding and randomisation method, statistics), participants' characteristics (inclusion criteria, sample size, recruitment process, retention rate, compliance, and demographics i. e. age, sex, race, ethnicity, education and other), intervention (protocol description, stressor, duration, primary and secondary outcome factors), comparison (details of care, other details), results (primary and secondary outcomes and statistical significance), conclusions (considering study limitations).

2.4 | Data analysis

The revised Cochrane risk-of-bias in randomised trials (ROB 2) tool was used to assess the quality of the studies on aspects of trial design (e.g. random-sequence generation and allocation concealment), trial conduct (e.g. appropriateness of analysis), and trial reporting (e.g. selective outcome reporting), and other sources of bias in accordance with the recommendations of the Cochrane Collaboration (Sterne et al., 2019). Since the review included both parallel group and crossover RCTs, both ROB 2 tools that correspond to each of these study designs were used. Studies were ranked by two authors (Gandhar V. Mandlik and George Siopis) as 'low risk', 'some concerns', or 'high risk'. Authors resolved discrepancies by discussion.

2.5 | Data synthesis

The heterogeneity of reported outcomes did not permit for a meta-analysis. Instead, the studies' findings were presented in a tabular manner and synthesised narratively.

3 | RESULTS

A total of 5137 records were identified from initial searches and after removing 1772 duplicates, 3365 abstracts were screened for possible inclusion. Of these, 121 articles were selected for full text screening. Finally, 28 studies meeting the inclusion criteria were selected for

qualitative synthesis (Figure 1—PRISMA 2020 flow diagram). The reasons for exclusion of full-text articles were: more than a single session of intervention ($n = 25$), no relevant outcome ($n = 16$), no laboratory stressor ($n = 12$), not RCT or crossover design ($n = 13$), no relevant population ($n = 9$), conference proceedings or symposium abstract or review protocol ($n = 8$), no relevant intervention ($n = 8$) and no control group ($n = 2$). The details of reasons for exclusion of studies is presented in Appendix A2.

3.1 | Study characteristics

Study characteristics are summarised in Table 1. Most studies were conducted in the USA ($n = 17$), two studies were from the UK and Canada, and one study each from South Africa, India, China, Germany, the Netherlands, Taiwan and Australia. A large majority of studies were parallel arm RCTs ($n = 25$) and three were randomised crossover trials. Most of the articles ($n = 26$) were published in the last 10 years.

Table 2 summarises the ROB for each individual trial for the outcome. Four RCTs were evaluated as high risk, two of which due to concerns regarding randomisation (Grant et al., 2013; Mohan et al., 2011) and two missing outcome data (Masters et al., 2020; Wheeler et al., 2019). The remainder of the trials were assessed as either low risk ($n = 6$) or with some concerns ($n = 16$). Two crossover trials were deemed to be low risk while one had some concerns.

3.2 | Participant characteristics

A total of 2574 participants were recruited across all 28 studies. Nine studies had 100 or more participants, 13 studies had 50 to 100 participants and six had 50 or less participants. Most studies had more female than male participants ($n = 20$) and only two studies had more males. Two studies recruited female participants only and two male participants only. One study included equal male and female participants and one more study did not report the gender. Most studies had young adults with a mean age between 18.9 and 27.3 years ($n = 24$) with two studies having participants with a mean age of 30 years or more. Two studies did not report the mean age. Across studies, participants were recruited mostly from universities and colleges ($n = 22$). Eight studies had participants with no or minimal yoga or meditation experience, while seven studies recruited either experienced and/or a mixed population (experienced and naive). The remaining studies did not report the yoga or meditation experience of the participants.

3.3 | Intervention

Studies included various yoga components as interventions, mostly meditation ($n = 22$), breathing techniques ($n = 4$) and yoga ($n = 5$).

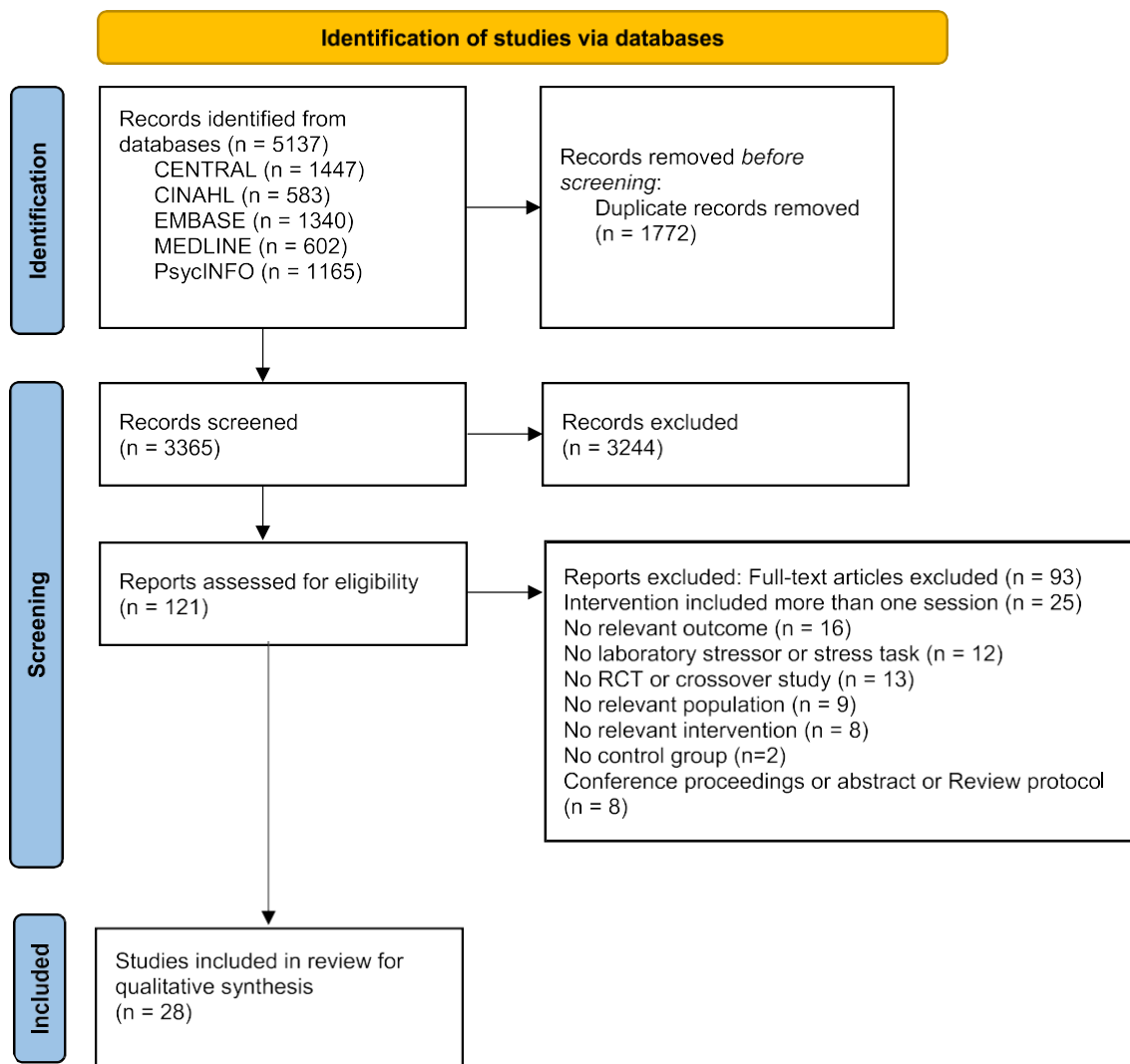


FIGURE 1 PRISMA 2020 flow diagram. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* 2021; 372:n71. Doi: 10.1136/bmj.n71. For more information, visit: <http://www.prisma-statement.org/>.

Five studies included multiple components of yoga (yoga poses, breathing, meditation, relaxation) as separate interventions. Of these, two included meditation and relaxation (Koerten et al., 2020; Rausch et al., 2006), while the other three included meditation and breathing (Chelidoni et al., 2020), breathing and relaxation (Smith & Norman, 2017), and meditation along with yoga poses and breathing (Wheeler et al., 2019). Meditation studies varied in type and duration. Fourteen studies used meditation based on mindfulness or components of mindfulness (such as awareness of breath and/or body, present moment awareness, loving-kindness meditation) while five other studies included focused attention meditation with focus on breath, body, relaxation or visualisation. Two studies used mantra meditation (Goleman & Schwartz, 1976; Rausch et al., 2006), and Masters et al. (2020) included secular meditation. Breathing techniques included deep breathing (rate of 5 to 6 breaths per minute) in three studies while the fourth study included various types of

breathing (e.g., deep breathing, nadi shodhan or alternate nostril breathing, ujjayi) (Wheeler et al., 2019). Regarding yoga, four studies selected hatha yoga or hatha yoga-based styles (Benvenuti et al., 2017; Chu et al., 2023; Kiecolt-Glaser et al., 2010; Robinson et al., 2023). One study did not report yoga style (Wheeler et al., 2019).

The duration of meditation varied between 5 and 20 min, lasting between 15 and 20 min for 12 studies, and less than 12 min for nine studies. One study did not report the duration (Wilson et al., 2014). Three yoga studies were of 30 min duration (Benvenuti et al., 2017; Chu et al., 2023; Robinson et al., 2023) while one study was 20 min (Wheeler et al., 2019), and another study was 85 min (Kiecolt-Glaser et al., 2010). The breathing duration was of 5 min in two studies (Chelidoni et al., 2020; Chin & Kales, 2019), 10 min in two other studies (Smith & Norman, 2017) and 20 min in one study (Wheeler et al., 2019).

TABLE 1 Summary of studies included.

Names, (year) country	Study design	Sample size	Demographics	Intervention protocol and duration	Control condition	Stressor	Physiological outcomes	Psychological outcomes
Meditation								
Archary and Thatcher (2021) South Africa	RCT	N = 60	Female = 65%, mean age 21.80, SD 6.09; age range 18-50	Focused attention meditation (breathing and sounds of ocean waves), 6 min Plant condition (indoor plants in the room), 6 min	Sit quietly (watch a blank computer screen)	Vigilance task		PANAS Dundee Stress State Questionnaire (DSSQ-S)
Azam et al. (2015) Canada	RCT	N = 68	Female = 43%; mean age for perfectionists 22.05, SD 1.57, and control 20.62, SD 0.82	Mindfulness meditation, 10 min	Audio (information on mindfulness meditation)	Computer-based pattern recognition task	HRV	
Borchardt and Zoccola (2018) USA	RCT	N = 107	Female = 56%; mean age 18.94, age range 18-22	Focused attention meditation, 20 min	1. Audio book 2 Sit quietly	PASAT	BP HR SC HRV (RMSSD)	PANAS
Carpenter et al. (2019) USA	RCT	N = 107	Female = 66%; mean age 19.0, SD 1.4	Mindfulness components (present-moment awareness and nonjudgment), 15 min	Music	CPT Hyperventilation Neutralisation task	Tidal volume	SUDS FFMQ Depression, Anxiety, and Stress Scale (DASS)
Carsley and Heath (2020) Canada	RCT	N = 167	Female = 81%; mean age 21.29, SD 4.46	Mindfulness meditation (draw a mandala), 15 min Free drawing, 15 min	Place the numbers, letters etc. in boxes on the page	Wide Range Achievement Test (WRAT-4) (spelling section)		STAI (state) Child and
Cruess et al. (2015) USA	RCT	N = 123	Female = 65%; mean age 19.08, SD 1.02	Mindfulness meditation, 15-20 min	Relaxation and brief attention	TSST	Cortisol (salivary) Alpha-amylase (salivary)	Acute subjective distress
Erisman and Roemer (2010) USA	RCT	N = 33	Female = 55%, mean age 24.10, SD 7.28; age range 18-50	Mindfulness meditation, 10 min	Educational information	Film clips	SC HR	Difficulties in Emotion Regulation Scale (DERS) PANAS

(Continues)

TABLE 1 (Continued)

Names, (year) country	Study design	Sample size	Demographics	Intervention protocol and duration	Control condition	Stressor	Physiological outcomes	Psychological outcomes
Goleman and Schwartz (1976) USA	RCT	N = 60	Gender not reported; meditators' mean age 25, non-meditators' mean age 23; age range 18-31	Transcendental meditation, 20 min	Sit quietly (eyes open)	Film clip	SC	Affect Adjective Check List (AACL)
					Sit quietly (eyes closed)		HR	Activity Preference Questionnaire (APQ) STAI
Grant et al. (2013) USA	RCT	N = 97	Female = 54%; 95.80% participants between age 18-21	Mindfulness component (breathing), 20 min	Audio book	CPT	BP	
							HR	Mirror tracing task (MT)
Hirshberg et al. (2018) USA	RCT	N = 166	Female = 61%, mean age 19.29, SD 0.74	Mindfulness component (breath awareness), 12 min	Attention control	CPT		Anxiety sensitivity index
				Mindfulness component (loving-kindness), 12 min				Gratitude questionnaire
				Mindfulness component (gratitude), 12 min				Implicit positive and negative affect task PANAS CPT aversiveness rating
Johnson et al. (2019) USA	RCT	N = 75	Female = 79.4%, mean age 21.84, SD 3.48	Mindfulness meditation 5 min	Do nothing control	Speech and anger recall task	BP	Momentary mood scale
Koerten et al. (2020) USA	RCT	N = 120	Female = 74%; mean age 19.39, SD 2.02	Mindfulness meditation (focus on nonjudgment), 10 min	Sit quietly	Cognitive task	HR	
				Mindfulness meditation (general), 10 min			HRV	
				Progressive muscle relaxation, 10 min				
Liu et al. (2013) China	RCT	N = 60	Female = 100%; mean age 20.48 years, SD 1.47	Mindfulness meditation, 15 min	Music	CPT	Pain tolerance	
				Distraction intervention, 15 min			Pain ratings	
Masters et al. (2020) USA	RCT	N = 85	Female = 55%; mean age 18.9, SD 1.2	Meditation (secular), 15 min	Sit quietly (watching nature landscapes)	Religious views interview	BP	PANAS
				Christian prayer, 15 min				HR

TABLE 1 (Continued)

Names, (year) country	Study design	Sample size	Demographics	Intervention protocol and duration	Control condition	Stressor	Physiological outcomes	Psychological outcomes
Mohan et al. (2011) India	RCT	N = 32	Female = 0%; mean age 27.3, SD 1.8; age range 23-30	Focused attention meditation, 20 min	Sit quietly	Stressful computer game	HR EMG SC QTc/QS2 Cortisol	Acute stress questionnaire
Rausch et al. (2006) USA	RCT	N = 405	Female = 71%; mean age 19, SD 3.37; age range 17-42	Meditation (mantra), 20 min Progressive muscle relaxation, 20 min	Sit quietly	Four negative affect- and arousal-evoking photographic slides.		STAI Cognitive Anxiety Scale (CAS) Smith Somatic Stress Symptoms Scale-State (SSSSS-S)
Rosenbaum et al. (2020) Germany	RCT	N = 67	Female = 72%; mean age mindfulness low rumination 28.6, SD 9.59; mindfulness high rumination 23.2, SD 3.15; instructed thinking low rumination 22.9, SD 3.46; instructed thinking high rumination 22.3, SD 3.46	Mindfulness meditation, 14 trials of 40 s	Instructed thinking (direct attention to past or future)	Movie clips with strongly negative or neutral valence.	Cortical activation	PANAS
Steffen and Larson (2015) USA	RCT	N = 62	Female = 50%; mean age mindfulness 19.9, SD 2.0; mean age control 20.6, SD 2.3	Mindfulness meditation, 14.33 min	Audio (related to mindfulness)	PASAT	1. BP 2. HR	STAI (state)
van Hooff and Baas (2013) Netherlands	RCT	N = 100	Female = 70%; mean age 21.99, SD 5.38	Focused attention meditation (visualisation), 15 min	Audio (related to meditation)	Speech preparation task		SUDS PANAS

(Continues)

TABLE 1 (Continued)

Names, (year) country	Study design	Sample size	Demographics	Intervention protocol and duration	Control condition	Stressor	Physiological outcomes	Psychological outcomes
Wilson et al. (2014) UK	RCT	N = 80	Female = 60%; mean age 27.12, SD 6.37; age range 18-40	Acceptance strategy Mindfulness strategy Suppression strategy Endurance strategy, duration not reported	Audio (content about nature)	Verbal analogy trials	SC	Relaxation and anxiety related adjectives
Breathing								
Chelidoni et al. (2020) UK	RCT	N = 75	Female = 64%; mean age 32.32, SD 10.46, age range 18-62	Mindfulness meditation (body scan), 5 min Breathing (using BioBase app), 5 min	Sit quietly	Continuous performance task Film clips	HRV	Samn-Perelli Fatigue Checklist Stanford Sleepiness Scale VAS for moods
Chin and Kales (2019) USA	RCT	N = 48	Female = 0%; mean age 29.7 Breathing - 29.7 Contraction & relaxation - 26.7 Breathing and contraction & relaxation - 32.3 Control - 30.3 Age range 18-55	Breathing, 5 min Contraction & relaxation of arm muscles, 5 min Breathing and contraction & relaxation, 5 min	Read four adapted articles	Stroop test	HRV	
Smith and Norman (2017) USA	RCT	N = 63	Female = 62%; mean age 20; age range 18-23	Breathing, 10min Progressive muscle relaxation, 10min	Sit quietly (watch a moving dot on screen)	CPT	ECG HRV	STAI PSS
Yoga								
Benvenuti et al. (2017) Australia	Randomised crossover	N = 24	Female = 46%; mean age 22.9, SD 3.5	Yoga (hatha), 30min	Video (history of yoga)	PASAT	BP HR Cortisol (salivary)	Immediate Anxiety Measures Scale (IAMS)
Chu et al. (2023) Taiwan	Randomised crossover	N = 44	Female = 52.3%; mean age = 24.66 SD 3.85years	Yoga (hatha), 30min	Video (history of earth)	Stroop task mental arithmetic task	HR, HRV	

TABLE 1 (Continued)

Names, (year) country	Study design	Sample size	Demographics	Intervention protocol and duration	Control condition	Stressor	Physiological outcomes	Psychological outcomes
Kiecolt-Glaser et al. (2010) USA	Randomised crossover	N = 50	Female = 100%; mean age 41.32, SD 10.33; age range, 30-65	Yoga (iyengar), 85min	Walking (on treadmill)	Stroop test (emotional)	IL-6	Pittsburgh Sleep Quality Index (PSQI)
					Neutral video	CPT	TNF- α	Mood and Anxiety Symptom Questionnaire
						Mental arithmetic task	CRP	PANAS
Robinson et al. (2023) USA	RCT	N = 97	Female = 65.5%; mean age 19.85, SD = 3.22	Yoga (hatha)	Nature documentary	TSST	Cortisol (salivary)	
Wheeler et al. (2019) USA	RCT	N = 117	Female = 91%; mean age 19.5	Yoga (poses), 20min	Audio (yoga lecture)	TSST	BP	PANAS
				Breathing (deep breathing, nadi shodhan, ujjayi etc.), 20min Meditation (visualisation), 20min			HR	STAI (state)

Abbreviations: BP, blood pressure; CPT, cold pressor task; CRP-C, reactive protein; EMG, electromyography; FFMQ, five factor mindfulness questionnaire; HR, heart rate; HRV, heart rate variability; IL, interleukin; PANAS, Positive and Negative Affect Schedule; PASAT, Paced Auditory Serial Addition Test; PSS, Perceived Stress Scale; QTc/QS2, sympathetic reactivity; SC, skin conductance; STAI, state trait anxiety inventory; SUDS, subjective units of distress; TNF, tumor necrosis factor; TSST, trier social stress test; VAS, visual analog scale.

TABLE 2 Risk of bias (ROB2).

RCT's						
Author	D1	D2	D3	D4	D5	Overall
Archary et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Azam et al.	Low risk	Low risk	Low risk	Low risk	Some concerns	Low risk
Borchardt et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Carpenter et al.	Low risk	Some concerns	Some concerns	Some concerns	Low risk	Low risk
Carsley et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Chelidoni et al.	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns
Cruess et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Erisman et al.	Low risk	Low risk	Low risk	Some concerns	Low risk	Some concerns
Goleman et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Grant et al.	Some concerns	Low risk	Some concerns	Low risk	Low risk	High risk
Hirshberg et al.	Some concerns	Low risk	Some concerns	Low risk	Low risk	Some concerns
Johnson et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Koerten et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Liu et al.	Low risk	Low risk	Some concerns	Low risk	Low risk	Some concerns
Masters et al.	Some concerns	Some concerns	High risk	Low risk	Low risk	High risk
Mohan et al.	High risk	Low risk	Low risk	Low risk	Low risk	High risk
Rausch et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Rosenbaum et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Smith et al.	Low risk	Low risk	Some concerns	Low risk	Low risk	Some concerns
Steffen et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
van Hooff et al.	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns
Wilson et al.	Low risk	Low risk	Low risk	Some concerns	Some concerns	Some concerns
Chin et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Robinson et al.	Some concerns	Low risk	Some concerns	Low risk	Low risk	Some concerns
Wheeler et al.	Some concerns	Low risk	High risk	Low risk	Low risk	High risk
Crossover trials						
Benvenuti et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Chu et al.	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Kiecolt-Glaser et al.	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

Note: D1, randomisation process; D2, deviations from the intended interventions; D3, missing outcome data; D4, measurement of the outcome; D5, selection of the reported result; DS, bias arising from period and carryover effects.

In terms of delivery of interventions, most studies used audio or video recordings ($n = 15$) or self-practice after brief instructions ($n = 9$). In four studies, the intervention was delivered by an instructor. There was substantial variation in control conditions, ranging from listening to an audio recording ($n = 9$), or music ($n = 2$), watching defined contents (video, images, blank computer screen or a dot) or reading ($n = 8$) to sitting quietly, focusing ($n = 7$), or thinking of a past or future event ($n = 1$) and sorting of numbers or letters ($n = 1$). Two studies included two control conditions (Goleman & Schwartz, 1976; Kiecolt-Glaser et al., 2010).

3.4 | Stressor characteristics

To invoke a stress response in participants, different types of stress tasks were used. Most studies used a single stressor ($n = 22$), but six studies included multiple stressors. Most used stressors were the cold pressor task (CPT) ($n = 6$), mathematical/arithmetic tasks ($n = 6$), film clips or images ($n = 4$), the trier social stress test (TSST) ($n = 3$), Stroop task ($n = 3$) and the remaining stressors are listed in Table 1. The order of intervention and stress task varied across the studies. For the physiological stressors, four out of five studies had the

intervention prior to the stress task, and one had both prior to and following the intervention. The order of psychological stressors was mixed with eight studies having it before and 11 after the interventions while four studies had stress task before and after the intervention.

3.5 | Physiological and psychological outcome measures

Eighteen studies included at least one physiological outcome measure of stress. Heart rate (HR) was the most used measure ($n = 9$) followed by blood pressure (BP) ($n = 7$), heart rate variability (HRV) ($n = 7$), skin conductance (SC) ($n = 5$), cortisol ($n = 4$), salivary Alfa-amylase (sAA) ($n = 1$), Interleukin (IL-6) ($n = 1$), C-reactive protein (CRP) ($n = 1$), Tumour necrosis factor (TNF- α) ($n = 1$), and sympathetic reactivity (QTc/QS2 ratio) ($n = 1$). Regarding psychological measures, 15 studies included various self-report questionnaires, including: Positive and Negative Affect Schedule (PANAS) ($n = 7$), The State-Trait Anxiety Inventory (STAI) ($n = 6$), Perceived Stress Scale (PSS) ($n = 1$), subjective units of distress ($n = 1$), acute stress questionnaire ($n = 1$), Dundee Stress State Questionnaire ($n = 1$), momentary mood scale ($n = 1$) and self-report relaxation and anxiety scales ($n = 1$). Ten out of 28 studies included both physiological and psychological measures. Thirteen studies used more than one physiological measure, and 11 studies included more than one psychological stress measure.

3.6 | Study findings

The summary of outcome measures and findings can be found in Table 3. Out of 28 studies included in this review, 21 studies reported statistically significant beneficial effect of yoga or breathing or meditation on stress outcomes. Seventy-seven percent (17 of 22) of meditation, 60% of yoga (3 of 5) and 50% (2 of 4) of breathing interventions reported beneficial effects of yoga-based interventions. Of the 21 studies that used physiological measures, 15 showed statistically significant effects in favour of yoga/meditation/breathing for at least one outcome. All four studies that included cortisol measures showed significant reduction favouring the intervention conditions. Four of five studies employing SC and four out of seven using HRV found significant results in favour of the intervention. For BP, only three out of seven studies showed significant effect of the intervention, no effect was found by three studies while one study reported a greater rise in SBP compared to the control condition (Grant et al., 2013) which was contrary to the hypothesis. For HR, three out of nine studies showed significant effect for the intervention and six found no difference. Regarding the psychological measures, 11 out of 17 studies reported statistically significant changes indicative of a beneficial effect of intervention on stress reactivity. For anxiety, four out of six studies reported significant reduction and three out of seven studies had significant changes in positive and/or

negative affect in favour of the intervention. Moreover, 10 studies included physiological and psychological stress measures, four found notable difference in both measures of stress reactivity (Crues et al., 2015; Goleman & Schwartz, 1976; Kiecolt-Glaser et al., 2010; Mohan et al., 2011). Nine out of 12 (75%) studies having 15-20 min meditation practice reported significant effect on stress reactivity in at least one outcome measure and six out of nine (67%) studies with <12 min practice duration reported favourable outcomes in one of the outcome measures.

For the studies that compared two or more yoga components, results of comparison between the effectiveness of components were mixed. One study found breathing was more effective than meditation (Chelidoni et al., 2020). Two studies comparing meditation with relaxation reported both interventions to be effective with one reporting meditation more effective (Koerten et al., 2020) and one reporting relaxation more effective (Rausch et al., 2006). In contrast, two studies comparing breathing with relaxation (Smith & Norman, 2017) and yoga poses with breathing and meditation (Wheeler et al., 2019) found no difference between any of the interventions and control.

4 | DISCUSSION

To our knowledge, this is the first systematic review to synthesise the acute effects of yoga and meditation on stress reactivity. Overall, the included studies reported beneficial effects of a single session of yoga or its components including meditation, on reducing acute stress reactivity which has implications for physical and mental health. We found more than three quarters of studies reporting reduced acute stress reactivity. In line with the previously hypothesised mechanisms (Gard et al., 2014), our findings suggest a single session of yoga components leads to deactivation of SNS, HPA axis and activation of PNS which lead to reduced acute stress reactivity.

Elucidating the optimal characteristics of practise of yoga components to maximise its effectiveness is necessary for making most effective recommendations for health benefits. Our analysis therefore examined features including duration of sessions, specificity of action regarding stressor type and the intervention task characteristics as well as the most commonly affected outcome measures.

There is a large variation in recommendations for duration of a single session of meditation practice. For example, mindfulness based stress reduction programme as designed by Kabat-Zinn recommends 45 min to one hour of meditation every day (Santorelli et al., 2017) while transcendental meditation (based on mantra repetition) recommends 15-20 min twice a day (Miller et al., 1995; Samuelson et al., 2007; Wallace, 1970). While a positive relationship between meditation time and health benefits have been established for long-term practice (Goyal et al., 2014), the current review based on a single session (acute effects) found benefits of meditation in ameliorating the stress reactivity irrespective of the duration of meditation. Regarding the duration of yoga, previous reviews of chronic practice have reported significant positive effects where the

TABLE 3 Summary of outcome measures and findings.

Author	Intervention	Physiological outcome measures							Psychological outcome measures			
		SBP	DBP	HR	HRV-HF	Cortisol	SC	Other	STAI-S	PANASp	PANAS-	Other
Meditation												
Archary et al.	Meditation (FA)										↔	↓ <i>p</i> < 0.05 DSSQ-S
Azam et al.	Meditation (MM)				↑ <i>p</i> < 0.001							
Borchardt et al.	Meditation (FA)	↔	↔	↔	↔		↓ <i>p</i> < 0.01			↔	↔	
Carpenter et al.	Meditation (MC)											↔ SUD
Carsley et al.	Meditation (MM)									↓ <i>p</i> < 0.001		
Cruess et al.	Relaxation					↓ <i>p</i> < 0.05		↔		↓ <i>p</i> < 0.05		
	Meditation					↔		↔		↓ <i>p</i> < 0.05		
									Alfa-amylase (s)			
Erisman et al.	Meditation (MM)			↔				↔				↓ <i>p</i> < 0.05
Goleman et al.	Meditation (TM)			↓ <i>p</i> < 0.01				↓ <i>p</i> < 0.05		↓ <i>p</i> < 0.001		
Grant et al.	Meditation (MC)	↑ <i>p</i> < 0.05	↔	↔								
		↔	↔	↔								
Hirshberg et al.	Meditation (MC)										↔	
	Meditation (MC)										↔	
	Gratitude											↑ <i>p</i> < 0.05
Johnson et al.	Meditation (MM)	↓ <i>p</i> < 0.001	↓ <i>p</i> < 0.001									↔
Koerten et al.	Meditation (MC)			↓ <i>p</i> < 0.001	↑ <i>p</i> < 0.001							
	Meditation (MM)			↓ <i>p</i> < 0.001	↔							
	Relaxation			↔	↔							
Liu et al.	Meditation (MM)								↓ <i>p</i> < 0.01	↓ <i>p</i> < 0.05		
	Distraction								↓ <i>p</i> < 0.01	↔		
								PT		DT		

TABLE 3 (Continued)

Author	Intervention	Physiological outcome measures							Psychological outcome measures			
		SBP	DBP	HR	HRV-HF	Cortisol	SC	Other	STAI-S	PANAS β	PANAS-	Other
Masters et al.	Meditation (secular)	↔	↔	↔								
Mohan et al.	Meditation (BS) (FA)			↓ <i>p</i> < 0.05		↓ <i>p</i> < 0.05	↓ <i>p</i> < 0.05	↓ <i>p</i> < 0.001	↓ <i>p</i> < 0.05			↓ <i>p</i> < 0.01
	Meditation (AS) (FA)			↔		↓ <i>p</i> < 0.001	↓ <i>p</i> < 0.001	↓ <i>p</i> < 0.01	↔			↓ <i>p</i> < 0.01
Rausch et al.	Meditation									↓ <i>p</i> < 0.05		
	Relaxation									↓ <i>p</i> < 0.05		
Rosenbaum et al.	Meditation (MM)											↓ <i>p</i> < 0.001 EDA
Steffen et al.	Meditation (MM)	↓ <i>p</i> < 0.001	↓ <i>p</i> < 0.05									
van Hooff et al.	Meditation (FA)										↑ <i>p</i> < 0.01	↓ <i>p</i> < 0.05 SUD
Wilson et al.	Acceptance						↓ <i>p</i> < 0.05					↔
	Meditation (MM)						↔					↔
	Suppression and						↔					↔
	Endurance											Anxiety
Breathing												
Chelidoni et al.	Breathing				↑ <i>p</i> = 0.01		↑ <i>p</i> < 0.01 HRV- RMSSD	↑ <i>p</i> < 0.01 HRV-pNN50				
Chin et al.	Breathing				↔							↔
	Contraction				↑ <i>p</i> < 0.001							↓ <i>p</i> < 0.01
	Breathing β contraction				↑ <i>p</i> < 0.001							↓ <i>p</i> < 0.001 HRV (LF and LF/HF)
Smith et al.	Breathing				↔					↔		↔
	Relaxation				↔					↔		↔ (PSS)

(Continues)

TABLE 3 (Continued)

Author	Intervention	Physiological outcome measures							Psychological outcome measures			
		SBP	DBP	HR	HRV-HF	Cortisol	SC	Other	STAI-S	PANAS β	PANAS-	Other
Yoga												
Benvenuti et al.	Yoga	↓ $p < 0.05$	↓ $p < 0.05$			↓ $p = 0.01$ (Salivary)						
Chu et al.	Yoga			↔	↔							
Kiecolt-Glaser et al.	Yoga versus movement			↓ $p < 0.001$				↓ $p < 0.05$		↑ $p < 0.001$		
	Yoga versus video			↓ $p < 0.05$				↓ $p < 0.05$ TNF- α		↑ $p < 0.001$		
Robinson et al.	Yoga versus biofeedback					↔						
	Yoga versus video					↓ $p = 0.01$ (salivary)						
Wheeler et al.	Yoga poses	↔	↔						↔	↔		
	Breathing	↔	↔						↔	↔		
	Meditation (FA)	↔	↔						↔	↔		

Note: ↑ = Significant increase, ↓ = Significant decrease, ↔ = No change.

Abbreviations: ASQ, acute stress questionnaire; DBP, diastolic blood pressure; DSSQ, Dundee Stress State Questionnaire; DT, distress ratings; EDA, emotional distress and avoidance; HR, heart rate; HRV, heart rate variability; Meditation (AS), meditation after stressor; Meditation (BS), meditation before stressor; Meditation (FA), focused attention meditation; Meditation (MC), mindfulness component; Meditation (MM), mindfulness meditation; Meditation (TM), transcendental meditation; PANAS(b)/(-), Positive affect/Negative affect; PSS, perceived stress scale; PT, pain tolerance time; QTc/QS2, sympathetic reactivity; SBP, systolic blood pressure; STAI-S, state anxiety; SUD, subjective units of distress; TNF- α , tumour necrosis factor.

duration of multiple yoga sessions was between 35 and 90 min (Chong et al., 2011; Pascoe & Bauer, 2015). Although we included only five studies of yoga, three studies showing beneficial effects used 30 min or more durations while two studies finding no effect were of 30 and 20 min durations giving partial support to greater efficacy of longer duration practice. In contrast, two out of four breathing interventions of 5 min duration reported significant effect, but the longer duration interventions did not find any evidence. The two studies having longer than 5 min duration used complex modality in breathing intervention such as nine types of breathing practices or synchronising breath while watching movement on the screen (Smith & Norman, 2017; Wheeler et al., 2019). In contrast, the 5 min breathing interventions used simple deep breathing technique (Chelidoni et al., 2020; Chin & Kales, 2019) and had beneficial effects on stress reactivity. Our findings support previous evidence of usefulness of deep breathing in reducing stress (Hamasaki, 2020).

In the studies included in this review, acute stress was induced using a variety of stress tasks administered at different points in the sequence of the experiment (before the intervention or after the intervention or both). Unsurprisingly, different stress tasks evoke different patterns and magnitudes of responses. For example, a mental arithmetic task versus CPT or cycling produced different SNS receptor activation (Winzer et al., 1999) and the TSST evoked greater HPA axis response compared with CPT (McRae et al., 2006; Skoluda et al., 2015). Given this, we considered the effects of stressors when broadly categorised as physical or psychological stressors (Dayas et al., 2001; Parati et al., 1988). Although the stress reactivity to physical stressors such as CPT can be reduced using multiple session practise of yoga-based interventions (Rankhambe & Pande, 2021), the four out of five meditation studies involving physical stressors (CPT) in this review did not report any significant effect (Carpenter et al., 2019; Grant et al., 2013; Hirshberg et al., 2018; Smith & Norman, 2017). On the contrary, 16 out of 17 studies involving psychological stressors did report beneficial effect of meditation. Protocol differences were reported in studies using different stressor types, but it appears that the timing of the stressor did not affect the intervention effect. All yoga and breathing interventions included psychological stressors with 60% and 50% respectively showing positive effect on response to stressors. These results show the effectiveness of a single session of yoga components in reducing stress reactivity where the stressor was based on psychological (cognitive or emotional or psychosocial or mental) stimuli. Whereas we found little evidence for effect when the stressor was physiological. Together, this evidence points to the top-down neuro-cognitive model in attenuating stress reactivity after the single session of yoga components.

Different meditation techniques were employed in included interventions. A number of these are techniques of meditation described in traditional yoga (for example, mantra meditation) that highlight the importance of uninterrupted sustained attention on a single object (Eliade, 2009). These different types of meditations can be broadly classified as focused attention (focusing on an object in a sustained manner) and open monitoring meditations (nonjudgmental

present awareness) (Lutz et al., 2008). Mindfulness meditation which is a systematic and unified attentional technique rooted in Buddhism and yoga (Kabat-Zinn et al., 1985) that combines both focused attention and open monitoring types (Lutz et al., 2008). In this review, the nine studies that included mindfulness meditation reported positive evidence of reduction in stress reactivity. Similarly, studies using focused attention meditation (e.g., focusing on breath or body scan or relaxation or visualisation) or mantra meditation also reported significant improvement in at least one stress related outcome. The mindfulness meditation typically includes various components such as breathing, body scan, present moment awareness, and loving-kindness meditation (Santorelli et al., 2017). Notably of the five meditation studies that reported no significant effect of intervention in any of the stress measures, four of these used individual components of mindfulness meditation (Carpenter et al., 2019; Grant et al., 2013; Hirshberg et al., 2018; Smith & Norman, 2017) and the fifth one used a secular meditation involving reading of passages and deep reflection (Masters et al., 2020). This suggests that traditional meditation techniques are more effective than separated components in providing attenuation of the stress response. A possible explanation is the very developed, logical, methodical and multimodal development of attentional focus in traditional meditations (Kabat-Zinn et al., 1985) compared to simplified and less progressive process when components are separated.

The three yoga interventions reporting positive effects support the previous findings of beneficial effects of hatha yoga-based styles (Cramer et al., 2016). Interestingly, these three yoga interventions included breathing and meditation components along with physical postures in the protocol. But the proportions of these components were not specified. Different yoga styles give varying importance to physical postures, breathing and meditation (Cramer, Lauche, & Dobos, 2014). However, the effects of the contribution of these components on stress reactivity and overall physical and mental health are yet to be evaluated.

The outcome measures we found most consistently attenuated by yoga-based practices were HRV, SC and cortisol. These findings indicate that meditation and yoga interventions can increase PNS activity during stress reactivity (indicated by HRV) (Michael et al., 2017), decrease stress-induced SNS activity (indicated by SC) (Boucsein, 2012) and attenuate HPA response (cortisol) (McEwen, 2008). Our synthesis of the findings supports previous evidence of immediate effect of yoga on downregulating HPA axis and SNS (Ross & Thomas, 2010). HR and BP outcomes were not consistently affected across studies. It is possible that this inconsistency in BP and HR measures is due to the composite nature of these measures given responses are controlled by many physiological processes including both sympathetic and parasympathetic activity as well as hormonal factors. The hypothesised mechanisms for the effect of yoga components include top-down and bottom-up approach. The effect of yoga interventions on stress reactivity to psychological stressor points to the role of top-down cognitive as well as bottom-up physiological model. While comparing the yoga interventions with meditation practices, such as mindfulness, yoga includes more

physical movements, static postures along with conscious breath control and attentional focus which may have a stronger effect on vagus nerve and subsequently on autonomic, emotional and cognitive regulation (Schmalzl et al., 2015). However, this review could not compare yoga and meditation interventions due to small number of yoga studies ($n = 5$), and the outcome measures were not comparable between most of the yoga and meditation studies.

Finally, two studies reporting significant effect of intervention also found differences in stress reactivity between novices and experienced practitioners. The experienced practitioners were quickly habituated to the stressor, had significantly faster stress recovery (Goleman & Schwartz, 1976) and less inflammatory response (Kiecolt-Glaser et al., 2010).

4.1 | Strengths and limitations

The strength of this review lies in the use of robust methodologies to synthesise existing evidence, such as those documented by PRISMA and the Cochrane Collaboration. It is worth noting that all studies classified as low risk of bias reported benefits of interventions on stress reactivity, while these benefits were less consistent in studies with some concerns or high risk of bias. However, only 29% of studies were classified as low risk of bias. Searches were not restricted by year of publication. Limitations of this review include the relatively small number of studies with diverse outcome measures. Additionally, most of the studies included a younger population, with greater proportion of female participants, limiting the generalisability of the findings. The variety in intervention protocols, delivery methods and reported outcomes, rendered a meta-analysis of the effect of yoga components in stress reactivity reduction impossible. Finally, this review only included studies published in English.

4.2 | Conclusion

Considering the important role of stress in development of physical and mental health problems, it is very helpful if simple practices such as yoga and meditation can be recommended for stress management and understanding the effects of a single session will support recommendations as well as understanding of mechanisms. Although this systematic review is based on a small number of studies, we found supporting evidence for a single session of meditation in deactivating HPA axis and SNS activity while increasing PNS activity associated with stress and limited similar evidence for yoga and breathing. These findings support the top-down neurocognitive model and bottom-up neurophysiological model of attenuation of stress especially related to single session of yoga. Future research is needed to understand and quantify the effects of different yoga components and their combinations for various health benefits. More high-quality studies conducted in larger groups which include different age groups are needed. Future research with comparable intervention protocols including duration

of yoga components is needed. Additionally, the inclusion of comparable stress tasks and outcome measures will help in developing deeper understanding of the mechanisms of yoga and meditation effects on stress.

AUTHOR CONTRIBUTIONS

Gandhar V. Mandlik: Conceptualisation (equal); investigation (equal); writing – original draft (lead), formal analysis (lead). **George Siopis:** Methodology (lead); investigation (equal); writing – review and editing (equal). **Binh Nguyen:** Conceptualisation (equal); writing – review and editing (equal); supervision (supporting). **Ding Ding:** Conceptualisation (equal); methodology (equal); writing – review and editing (equal); supervision (supporting). **Kate M. Edwards:** Conceptualisation (equal); methodology (equal); investigation (lead); writing – review and editing (equal); supervision (lead). All authors have read and approved the article.

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All authors declare no conflicts of interest, financial or otherwise.

DATA AVAILABILITY STATEMENT

Template data collection forms, data extracted from included studies, and data used for analyses can all be made available upon request.

HUMAN AND ANIMAL RIGHTS

This article does not contain any studies with human participants or animals performed by any of the authors.

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SUPPORTING INFORMATION

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