THE PSYCHOPHYSIOLOGY OF YOGA

Characteristics of the main components and review of research studies

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Introduction: yoga as a multicomponent practice

As the prevalence of yoga practice is now surpassing 14% of the US adult population (Clarke et al. 2018), yoga practices are being implemented in mainstream institutions. Yoga instruction is appearing in educational institutions and in occupational and healthcare settings. Biomedical research on the psychophysiology of yoga and its therapeutic potential is critically important for the justification of such implementation. Yoga instructors and therapists increasingly need to acquire a basic understanding of biomedical and scientific research in order to justify the efficacy and cost-effectiveness of yoga within these mainstream societal venues. This research is also of interest to yoga practitioners who want to increase their understanding of the synergistic mechanisms of yoga as a multicomponent practice. An otherwise healthy yoga student may find benefit from any number of yoga classes. However, a yoga student or patient seeking yoga as therapy for a specific condition, whether it be mental health or chronic pain conditions, is likely to achieve greater benefit from understanding the evidence base and consulting with an expert.

It is important for the research and clinical community to have a fundamental understanding of the contemporary, social and historical context in which the evolving practices are conducted. For example, modern yoga-based practices originate from various schools and lineages. Most of them are multifaceted in nature, typically involving a combination of specific postures or movement sequences, breath regulation, deep relaxation and meditative techniques, as well as spiritual teachings (Gard et al. 2014a; Schmalzl et al., 2015; Sullivan et al. 2017). The way these components are taught and the emphasis on each element differs across styles, which in turn impacts psychophysiological effects. As a clinician or scientist, it is key to understand the purported benefits of specific components or combinations of techniques that is applied in a research setting for evaluating specific mechanisms or effects on clinical conditions. Often the delivery of the yoga intervention in research studies is highly standardised to improve validity and rigour, but this may not be generalisable to real-world yoga classes. An emerging discipline is that of yoga therapy, which requires more specialised training (>600 hours) than for the average yoga teacher; one growing certification credential is offered by the International Association
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This chapter summarises what is currently known about the psychophysiology of the main components of yoga-based practices (including meditation) and how they are proposed to work in synergy. The primary emphasis will be on a selection of basic, mechanistic studies, as well as some clinical research studies examining psychophysiological aspects of yoga as a multicomponent practice. Although the focus on the psychophysiological lends itself to an emphasis on underlying biological or physical mechanisms, this chapter will also discuss the potential for these mechanisms to influence or co-occur with psychological and clinical outcomes. While yoga may affect physiological parameters, this may not necessarily translate to a beneficial outcome for treating a clinical condition. Reviewing the wide range of existing clinical yoga research studies on specific disease conditions is, however, beyond the scope of this chapter. It is also important to note that while the emerging field of yoga research has been rapidly evolving, some of the currently published literature has methodological limitations, which we will address in the final section of this chapter.

The movement component

In modern western contexts, yoga-based practices typically have a strong emphasis on postures and movement sequences. The movement component of yoga can range from large and intense to small and subtle motion and may even include purely internal motion or motor imagery (Schmalzl et al. 2014). Some traditions primarily involve series of static individual postures that are held for a prolonged period of time (up to several minutes), some involve more dynamic and continuous physical movement and some employ a combination of static postures and flowing movement sequences.

Across different yoga styles there are numerous individual yoga postures and variations. Broadly speaking, they can be divided into categories that include standing postures, seated postures, supine postures, forward folds, backbends, lateral bends of the spine, twists, hip-openers and inversions. Individual postures are mostly instructed using very precise alignment cues, and when practices involve dynamic sequencing of movements they are typically performed in a slow, rhythmic and symmetric manner that is synchronised with the breath. Independently of the specific style, yogic movement is typically aimed at increasing range of motion, strength, endurance, flexibility and balance, as well as promoting relaxation and wellbeing.

An important characteristic of posture practice is the emphasis on cultivating awareness of interoceptive, proprioceptive, kinesthetic and spatial sensations, and using them to adjust and fine-tune one’s positioning and movements. Typically, there is a focus on obtaining and maintaining a balanced muscle tone that supports a quality of movement that is grounded and stable, yet light and fluid. Some postures are characterised by hypertonic (e.g. arm balances that require a high level of muscle tension) or hypotonic (e.g. a supine relaxation pose) muscle activation, but the general aim is that of obtaining a state of eutony or ‘well-balanced tension’ (Alexander 1985). This is often facilitated by engagement of interior muscle groups, which supports the stability of core musculature and the maintenance of breath regulation while moving through the postures.

Even though there is such a strong emphasis on the physical component of yoga-based practices in modern contexts, to date little is known about the specific effects of the postures and movement sequences in and of themselves. One of the challenges that research faces in isolating the effects of the movement component per se is that the postures are typically instructed in combination with some type of breathing and/or meditation techniques. That said, a number
of studies have characterised general aspects of the movement component. Compared to more vigorous forms of exercise, such coordinated movement of moderate intensity has been proposed to help promote parasympathetic tone (Payne and Crane-Godreau 2013). It has also been suggested that movement sequences such as sun salutations, in which joint load is mostly kept at submaximal levels, support bone remodelling and osteogenesis (Omkar et al. 2011). Furthermore, one study suggests that the musculoskeletal demands vary across different yoga poses, such as chair or tree pose, which has implications to inform individualised yoga therapy and rehabilitation goals (Wang et al. 2013).

Movement-based yoga practices have been reported to positively impact muscular strength and endurance, flexibility and cardiorespiratory fitness (Tran et al. 2001). In addition, studies comparing yoga-based movement with other forms of physical exercise have suggested that yoga can be equally effective for improving fatigue, self-esteem and quality of life (Taspinar et al. 2014). Corroborating the claim that the benefits of posture practice extend beyond the physical realm, it has been reported that yoga can be as effective as conventional exercise in improving mood and decreasing anxiety (Streeter et al. 2010). When it comes to energy expenditure (Ray et al. 2011) and certain pulmonary functions (Gupta and Sawane 2012), yoga-based practices are generally considered to be at a lower level compared to other types of aerobic exercise in young healthy adults. Unless practices incorporate a substantial amount of dynamic movement sequences such as vigorous or rapid sun salutations (Hagins et al. 2007), yoga practice may often not meet the criteria recommended for improving or even maintaining cardiovascular fitness and pulmonary function in the general population (Beutler et al. 2016). Although yoga may not improve aerobic exercise capacity in young healthy adults, there is some evidence to suggest an improvement in respiration regulation at rest, which may have implications for sedentary or clinical populations (e.g. those with cardiovascular risk factors) in future research.

Yoga-based movement has been proposed to affect, and mediate, several neurophysiological and neurocognitive mechanisms. One of these relates to the biomechanical behaviour of the connective tissue or fascia, which is particularly affected by deep stretching. Stretching of the connective tissue causes fibroblasts to expand by actively remodelling their cytoskeleton, which in turn contributes to a change in extracellular fluid dynamics that prevents swelling and tension. If stretching is prolonged it can cause the overall compactness of the connective tissue in a given area to decrease, promoting the flow of fluid from the capillary bed into the extracellular space. In a recent study in mice, it was shown that stretching activates inflammation-regulating mechanisms within connective tissues (Berrueta et al. 2016). These mechanisms are proposed to play an important role in the regulation of tissue fluid, metabolic homeostasis and even immune surveillance (Langevin et al. 2013).

A second proposed mechanism is the promotion of afferent signaling by the vagus nerve (Porges 2001). The vagus nerve is one of the key components of autonomic regulation (Porges 1995), with its afferent fibres communicating peripheral information about bodily states to the brain (Berthoud and Neuhuber 2000). While vagal tone is said to be primarily impacted by the slow and rhythmic breathing employed in yoga-based practices (Brown and Gerbarg 2005), the movement component may also contribute to it through enhancing the depth of the breath (e.g. active expansions/contractions of the rib cage during back/forward bends), further strengthening core diaphragmatic muscles and increasing baroreceptor sensitivity (Strongoli et al. 2010). Moreover, the interior muscle activation and abdominal tone emphasised in many yoga postures can promote peripheral vagal stimulation and afference (Ritter et al. 1992).

A third proposed mechanism relates to functional characteristics of neural circuits involving the basal ganglia (BG) (McHaffie et al. 2005). BG circuits consist of semi-independent loops originating from specific cortical areas, passing through functionally corresponding portions of the
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BG and returning to the same cortical areas via the thalamus (Alexander 1994). Functions that are supported by these cortico-BG-thalamic loops, and that are all implicated in the movement aspect of yoga-based practices, include body awareness, motor coordination and procedural learning. Additional functions supported by BG loops include more complex higher-order cognitive functions as well as social behaviour (Arsalidou et al. 2013). Recent neuroimaging work found that a group of expert yoga practitioners showed more widespread functional connectivity within BG circuits compared to controls (Gard et al. 2015). This finding can be interpreted to suggest that yoga-based practices may potentially promote increased connectivity within, and dynamic shifting between, motor, cognitive and emotional circuits, with subsequent beneficial effects for mind-body integration and self-regulation.

Lastly, it has been proposed that selective physical postures and movements can be used to target specific psychophysiological effects, and impact not only physical functioning but also psychological states. For example, it has been suggested that physical posture can affect pain tolerance, neuroendocrine levels and even risk propensity. Adopting a dominant, as opposed to a submissive or neutral, physical posture has been shown to positively affect pain tolerance (Bohns and Wiltermuth 2012). Similarly, ‘high-power’ postures characterised by and suggestive of high degrees of expansiveness, openness, assertiveness and confidence, have been associated with decreased levels of cortisol, increased levels of testosterone and enhanced feelings of psychological power (Carney et al. 2010). It has also been suggested that upright postures favour the generation and recall of positive thoughts (Wilson and Peper 2004), whereas assuming a slumped posture may promote higher degrees of perceived helplessness (Riskind and Gotay 1982). With specific reference to yoga postures, preliminary evidence suggests that backbends may be associated with greater increases in positive mood compared to forward folds or standing poses (Shapiro and Cline, 2004). This observation is intriguing and calls for further studies comparing the differential efficacy of selective yoga postures for clinical populations affected by mood disorders.

The breathing component

A multitude of breathing practices exist within yoga traditions, and they can be practised alone or in the context of postures and movement sequences. In some practices, breathing patterns are instructed in conjunction with postures and movement sequences, and specific emphasis is put on linking the breath and the movement. In other practices there is simply a focus on maintaining an even rhythm of inhalations and exhalations, or the breath can also merely serve as an object of attention as in many meditation practices. Depending on the type of breathing that is emphasised, breath regulation can have a number of different physiological effects (Brown and Gerbarg 2005). While slow and rhythmic breathing is proposed to promote parasympathetic dominance, more forceful breathing practices can actually promote sympathetic activation (Beauchaine 2001). The most common yogic breathing practice is a slow and rhythmic abdominal breathing pattern, with a frequency of about six breaths per minute or slower. This so-called diaphragmatic breathing, in which there is an emphasis on involving the entire abdominal cavity as opposed to just the chest, has long been adopted by many western therapists as it ensures a deeper breath with a larger tidal volume.

One of the most common slow breathing techniques used in modern yoga-based practices is the so-called ‘ujjayi breath’ (Brown and Gerbarg 2005). It is a deep, slow and rhythmic diaphragmatic breath performed through the nostrils which in some traditions also includes the concomitant narrowing of the glottis, creating a soft and soothing sound. It can involve visualising the breath as rising from the lower belly, through the ribcage, to the upper chest.
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and throat during inhalations, and follow the opposite order during exhalations. Inhalations
and exhalations are typically of equal length, and their duration can be gradually expanded
with practice. Additional common yogic breathing techniques include ‘kapālabhāti’ (rapid
abdominal breathing involving short and forceful contraction of the anterior abdominal wall),
‘bhastrīkā’ (rapid thoracic breathing using intercostal and accessory muscles), ‘śītalī prānāyāma’
(slow breathing through puckered lips with a curled tongue), ‘nāḍī śodhana’ (alternate nostril
breathing), and ‘kumbhaka’ (retention of the breath for various durations either after inhalations,
exhalations or both).

Breathing practices have been associated with several psychophysiological effects (Sovik
2000; Vinay et al. 2016; Critchley et al. 2015; Nivethitha et al. 2016; Russo et al. 2017; Steffen
et al. 2017). In fact, the view that emotional states can be expressed in breathing patterns, and
that breath regulation can consequently influence emotional states, is supported by both yoga
traditions and biomedical science on respiratory physiology (Boiten et al. 1994; Brown and
Gerbarg 2005; Henje Blom et al. 2014). A common autonomic response to stress, for example,
is rapid thoracic breathing, which can lead in turn lead to hyperventilation and a change in tidal
volume (Laffey and Kavanagh 2002).

Slow and rhythmic yogic breathing with a frequency of about six breaths per minute has
been reported to decreases chemoreflex sensitivity (Spicuzza et al. 2000) and oxidative stress
(Sharma et al. 2003), increase cardiac–vagal baroreflex sensitivity (Esposito et al. 2015) and pro-
mote the release of prolactin and oxytocin, which are associated with feelings of calmness and
social bonding (Torner et al. 2002).

As noted above, one of the main mechanisms through which slow breathing is said to impact
autonomic regulation is by promoting vagal afference (Porges 2001). Vagal tone is proposed to
be reflected by heart rate variability (HRV), i.e. the variability of the inter-beat intervals of the
heart (Porges 2001), and especially mirrored by respiratory sinus arrhythmia (RSA), i.e. the
HRV within the frequency of respiration (Calabrese et al. 2000). In addition, there is a cor-
relation between breathing frequency and both HRV and arterial baroreflex sensitivity, with
slower breathing rates increasing both of these indices (Bernardi et al. 2001).

In terms of specific yogic breathing techniques, ujjāyi breath has been proposed to be par-
ticularly effective in stimulating somatosensory vagal afferents to the brain (Nivethitha et al.
2017) (primarily via contraction of laryngeal muscles) (Brown and Gerbarg 2005) and con-
sequently promoting autonomic regulation (Calabrese et al. 2000). Alternate nostril breathing
has also been associated with increased parasympathetic nervous system activity as measured by
heart rate parameters and orthostatic tolerance (Sinha et al. 2013), increased HRV and decreased
systolic blood pressure (Telles et al. 2014, Telles et al. 2017), as well as changes in the P300
auditory evoked potential, which is a neural marker for sustained attention (Telles et al. 2013).
Moreover, some studies have documented laterality effects, with breathing through individual
nostrils affecting brain responses and autonomic regulation in specific ways. Examples include
differential effects of left and right nostril breathing respectively on oxygen consumption (Telles
et al. 1994) and blood pressure parameters (Raghuraj and Telles 2008), as well as the P300 audi-
tory evoked potential, which was found to be more affected in the contralateral brain hemi-
sphere (Telles et al. 2012).

While most of the published literature focuses on the positive effects of slow breathing, it is
worth noting that more rapidly paced breathing can have specific benefits as well. For example,
pulmonary deficiencies that require strengthening of the respiratory system may improve more
rapidly with breathing techniques that require a higher rate of respiratory muscle activity and
breath coordination (Dinesh et al. 2015). Moreover, it has been proposed that fast breathing
may positively impact working memory and sensory–motor performance (Sharma et al. 2014).
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The relaxation component

A fundamental aspect of most yoga practices is deep relaxation. Relaxation techniques can constitute a practice in their own right (e.g. in restorative yoga) or be included at various points of a practice session to complement more vigorous movement or breathing exercises. Independently of the practice style, individual sessions typically end with a supine relaxation pose called corpse pose or sāvāsana, which can involve explicit instructions for systematic progressive relaxation throughout the body’s musculature. A well-known relaxation practice is yoga nidra (Miller 2005). It consists of a gradual progression from deep relaxation to a near sleep-like state in which individuals remain aware of their surroundings, which can be accompanied by a change in brain waves (Lou et al. 1990). It typically includes relaxation, breath awareness, meditation and guided imagery (Parker et al. 2013).

Modern medicine and clinical psychology have been using relaxation techniques such as progressive muscle relaxation for decades (McGuigan and Lehrer, 2007). Relaxation techniques are an easily accessible nonpharmacological approach for a variety of populations and clinical conditions and lend themselves very well to being integrated in various community, educational and hospital settings (Klainin-Yobas et al. 2015). Clinical conditions for which progressive relaxation has been implemented and studied include anxiety-related disorders, as well as psychosomatic conditions such as insomnia and chronic pain (Manzoni et al. 2008). Studies investigating the specific effects of sāvāsana have documented that it can promote reductions in HRV, blood pressure (Pal et al. 2014), respiration rate and oxygen consumption (Sarang and Telles, 2006), energy expenditure (Ray et al. 2011) and symptoms of anxiety (Subramanya and Telles, 2006). The practice of yoga nidra has been found to reduce symptoms of stress, depression and anxiety, and promote states of mindfulness (Eastman-Mueller et al. 2013). Moreover, there is preliminary evidence from electroencephalography (EEG) studies that the practice may be associated with increases in both alpha and theta waves (Kjaer et al. 2002; Kumar and Joshi 2009; Lou et al. 1990). It should be noted, however, that so far, most published studies on yoga nidra are confounded by a lack of empirical consistency (Parker et al. 2013).

The meditation component

Contemplative practices – including various forms of meditation – broadly refer to practices involving sustained and non-analytic attention and/or deep consideration of an object of interest. Individual practices differ in terms of their specific techniques, but what they typically share is a disciplined process of becoming reflectively attentive to experience (Schmalzl et al. 2014) and the cultivation of a state of equanimity (Desbordes et al. 2015). Recent theoretical accounts of meditation practice have defined it as a process that develops self-awareness (awareness of one’s own physical, emotional and mental states), increases self-regulation (the ability to effectively modulate one’s physiological responses and behaviour) and promotes self-transcendence (a progressive and positive shift from predominantly self-focused to increasingly decentred and prosocial views of the world) (Vago and Silbersweig 2012).

Meta-cognitive awareness refers to the conscious monitoring of one’s own mental processes (Teasdale 1999) and is emphasised in many meditative practices. The specific role of meta-cognitive awareness can differ depending on the style of meditation (Fox and Christoff 2014; Irrmischer et al. 2018; Lutz et al. 2016; Tomasinno and Fabbro 2016). In forms of meditation practice characterised by focused attention (FA), also referred to as concentrative, closed-focus or single-point-focus meditation, it includes the activity of noticing drifts from a selected single object of attention, and subsequently redirecting attention towards it when the attention
wanders. In forms of meditation practice characterised by open-monitoring attention (OM), also referred to as open-focus or mindfulness meditation, it can have the role of monitoring one’s stream of thought or sensation while attempting to maintain detachment and refrain from any cognitive elaboration, analysis or judgement (Lutz et al. 2008). Some of the meditative techniques employed in yoga-based practices emphasise FA and include body-scan meditation (Mirams et al. 2013), guided imagery meditation or Transcendental Meditation (TM) (Balaji et al. 2012). If no specific meditative technique is employed, however, and there is simply a general emphasis on cultivating awareness to present-moment experience, yoga practitioners may gradually transition from a predominantly FA to a more OM approach as they progress in their practice. While practitioners may initially only be able to allocate their attention to a single element of the practice at the time, they may eventually become skilled at simultaneously monitoring movement, breath and any accompanying interoceptive and exteroceptive sensations that may arise.

Cultivation of attention to bodily sensations and sensory experience, including interoceptive, proprioceptive, kinaesthetic and spatial awareness, is another central characteristic of many meditative techniques in the context of yoga-based practices (Farb et al. 2015). Body awareness is primarily cultivated by directing attention to sensations arising from the movement and breath components of the practice, and there is increasing consensus that it is of substantial significance for health and self-regulation. Enhancing body awareness can increase one’s ability to detect bodily signals of emotional states as they arise, and consequently facilitate self-regulatory responses to them (Baas et al. 2004).

Lastly, a putative general mechanism through which cultivating attention may account for psychological wellbeing across various forms of meditation practices is by decreasing mind-wandering and rumination (Brandmeyer and Delorme 2018; Hasenkamp et al. 2012; Wolkin 2015). Mind-wandering is defined as spontaneous and undirected thought processes that mostly occur unintentionally, and rumination refers to a repetitive process of dwelling upon predominantly negative thoughts and emotions that are frequently self-focused. High levels of mind-wandering have been shown to correlate with negative mood states (Killingsworth and Gilbert 2010), and high levels of rumination have been found to constitute a risk factor for the development of depression and depressive relapse (Smith and Alloy 2009). It has been reported that both mind-wandering and rumination may decrease by engaging in meditative practices that promote the ability to decentre and disentangle one’s self-identification with negative thoughts (Segal et al. 2002).

Several preliminary studies have documented positive effects of meditation on cognitive and health-related functions, including attention (Jha et al. 2007), interoceptive awareness (Farb et al. 2013; Sharp et al. 2018), somatosensory processing (Kerr et al. 2013), self-regulation (Tang et al. 2014), stress (Jain et al. 2007), immune function (Infante et al. 2014), blood pressure (Bai et al. 2015), chronic pain (La Cour and Petersen 2015) and sleep (Nagendra et al. 2012).

Recent research has also focused on investigating the neural mechanisms underlying meditative practices. Neuroimaging investigations using functional magnetic resonance imaging (fMRI) (Manna et al. 2010) seem to suggest that, broadly speaking, FA predominantly engages right frontal brain areas, whereas OM predominantly engages left frontal brain areas. With respect to FA specifically, recent neuroimaging work has proposed the existence of four distinguishable phases that naturally occur during practice, and that are supported by partly independent neural networks (Hasenkamp et al. 2012). The consecutive phases include mind-wandering, the awareness that one’s mind has wandered, the redirecting of attention to the chosen object of meditation and the active maintenance of sustained attention on that object. Mind-wandering engages brain regions associated with the so-called default mode network (DMN) (Raichle et al. 2001), the activation of which is increased during wakeful rest and attenuated during
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goal-directed behaviour. Brain areas involved in the DMN include the posterior cingulate cortex, the medial prefrontal cortex, the posterior parietal/temporal cortex and the parahippocampal gyrus. The awareness of mind-wandering engages a subdivision of the so-called salience network, which is generally associated with supporting conflict monitoring and error detection and includes the anterior insular cortex and anterior cingulate cortex. The redirecting of attention to the object of meditation engages the so-called executive network, which includes the lateral prefrontal cortex and the lateral inferior parietal cortex. Lastly, sustained attention on the object of meditation also may engage a portion of the executive network, with selective clusters in the dorsolateral prefrontal cortex. With respect to OM, neuroimaging studies have also documented activation changes in both DMN and meta-cognitive networks, which is again indicative of concomitant presence of mind-wandering as well as attentional processes (Fox and Christoff 2014). Since OM meditation does not involve selected focus on a discrete single object of meditation, however, the attentional component relies less on brain regions involved in engaging or sustaining attention. Instead, it primarily engages brain regions involved in monitoring, vigilance (Telles et al. 2017) and processing of sensations related to present-moment experience (Lutz et al., 2008), which include higher-order prefrontal regions (Fleming and Dolan, 2012), the anterior cingulate cortex and the insular cortex (Critchley 2005).

Neuroimaging studies have also shed light on the neural underpinnings of cultivating attention to bodily sensations and sensory experience in the context of meditation practices, and both structural and functional brain changes have been reported. According to a meta-analysis (Fox et al. 2014), structural brain changes associated with meditation practices have been repeatedly found in the insular cortex, primary and secondary sensorimotor cortices, and the anterior precuneus. These areas are thought to be involved in interoceptive awareness, the processing of tactile and proprioceptive sensations, and higher-order body awareness, respectively. Similarly, a meta-analysis looking at functional brain changes associated with meditation practices (Fox et al. 2016) also revealed changes in a number of regions involved in the processing of bodily signals. These include the posterior parietal cortex, the right supramarginal gyrus and, again, the insular cortex.

A further aspect of interest to neuroimaging studies is the reported reduction of rumination, and consequent enhancement of psychological wellbeing, associated with meditation practices (Wolkin 2015). It has been proposed that on a neural level this is supported by a shift away, and repeated disengagement, from DMN activity (Hasenkamp et al. 2012). Apart from mind-wandering, the DMN is also said to be involved in the construction of the autobiographical self, which involves the assessment of stimuli for their relevance to one’s mentally constructed and sustained image of oneself. DMN activity change during meditative states has therefore been suggested to underlie a shift to less self-centred and more objective awareness of interoceptive as well as exteroceptive present-moment experience (Brewer et al. 2011). This theory is corroborated by studies showing that increased DMN activity is associated with negative mental health outcomes (Sheline et al. 2009). Recent research also suggests that mindfulness interventions in stressed adults can be associated with alterations in DMN coupled with reductions of the inflammatory marker interleukin-6 (Creswell et al. 2016). Moreover, it has been shown that meditation can reduce depression vulnerability, thereby reducing trait rumination and negative bias (Paul et al. 2013).

The spiritual experience component

An interest in spirituality has been a quantifiable reason why some yoga and meditation practitioners have reported adopting a yoga practice (Park et al. 2015; Quilty et al. 2013).
Specific experiences have often been reported and described by adherents of religious and contemplative practices which can be conceptualised as directly affecting spirituality. Cross-tradition explorations have described this experience generally as a transcendent immersive unitive state, in which the universe is experienced all at once in a complete state of oneness with no sense of duality (Wahbeh et al. 2018). Other descriptions include a noetic quality in which one appears to appreciate the ultimate truth of reality, a positive mood state typically involving peace, serenity, joy and ecstasy, a sense of timelessness, as well as a sense of the holy, sacred or divine. A common consequence of these profound types of experiences is a psychological transformation of the individual, in which one's sense of life purpose and meaning have been permanently changed in a positive direction. Long-term practitioners of yoga and meditation will use phrases such as ‘yoga changed my life’ to describe this transformation (Ross et al. 2014).

From a biomedical perspective, there is evidence that these experiences are likely a consequence of the activation of specific brain regions (Newberg 2014). Support for this comes from recent research conducted on hallucinogenic agents, which can generate these experiences in most individuals (Barrett and Griffiths 2018). Historically, it has been suggested that the prevalence of psychedelic experiences in the 1960s counter-culture may have been related to the increased interest in contemplative practices such as yoga (Richert and DeCloedt 2018).

Studies of meditators and yoga practitioners have reported increases in experiences consistent with unitive transcendent states as well as overall spirituality. These have often used outcome measures designed to capture detailed accounts of mystical experiences, transcendence and spirituality (MacDonald and Friedman 2009), and yoga practitioners have been found to score highly on these measures (Fiori et al. 2014). A systematic review (Wahbeh et al. 2018) identified twenty-five studies related to transcendence over a wide variety of contemplative practices and investigative techniques including neuroimaging, psychophysiological measurements and qualitative accounts. The review concluded that ‘transcendence most commonly describes an experience associated with deeper stages of meditation and across traditions’ (Wahbeh et al. 2018: 33).

Some studies have shown that duration and intensity of yoga practice are positively correlated with the experience of this unitive state and its positive consequences. A study of yoga practitioners in an ashram community setting undergoing regular practice as part of a yoga lifestyle showed that higher percentages of practitioners reported experiences of oneness (83%) and being in touch with the divine or spiritual (91%) than did a control group of non-practitioners (40% and 43%, respectively) (Wilson and Spencer 1990).

There is also evidence that transcendent experiential characteristics are directly correlated with both intensity and duration of practice. An internet survey study of older female yoga practitioners showed statistically significant correlations between transcendence (as measured by the transcendence subscale of the WHO Subjective Well-Being Inventory) and three self-reported yoga practice measures (current hours per week, total lifetime hours and total calendar years) (Moliver et al. 2013). These data suggest that longer duration of practice is more likely to yield transcendent experiences, as one would expect with mastery of practice increasing over time. Another recent internet survey of yoga practitioners divided them into three categories of marginal, moderate and high levels of involvement with yoga practice (Gaiswinkler and Unterrainer 2016). Scores on the Multidimensional Inventory for Religious/Spiritual Well-Being measure showed a statistically significant relationship to yoga practice intensity, with high levels of involvement having the highest scores. Scores on subscales of this questionnaire assessing connectedness, immanent hope, transcendent hope and experiences of sense and meaning showed a similar trend with the level of yoga involvement.

While one would expect that transcendent experiences and spirituality are more likely to occur over a longer time frame, there are studies suggesting that these changes can take place...
over a short period as well. A recent controlled study of a four-week yoga intervention showed statistically significant increases in transpersonal characteristics in the yoga group (Gobec and Travis 2018). The flow state, as measured with the Dispositional Flow Scale, before and after only six weeks of yoga in young adult musicians showed significant increases as compared with controls (Butzer et al. 2016). The Autotelic Experience subscale of this questionnaire, which is a direct measure of the transcendent experience, also showed statistically significant negative correlations with music performance anxiety, suggesting the possibility that yoga is facilitating flow by inhibiting the interference from compromising mood states. Another yoga study showed that yoga practitioners, non-practitioners and metabolic syndrome patients all showed increases in the flow state following yoga practices lasting less than one hour, with the yoga practitioners showing the greatest increase and highest scores (Tyagi et al. 2016).

Although this field of inquiry has very little biomedical research at present, it represents an important area of investigation into the deeper benefits of yoga practices. Yoga practice, especially over the long term and with a meditative component, likely leads to significant improvements in important quality of life measures, including spiritual wellbeing, transcendence, flow, and life meaning and purpose (Sullivan et al. 2017). These qualities are viewed as inherently valuable and desirable and are becoming increasingly more important in both modern medicine and in society as a whole.

Yoga practice as a whole

The model in Figure 30.1 depicts the major areas by which yoga practices impact psychophysiological states and ultimately modify experience and behaviour. In line with the previous sections of this chapter, the top box defines yoga as a multicomponent practice that includes postures/movement sequences, breathing techniques, deep relaxation practices and meditation – and that leads to the skills and attributes listed in the boxes below. Physical and respiratory components of yoga practice improve physical functioning, including flexibility, strength, endurance and balance, as well as respiratory function, which ultimately leads to improved physical self-efficacy. Through the meditative component in particular, practitioners enhance their ability to regulate and sustain attention on both physical (sensations) and mental (thoughts and emotions) events. This leads to enhanced mind–body awareness which includes mindfulness, concentration and cognitive functioning, as well as self and social awareness. Self-regulation, especially when it comes to stress responses and emotion regulation, is likely impacted by all components of yoga practice. Increased self-regulation in turn leads to improved resilience, stress tolerance, equanimity and, ultimately, psychological self-efficacy. Lastly, a sustained regular yoga practice together with living a lifestyle based on yogic principles can impact an individual’s spirituality, promote feelings of unity and transcendence, and enhance a sense of meaning and purpose. The arrows between the boxes indicate that the aspects described in the three boxes are all mechanistically linked. Together, all of the listed skills and attributes work together synergistically to improve a multitude of behaviours, mental states and health-related aspects that are all depicted in the bottom box. In sum, the model outlines how yoga ultimately works in a global and holistic manner to improve human functioning on multiple levels and domains.

Yoga-based practices have been documented to affect a series of physiological parameters that impact physical health, including stress hormones, inflammatory markers and cardiovascular indices. It has been suggested that yoga can reduce cortisol levels more than common exercise (Rocha et al. 2012), that reductions in cortisol may be evident even after just a single yoga session (Kamei et al. 2000) and that both movement-focused and breath-focused yoga practices can reduce cortisol levels alike (Schmalzl et al. 2018). Yoga practice has also been found
to increase levels of γ-aminobutyric acid (GABA), an inhibitory neurotransmitter that tends to be reduced in several clinical conditions, including epilepsy (Streeter et al. 2012). Lastly, yoga can elicit measurable changes in several cardiovascular indices, including total peripheral resistance (TPR), arterial compliance (CWK), stroke volume (SV) and cardiac output (CO) (Parshad et al. 2011), as well as HRV (Papp et al. 2013), which is one of the primary indicators of balanced nervous system activity.

**Body awareness and mindfulness**

As mentioned earlier, body awareness is a multidimensional construct that entails a combination of proprioceptive and interoceptive awareness (Mehling et al. 2012). Early studies of yoga-based practices have documented increases in self-reported body awareness following a three-month programme (Rani and Rao 1994). More recently it has been reported that self-reported levels of body awareness in advanced yoga practitioners seem to be related to the character trait of self-transcendence (reflecting an individual’s inclination to perceive a strong connection between themselves and all other forms of life) (David et al., 2014). An elegant study employing both sensory testing and neuroimaging techniques showed that advanced yoga practitioners exhibited increased pain tolerance compared to controls with no yoga experience, and that this increase was correlated with structural brain differences in brain regions supporting body awareness, including the insular cortex, the cingulate cortex and parietal areas (Villemure et al. 2014). Similarly, a recent neuroimaging study found a positive correlation between trait mindfulness and pain tolerance, which was in turn associated with greater deactivation of the posterior cingulate cortex, which is known to be involved in the affective appraisal of stimuli (Zeidan et al. 2018). Mindfulness and self-compassion have also been shown to increase with yoga-based practices. For example, a study evaluating the effects of a residential yoga programme on quality of life found that attendees exhibited reduced perceived stress, which was
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Statistically demonstrated to be mediated by increased levels of mindfulness and self-compassion (Gard et al. 2012). The authors proposed that this finding indicates that yoga and mindfulness-based interventions share underlying mechanisms. Another study found that the amount of yoga practice implemented in a mindfulness-based stress reduction (MBSR) programme which also included sitting meditation and body scan was significantly correlated with increases in mindfulness (Carmody and Baer 2008). The view that yoga increases mindfulness is further corroborated by additional investigations with novices (Bowden et al. 2012), advanced yoga practitioners (Brisbon and Lowery 2011) and yoga teacher trainees (Büssing et al. 2012).

Self-regulation

Improvements in stress and emotion regulation are a hallmark of the effects of yoga-based practices (Li and Goldsmith 2012; Riley and Park 2015; Sharma 2014). The idea that yoga as a multicomponent practice enhances self-regulation is not surprising given that both meditation and breathing practices alone can improve stress regulation and impact autonomic functioning. Early studies documented positive effects of yoga programmes on self-reported levels of subjective wellbeing (Sell and Nagpal 1992), as well as vitality (e.g. perceived levels of alertness, sleepiness, enthusiasm, sluggishness, calmness, nervousness, etc.) (Wood 1993). More recent studies found self-reported levels of stress to decrease in individuals participating in residential programmes involving daily yoga classes and didactic coursework focusing on the integration of yoga practices into daily life activities (Gard et al. 2012). Lastly, reduced levels of self-reported stress have also been reported in military populations participating in yoga programmes, which is of particular significance given the high levels of stress that these individuals are exposed to on a daily basis (Rocha et al. 2012).

Cognitive functioning

A growing body of research has investigated the effects of yoga-based practices on cognition, including attention, memory and executive functioning. In terms of visual attention, studies have reported measurable improvements in the ability to detect subtle changes in visual stimuli (Telles et al. 1995) as well as colour discrimination (Narayana 2009). A recent study investigating the differential effect of movement-focused and breath-focused yoga practices suggested that only the breath-focused practice yielded specific improvements in visual sustained attention and response inhibition (Schmalzl et al. 2018). With respect to memory, improvements have been documented for short-term and long-term memory (Rocha et al. 2012), as well as working memory (Gothe et al. 2013). In relation to executive functioning, yoga has been suggested to positively impact problem-solving ability (Manjunath and Telles 2001), and potentially to promote neuroplastic changes in neural systems that support executive functioning (Froeliger et al. 2012a; Hernandez et al. 2018). It has also been documented that yoga practitioners more efficiently activate cognitive control brain networks in the presence of emotionally salient stimuli (Froeliger et al. 2012b). Lastly, it has been reported that, compared to controls, experienced yoga and meditation practitioners exhibit less age-related decline in fluid intelligence (a set of abilities involved in coping with novel environments and abstract reasoning) (Gard et al. 2014b).

Limitations of current research on yoga-based practices

From the previous sections of this chapter it is clear that yoga research has witnessed strong growth during recent decades (Jeter et al. 2015). That being said, it is important to draw awareness
to the fact that some of the currently published research studies on yoga-based practices have methodological limitations that undermine our ability to make conclusive claims about their findings.

Some common weaknesses in the literature include the use of self-selected populations and, often, inappropriate control groups. Many of the currently published studies have been conducted on either advanced practitioners (David et al. 2014; Villemure et al. 2014) or individuals participating in residential yoga programmes (Gard et al. 2012; Telles et al. 1995), whereas control groups often consist of individuals with no yoga experience. It can therefore not be precluded that some of the observed physiological or behavioural differences may therefore be driven by pre-existing characteristics of individuals who are naturally inclined to practise yoga (Gard et al. 2014b). In addition, several studies did not have an active control group, which prevents the evaluation of comparative effectiveness of yoga compared to other interventions (Fiori et al. 2014; Froeliger et al. 2012a).

Another limitation is that many of the studies evaluating the effect of yoga-based practices on stress and emotional states are exclusively based on self-report measures (Malathi et al. 2000; Wood 1993). This is problematic in the context of contemplative practices in particular, as an individual’s perception and judgement of their own coping mechanisms can actually change as a result of the practices themselves. In addition, there is a danger of biased responses towards expecting, believing and reporting beneficial effects, due to common beliefs about the positive impact of yoga on one’s overall wellbeing (Grossman 2008). Future research employing complementary assessment of behavioural, physiological, neural and cognitive changes is highly desirable.

Additionally, in many of the currently published research studies the protocols of the yoga interventions are not described with the necessary detail to allow experimental replication. (Narayana 2009; Rani and Rao 1994). Given the multifaceted nature of yoga-based practices, it will be of particular importance for future research to improve in this aspect. Only carefully designed studies with detailed intervention protocols will allow researchers to further deconstruct the role of the individual component parts and elucidate whether their effect is cumulative or synergistic in nature (Payne and Crane-Godreau 2013).

Finally, there is continued need for further studies outlining specific mechanistic hypotheses about the physiological and neural processes underlying the reported effects of yoga-based practices. While some recently published theoretical frameworks are an encouraging step forward (Gard et al. 2014a; Schmalzl et al. 2015; Sullivan et al. 2018), many of the proposed mechanistic hypotheses refer to general mechanisms known to underlie the effect of mindfulness-based practices (Froeliger et al. 2012b; Gard et al. 2012; Villemure et al. 2014). Further research testing the hypothesised interaction between bottom-up physiological and top-down cognitive processes will be of particular relevance, and will require multidisciplinary studies across the domains of physiology, neuroscience and psychology.

Prior to this body of published research, it was not possible for yoga instructors and therapists to justify and convey the benefits of yoga practice for mainstream society and in a biomedical context. In general, yoga instructors and therapists are highly appreciative of this new biomedical research information. It provides greater credibility for yoga’s benefits and allows for a professional presentation of yoga’s effects and mechanisms; we are seeing an increasing implementation of psychophysiological research literacy in yoga teacher and yoga therapist training programmes and schools (e.g. Khalsa et al. 2016).
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Bibliography


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