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Effects of yoga on brain waves and structural activation: A review

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A B S T R A C T

Previous research has shown the vast mental and physical health benefits associated with yoga. Yoga practice can be divided into subcategories that include posture-holding exercise (asana), breathing (pranayama, Kriya), and meditation (Sahaj) practice. Studies measuring mental health outcomes have shown decreases in anxiety, and increases in cognitive performance after yoga interventions. Similar studies have also shown cognitive advantages amongst yoga practitioners versus non-practitioners. The mental health and cognitive benefits of yoga are evident, but the physiological and structural changes in the brain that lead to this remain a topic that lacks consensus. Therefore, the purpose of this study was to examine and review existing literature on the effects of yoga on brain waves and structural changes and activation. After a narrowed search through a set of specific inclusion and exclusion criteria, 15 articles were used in this review. It was concluded that breathing, meditation, and posture-based yoga increased overall brain wave activity. Increases in graygray matter along with increases in amygdala and frontal cortex activation were evident after a yoga intervention. Yoga practice may be an effective adjunctive treatment for a clinical and healthy aging population. Further research can examine the effects of specific branches of yoga on a designated clinical population.

1. Introduction

The popularity of yoga has risen in recent years as not just recreational exercise but as a means of reducing stress and anxiety, increasing physical fitness, and improving mood and overall well-being. It has been shown to improve mood and life satisfaction scores while reducing aggressiveness, emotional distress, and anxiety [10,19]. Interventions involving yoga have also shown to improve various health, and physical fitness parameters at both physiological and cellular levels.

Yoga has been demonstrated to have several positive effects on cardiorespiratory health. Multiple studies provide evidence that yoga can increase cardiorespiratory efficiency and respiratory capacity [3,12]. 6 months of yoga practice resulted in significantly decreased resting heart rate and blood pressure [3]. Yoga has also been beneficial for individuals with metabolic conditions such as Type 2 diabetes and obesity, as it has shown to increase glycemic control and nerve conduction velocity, and decrease BMI and total serum cholesterol level [4,23].

In addition the cardiorespiratory and metabolic improvements, yoga practice has been correlated with musculoskeletal benefits. Weight-bearing yoga training can attenuate bone reabsorption and reduce the risk of osteoporosis in postmenopausal women [27]. Yoga has been shown to improve symptoms of OA of the hand as well as Carpal Tunnel Syndrome.

While some of the aforementioned studies have examined the effects of a general yoga practice on health, other have explored the effects, of a specific branch of yoga. Each branch of yoga involves a component of mindfulness and breathing, but the body system being used will vary. This variation between yoga branches may elicit different effects to the mind and body. The three main branches of yoga include asana-based yoga, meditation-based yoga, and breathing-based yoga.

An asana-based practice is what is traditionally thought of as “yoga” in Western culture. Among the three types of yoga practices, this practice is most considered as a form of exercise, as it demands the involvement of various muscle groups [4]. Asana-based yoga practice is comprised of various postures, or asanas, that the person performs dynamically. Each asana may also be held isometrically for an allotted amount of time or breath cycles. Vinyasa, hatha, bikram, and kundalini yoga are several styles of yoga that fall into the category of asana-based yoga. These styles can be practiced individually or in a classroom environment.

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Many consider yoga a form of meditation. Meditation-based practice involves a purposeful relaxation of the mind through the dissociation of thoughts and/or concentration on one's own breathing. Meditation is typically practiced sitting down and, aside from breathing, does not require any dynamic movements. Similar to asana-based practice, meditation can be practiced on an individual basis or can be instructed in a group environment [9].

The third type of yoga practice is a breathing-based practice. This practice involves purposeful inhalations and exhalations at a designated speed and intensity, which is referred to as pranayama. Pranayama can also be broken down into various breathing practices, which include sudarshan kriya and bhastrika pranayama. Breathing-based practices are also practiced in a still and seated position and can be practiced on an individual or classroom basis [15,35].

The above three categories of yoga can be combined into one session or can be practiced separately. Asana, meditation, and breathing-based practices elicit various and specific effects on cognitive and neurological functions. In particular, their effects on brain waves and structural activation will be further explored in this review.

With the positive impact of yoga on the body, recent research has begun to explore the cognitive effects of yoga. Previous qualitative studies have shown subject self-reported positive effects of yoga on depression and anxiety [30,33]. Various studies have also shown an increase in cognitive performance after a yoga intervention or greater perceived cognition in practitioners versus non practitioners. A study examining 108 school children, ages 10–17, assessed spatial and verbal memory before and after a 10 day pranayama training protocol. The results showed an improvement in spatial and verbal memory scores after the Sudarshan Kriya yoga training protocol [24]. A study examining adjunctive treatments for bipolar patients saw a high rate of self-reported cognitive benefits as a result of yoga practice. Many subjects with bipolar depression reported that ongoing yoga practice assisted with their focus and sense of acceptance [36]. Also related to cognitive benefits, another study showed that 6 weeks of hatha yoga improved working memory and attention-switching ability in healthy older adults [11]. Breathing based yoga, in the form of fast and slow pranayama practice has also shown to improve cognitive performance, in the domains of reaction time [29]. After 12 weeks of pranayama practice, 84 healthy adult participants had significantly improved scores in psychometric tests that included the letter cancellation test, trail making tests A and B, forward and reverse digit spans and auditory and visual reaction times for red light and green light.

The improvement in cognitive performance from yoga practice and interventions is evident, but the mechanisms behind this improvement remain unclear. Changes in cognition are often a result of changes in neuronal activity, structural activation, and general structural changes within the brain. Understanding what can elicit changes that are occurring within the brain that lead to improved cognition, can give insight into the development of cognitive interventions in both healthy and clinical populations. Therefore, the purpose of this review is to examine the specific neural changes that occur as a result of yoga practice which may influence the mental health and overall wellbeing.

2. Methods

The literature that was chosen for this review began by searching for the terms “yoga” and/or “pranayama” with the terms “EEG”, “brain”, “cognition”, “activation”, and/or “brain waves”. The databases used, to search for studies with these terms, included PubMed, Google Scholar, and EBSCO host. Potential articles were categorized into groups including, quantitative research, qualitative research, and single case studies. The inclusion criteria consisted of quantitative studies that were conducted between the years 1990–2014 that were published in journals, and examined either the effects of a yoga intervention or differences between yoga practitioners and non-practitioners.

The inclusion criteria was narrowed to studies that examined posture (asana), breathing, and meditation-based yoga and used brain waves, brain structural activation, and/or changes in brain structure as outcome variables. The exclusion criteria was composed of studies conducted before the year 1990, studies not written in English, unpublished work, or articles based on an single individual's opinion.

After screening for inclusion and exclusion criteria, 15 studies were reviewed. These studies were then further categorized based on the outcome variables measured, into the groups: “Brain Waves”, “Structural Activation”, and “Structural Changes”.

2.1. Brain waves

Brain wave activation represents the electrical activity of neurons, specifically the voltage fluctuations from ionic flow within neurons, in the brain. This electrical activity is recorded via electroencephalogram, and the EEG will represent this electrical activity as waves or oscillations. These oscillations are representative of specific activities throughout the brain.

Brain waves are naturally occurring during both an active and resting state. However, external instruments can also elicit these waves. Repetitive transcranial magnetic stimulation, transcranial direct current stimulation, and transcranial alternating current stimulation are several traditional methods of eliciting and altering brain waves. These methods are used in both clinical and research settings to help assess the integrity of and better understand the central nervous system. These three methods can help to modulate and influence existing rhythmic brain activity and elicit specific brain wave types.

2.1.1. Alpha waves

Alpha waves are neural oscillations at the frequency of 8–13 Hz [17] that are found within the cortex, occipital lobe, and thalamic regions. Typically alpha waves are detected via electroencephalogram, or EEG. EEG recordings begin with the placement of an array of electrodes across the human scalp. EEG will then measure the voltage fluctuations from ionic flows of neurons in the brain. EEG detects these fluctuations and represents them as a wave, or oscillation, and notes at which times they are activated and at which frequency.

Alpha waves typically have large amplitudes and occur during moderate levels of brain activity [26]. Specifically, Alpha waves occur while and individual is temporarily idle, but still alert. It is atypical for significant amounts of these waves to occur during a sleeping or drowsy state. Functionally, alpha waves inhibit areas of the cortex and play a vital role in networking between neurons.

Alpha brainwave activity has been correlated with physiologic behavior such as decreased degree of pain and discomfort [26]. Alpha frequency was also shown to be correlated to cognitive performance, including the speed at which information is retrieved from memory. A positive correlation between fast and accurate memory performance and alpha frequency was found. Alpha wave activity may also improve word recognition in older adults as well as facilitate working memory [18]. Along with cognitive benefits, elevations in alpha wave activity have also been associated with an increased perception of calmness.

2.1.2. Beta waves

Unlike alpha waves, beta waves, at the frequency of 12–38 Hz [37], occur during a heightened state of awareness. The beta state is a type of brain oscillation that occur as a task is being completed, and throughout active concentration. Beta waves are also very present throughout the motor cortex during isotonic contractions and slow movements, and similar to alpha waves, are also detected by EEG.

Beta activation is correlated with gains in academic performance. Increased in beta activation have been associated with high arithmetic calculation ability [8]. Similarly, greater existing beta wave activity has also been associated with higher GPA among students. These findings may indicate an association between beta waves and increases in cognitive skills.

Along with cognition, beta waves have also been shown to affect mood and emotions. For example, transcranial magnetic beta wave stimulation has shown a significant decreases in emotional exhaustion and state anxiety [25]. Another study reported reduced feelings of fatigue after seven weeks of beta stimulation [37].

2.1.3. Theta waves

Theta waves (4–7 Hz) [5], also known as theta rhythm, occur once a repetitive task becomes autonomous, hardly requiring any focus to be completed. In essence the theta state is established once the task(s) are completed in a recognizable routine. A study examining this, presents a review regarding studies which utilized EEG stimulation to indicate theta activity with repetitive tasks [5]. Theta waves can occur in both cortical and hippocampal regions.

When stimulated, theta waves, similar to alpha waves, have been shown to reduce anxiety. Theta waves may play a role in the function of short-term memory, according to studies which [21] reported the most prominent theta activity in the hippocampus, suggesting theta waves may influence the process of building memories.

2.1.4. Gamma waves

Gamma waves are brain oscillations that occur at the frequency of 40–100 Hz [37]. It has been thought that these brain waves are involved in conscious attention. Previous research has observed that gamma waves originate from thalamus and will move anteriorly as they are activated to synchronize neuronal activity. Along with this, gamma waves at the frequency of 40 Hz are involved with establishing neuronal circuitry.

It has been noted that the absence of this wave, often times as a result of thalamic injury, conscious awareness can no longer form, and the individual slips into profound coma. Gamma waves have been induced in a mice population by stimulating a set of fast-spiking interneurons [37].

2.2. Structural activation and changes

Structural changes are measured and examined by magnetic resonance imaging (MRI), or functional magnetic resonance imaging (fMRI). An MRI allows viewing of structures in an individual's brain, thereby allowing one to make conclusions regarding the integrity of a structure. In MRI, image contrasts are weighted by providing different amounts of magnetization to structures, and waiting for each structure to return to equilibrium. Creating T-1 (spin-lattice) weighted images involves waiting for the recovery of different amounts of magnetization, followed by measuring the magnetic resonance by changing repetition time. When examining the brain, T-1 weighted images are used to measure gray matter volume, and assess the cerebral cortex. To create T-2 weighted images, time to initial magnetization decay is determined, followed by measuring the magnetic resonance signal by changing the echo time. T-2 weighted images are used to assess matter, and are helpful for revealing lesions.

Diffusion MRI involves examining the diffusion of water across tissues. This method helps to reveal more about tissue architecture and microscopic details. It is clinically important, especially in a stroke population, in that it can show abnormalities in white matter fibers.

fMRI allows to see ongoing brain activity of an individual, as changes in blood flow occur due to use or activation. Individuals are placed into the MRI scanner and are assigned single or multiple tasks to perform. fMRI can show the degree of activation of multiple regions of the brain.

fMRI measurements involves using blood-oxygen level dependent contrasts, so that changes in blood flow due to activation and the degree of activation can be imaged. This method is similar to MRI, except that changes of magnetization are examined between oxygen-rich and oxygen-poor blood, due to varying levels of iron. When fMRI data is collected, a computer then processes these signals into three-dimensional images of the brain that researchers can examine. Brain activity with these methods, are mapped in square images called voxels. Each voxel represents thousands of neurons. Color is then added to the image to create a map of the most active areas in the brain.

PET scans, or positron emission topography, is an imaging technique that produces 3D images of ongoing physiological functions. This method involves the detection of gamma rays from a biologically active tracer that is ingested by the participant prior to the test. The methodologies stated above are used to examine structural changes and activation that occurs as a result of yoga practice.

3. Results

The following results section will first present the effects of yoga on brain wave activity, followed by the effects of yoga on structural and activation changes in the brain.

3.1. Brain wave activity changes

With the cognitive benefits associated with various brain wave activity, a natural way to induce this activity could be beneficial. Yoga and Pranayama training may be one such solution. Previous work examining the effects of a breathing and relaxation form of yoga, known as Santhi Kriya, reported a gradual and significant increases in alpha activity over 30 consecutive days of training at 50 min bouts [28] Santhi Kriya. This training involved 20 min of seated fast and slow breathing exercises, followed by 30 min of relaxation and meditation, where subjects were instructed to direct their attention to breath and then body (Table 1). EEG and ECG measurements were taken before, after, and at 10 day increments during the training cycle. Increases in alpha wave activity were found in occipital and prefrontal cortices in both hemispheres. The effects of yoga asana training, pranayama training, and asana-pranayama training on alpha wave was examined in police trainees in a separate study [35]. Subjects performing asana-based yoga performed a designated series of various yoga postures. Pranayama practice in this study also involved seated fast and slow breathing exercise. The results reported a significant increase in alpha wave activity in asana and asana-pranayama groups, but not in the pranayama group. Contrary to the aforementioned study, another study Stancak Jr [31] reported increased alpha wave and beta wave activation during two bouts of pranayama practice, involving seated forced alternate nostril breathing in subjects practicing for 2–20 years. EEG recordings were taken during the breathing practice that consisted of a rest period followed by a breathing period, which was then repeated twice. Similar findings were also reported with two months of Sahaj yoga meditation training [39] (Table 1).

Yoga training may be associated with higher alpha power, but more research is needed on the effects of pranayama on alpha wave activity, and whether yoga asanas or pranayama has a more profound effect on alpha power, and consequently, on memory and cognition. Several studies have shown beta wave stimulation after yoga and pranayama training. During alternate nostril breathing, a form of pranayama, beta power was seen to increase [35].

A separate study aimed to examine the long-term effects of Sudarshan Kriya Yoga and Pranyama on brain waves and function [2]. EEG recordings were done outside of practice on 19 practitioners that have been practicing regularly for a minimum of 1 year, and 16 non practitioners, comprised of doctors and medical professionals. The EEG recordings were performed for 10 s durations before and after Kriya and Pranayama training, in a supine relaxed position. The results showed that practitioners of this type of yoga had significantly larger beta waves and spurts of alpha waves, indicating relaxation with the coexistence of alertness (Table 1).

Yoga and pranayama training may be associated with increased beta activity, and subsequently, reduction of parameters such as emotional exhaustion, state anxiety, and fatigue. However, further research is needed to verify a direct correlation between yoga and improvements in these parameters. Yoga may be a method to stimulate theta activity and obtain the associated benefits in anxiety and memory. Increased theta activity during Bramari Pranayama has been reported. A similar study also reported significantly increased theta and beta power in a longitudinal study consisting of 48 subjects that were divided into asan-pranayama and pranayama groups, that practiced for 4 days a week for 6 months [35]. EEG recordings were performed before and after the training protocol for both groups. Both groups also performed a visual reaction time task, consisting of a red-green discriminatory task, before after yoga/pranayama training. The improved performance in this visual discriminatory task post-training, may also indicate that the increase in beta and theta waves had a functional result.

Kriya-based yoga practice has also been shown to elicit theta wave responses. A study examining Santhi Kriya [28], measured brain waves in 11 kriya yoga instructors, with at least one year of consistent practice, before and after a two-hour Kriya Yoga class. The Kriya Yoga class consisted of a slow breathing phase, a fast breathing pace, followed by a period of meditation and contemplation. The study found that alpha waves and theta waves increased by 40 percent, primarily in the parietal region. This meant that the brain was more deeply relaxed after yoga and the subjects reported having reduced feelings of anxiousness and having better control of his or her emotional state.

Two forms of pranayama, right and left nostril yoga breathing, seem to have a positive effect on memory and cognition by affecting the contralateral hemisphere of the brain. A similar EEG study examined P300 wave, a type of event related potential (ERP) elicited during decision-making processes, during a pranayama practice [34]. An event related potential is an electrophysiological response to a stimulus. This study reported that during right nostril

Table 1
Changes in brain wave activity.

Study	Type of yoga	Study type	Subjects	Intervention	Outcome variables	Key findings
[28]	Santhi Kriya yoga	Longitudinal	8 healthy males aged 25.9 ± 3 years, not experienced	Santhi Kriya practice, daily, 50 min, for 30 days	Peak amplitude and frequency of alpha wave activity	Increased alpha wave activity
[31]	Alternate nostril breathing	Cross sectional	8 healthy females and 10 males aged 28.4 ± 3.9 years, 2–20 years of yoga training	5 min of rest, 10 min of alternate nostril breathing, for 2 cycles, 30 min, 1 bout	Peak amplitude and frequency of alpha wave activity	Increased alpha wave activity
[29]	Sahaj yoga	Cross sectional	9 healthy subjects experiencing major depressive disorder, aged 33–49, and 10 healthy age-matched controls	Sahaj yoga training, 30 min, 4–5/week, 2 months	Peak amplitude and frequency of alpha wave activity	Increased alpha activity
[35]	Various yogasanas and pranayamas.	Experimental design	80 healthy males, aged 24.82 ± 3.20 years	Subjects randomly divided into asan group, pranayama group, asan-pranayama group, and control group. Practice: 1 h daily, 4 days a week, for 6 months	Peak amplitude and frequency of alpha wave activity	Increased alpha wave activity in asana and asana-pranayama groups, increased theta power in asan-pranayama and pranayama groups
[2]	Sudarshan kriya yoga	Cross sectional	19 healthy yoga practitioners (1year + experience), 15 controls, aged 37 ± 14 years	Sudarshan kriya practice, 30 min, 1 bout	Peak amplitude and frequency of beta wave activity	Increased beta activity after practice
[37]	Bhramari pranayama	Cross sectional	4 trained and 4 untrained healthy males, aged 30–41 years	1–2 consecutive sessions of Bhramari pranayama with 20 breathing cycles.	Peak amplitude and frequency of theta wave activity	Increased theta activity after practice
[34]	Uninostril and alternate nostril yoga breathing	Experimental design	29 healthy males between, ages 20–45 years	5 sessions of 45 min each session of uninostril yoga breathing, alternate nostril yoga breathing, breath awareness, or no intervention	Peak amplitude, frequency, and latency of P300 wave	Significantly lower P300 (brain wave related to decision-making process) peak latency in the left brain hemisphere compared to right during right nostril yoga breathing

yoga breathing, there was a significantly lower P300 peak latency in the left hemisphere of the brain than the right hemisphere, indicating greater cognitive performance in the left hemisphere during right nostril yoga breathing. Similarly, a separate study Jella [15] found increased verbal task performance during right nostril yoga breathing, however this result was not significant. Another study also examined the effects of right nostril yoga breathing during a letter-cancelation task and found the scores on the task were significantly higher after alternate nostril breathing, and more notably, right alternate nostril breathing. Left nostril yoga breathing increased spatial memory scores [24,31]. Coupling the results of these studies, there seems to be an effect of nostril yoga breathing on the contralateral brain hemisphere (Table 1).

Lastly, the effects on gamma wave activation were examined after a pranayama practice [37]. Eight male subjects were recruited to perform Bhramari pranayama. The subjects belong to three separate groups including beginner, intermediate, and expert. EEG recordings were performed during pranayama. The results showed an increase in high frequency patterns only during pranayama practice [37].

While the research in the efficacy of yoga and pranayama on theta wave stimulation is limited, training in both may prove beneficial in parameters of anxiety and memory. Further research should compare the degree of theta stimulation between various forms of yoga to verify whether this stimulation is style-specific or is seen across multiple styles of yoga.

3.2. Structural and activation changes: effects on emotion, memory and stress and pain response

Yoga practice has been associated with changes in emotion and memory, and is particularly associated with increases in positive mood, memory, and decreases in pain perception. Specifically, much of memory and emotional regulation is controlled largely by the frontal lobe and the amygdala. Therefore, previous studies examined the effects of yoga practice on the frontal lobe and amygdala. A study examining the activation of the right amygdala amongst subjects [6], reported decreased blood flow, as reported through a PET scan, as a result of 12 weeks of Iyengar yoga training (Table 2). These results also reported increased cerebral blood flow to the frontal lobes, as areas within the frontal lobe are involved in prolonged focus and attention. However, no controls were used in the study. While viewing negative emotional images and when presented with distracters, yoga practitioners had less activation in the dorsolateral prefrontal cortex, a section within the frontal lobe, than non-practicing controls, as show in an fMRI study [9]. This suggests yoga training may prevent negative emotional stimuli from distracting working memory and thus ameliorate negative emotional response to incoming sensory information. This study also found a distinction in the correlation of amygdala activation and decay of positive affect. Non-practitioner controls showed that decreased positive affect could be predicted by the magnitude of amygdala activation; however this wasn't seen with Yoga practitioners. This suggests that while yoga practitioners do display amgydala activation when presented with negative emotional stimuli, their mood was unaffected. A separate study also measuring changes in the frontal lobe, examined the differences between [9] yoga and meditation practitioners and age-matched controls. Subjects performed a series of cognitive assessments, including several memory tasks. The results indicated better cognitive performance in yoga practitioners when compared to non-practitioners, and a positive correlation between gray matter volume and yoga experience [9]. This suggests that long-term practice of yoga increases gray matter volume. In congruence, these studies suggest that yoga may be a helpful therapy for neurologically disordered populations that are associated with reduced gray matter volume (Table 2).

Along with changes of activation patterns within the brain, yoga has been reported to alter the perception of pain. Pain perception and processing is largely occurring within the insula and insular

Table 2
Structural activation and changes.

Study	Type of yoga	Study type	Subjects	Intervention	Outcome variables	Key findings
[6]	Iyengar yoga	Longitudinal	2 healthy males, 2 healthy females, untrained in Iyengar yoga, ages 41–51 years	Iyengar yoga training, 60 min, daily, 12 weeks	Activation and blood flow to cerebral cortex, frontal lobes, and midbrain	Decreased cerebral blood flow in amygdala and increased activation of frontal lobes
[9]	Hatha yoga	Cross sectional	7 healthy trained, and 7 healthy untrained subjects, ages of 18–55 years	1 training session of Hatha yoga	Activation and blood flow to cerebral cortex, frontal lobes, and midbrain	Less dorsolateral prefrontal cortex activation in yoga practitioners while viewing negative emotional images and distractors, greater Stroop task response in the ventrolateral prefrontal cortex with yoga practitioners when presented with emotionally negative distractor images
[13]	Various yogasanas and pranayamas.	Longitudinal	4 healthy male and 3 healthy females, elderly subjects, ages 55–63 years	Received yoga training for 1 h/day, 5 days/week for 3 months, then continue same protocol for 3 months without instruction	Grey and white matter volume in the hippocampus	Increased hippocampal volume
[38]	Varying types	Ex Post Facto	5 healthy males, and 9 healthy females, with a minimum of 2 years of practice, ages 30 ± 7 years, and aged matched controls	No intervention	Images of white matter connectivity of insular cortex	Greater amounts of white matter connectivity in the insular cortex in practitioners, indicated greater pain tolerance.

Table 3
Task performance and behavioral changes.

Study	Type of yoga	Study type	Subjects	Intervention	Outcome variables	Key findings
[34]	Uninostril and alternate nostril yoga breathing	Experimental	20 healthy males, ages 20–45 years	Uninostril yoga breathing, alternate nostril yoga breathing, breath awareness, 30 min, 4 days	Scores on letter-cancellation test	Higher scores on a letter-cancellation task after alternate and right nostril yoga breathing
[24]	Uninostril and alternate nostril breathing	Experimental	108 healthy children ages of 10–17 years	Uninostril yoga breathing, alternate yoga breathing, breath awareness, 30 min, 10 days	Scores on spatial memory tests	Increased spatial memory scores in left nostril breathing
[15]	Unilateral forced nostril breathing	Cross sectional	25 males and 26 females aged 21 ± 3 years, not experienced	Unilateral forced nostril breathing, 30 min, 1 bout	Scores on verbal task test	Increase in verbal task performance

cortex (Table 2). A cross-sectional study on American yoga practitioners and age-matched controls found asana-based yoga practitioners, with 6–11 years of experience that practiced 4–10 times a week, had increased gray matter, mostly in the insular cortex [38]. They also reported gray matter volume to increase with yoga experience [38]. This increase in gray matter volume in the insular cortex was found to be correlated with the larger pain thresholds the practitioners exhibited during thermal and pain threshold tasks (see Table 3).

Much like pain, stress and heightened levels of cortisol can place and incredible toll on an individual's sense of well-being. Cortisol is a primary hormone released in response to stress. In healthy amounts, cortisol acts to regulate general processes, but at excessive levels, this hormone can ultimately be detrimental to overall health and well-being. Cortisol levels can be augmented and controlled at the peripheral level and at the level of the hippocampus. Peripheral regulation of cortisol can ultimately lead to feedback loops that would influence the hippocampus. Although the hippocampus regulates the release of cortisol, other functions of the hippocampus can be compromised as a result of excess levels of cortisol. Some studies sought to examine the changes occurring to the hippocampus and cortisol levels, as yoga has been associated with decreases in self-reported stress perception.

Hippocampal atrophy is seen in depression patients [14], and it is widely associated with the progression of Alzheimer's Disease [14,22,32]. Hippocampal volume was also shown to decrease as a result of the aging process. A study examining 7 elderly adults between the ages of 69–81, used MRI scans to find that the volume of the hippocampus increased in the elderly subjects, as a result of a 6 month yoga intervention. This study provided a yoga intervention consisting of asana-based and breathing-based training 5 days a week for 3 months. For the remaining 3 months, participants were asked to practice daily on an individual basis. The results indicated significant increases in bilateral hippocampal bilateral from pre-test to post-intervention scans [13]. Yoga training may be a protective therapy against the loss of hippocampal volume due to certain neurological disorders or aging. However the direct effects of yoga therapy on these populations should be pursued in future research.

Aside from hippocampal volume, yoga has shown to effect cortisol levels in the body Kushei et al. A previous study examined blood serum levels of cortisol in 8 yoga practitioners after a single bout of yoga [16]. This single bout of yoga lasted approximately 60 min and consisted of breathing, asanas, and meditation practice. The results showed decreases in blood serum levels of cortisol post-intervention, indicating that yoga may be an intervention to consider with patients with chronic cortisol levels.

4. Discussion

The general trend that was evident, among the studies that were reviewed, was in favor of yoga practice. Despite the fact that yoga within this review was divided into three separate branches, all three branches elicited improvements in the variable of interest.

Among the studies that examined brain waves, alpha waves amplitude and frequency, which is associated with an increased perception of calmness, was increased after breathing, meditation, and asana-based yoga practice. Beta waves, which are associated with task performance, were also seen to improve in frequency and amplitude during and after mainly breathing based yoga. Theta wave activity, which is naturally occurring during repetitive tasks and autonomy, improved primarily after asana and breathing based yoga practice. The overall increase in brain wave activity may explain the decreases in anxiety and increases in focus that are evident after yoga training programs.

This improvement can have positive implications for a clinical population. Although the research studies that were reviewed mainly used healthy young and healthy older subjects, there remains a possibility that their results could be generalized to a population outside of the populations that were studied. Amongst the stroke population, cognitive dysfunction is significant and debilitating problem. This apparent cognitive dysfunction can be attributed to neurobiological changes within the brain after stroke [7]. The reviewed studies have been able to show neurobiological advantages related to cognition either among yoga practitioners or after a yoga intervention. Specifically, a stroke population is more susceptible to diminished gray matter when compared to healthy controls [1]. Therefore, yoga may be an affective adjunctive treatment to help improve gray matter volume and to attenuate cognitive dysfunction within this population. Cognitive decline, specifically impaired memory, has also been evident in individuals with Parkinson's disease, and can be attributed to a decrease in hippocampal volume [20]. Yoga practice may also serve as an affective adjunctive treatment for patients with Parkinson's disease, as yoga practice generally improved bilateral hippocampal volume. General cognitive decline in an aging population does not stem from a single cause. Therefore, both of the aforementioned neurobiological changes as a result of yoga practice may also be beneficial for an aging population.

Neurological conditions such as schizophrenia, bipolar disorder, and depression are conditions that can also greatly benefit from general yoga practice. Anxiety is a common symptom that exists amongst these three neurological conditions. Reductions in anxiety are associated with alpha and theta brain waves, both of which were seen to increase in frequency and amplitude during and after yoga practice. Mood disturbances are also common in these three neurological populations. Yoga also shows to be an effective adjunctive treatment for these disorders, as a regulated amygdala and increased brain wave activity were associated with increases in positive mood perception.

The neurobiological changes that occur due to yoga can also have implications on mood, anxiety and the general state of well-being among clinical populations. The improvements that were seen in various brain wave activity and amplitude as a result of yoga either yielded or were correlated with improvements in mood, focus, and an over-all sense of well-being. Although each population, including those that fall into the category of clinical or healthy, will endure their respective conditions and symptoms, it can be accepted that improvement in a sense of well-being will remain a universal demand.

5. Conclusion

In conclusion, yoga seems to have positive effects on brainwave activity in terms of stimulating the activation of alpha, beta, and theta brainwaves, which have been associated with improvements in cognition, memory, mood, and anxiety. Yoga training has been correlated with decreased amygdala activation and decreased negative emotion in response to emotional distracter images. Alternate nostril breathing was reported to activate the contralateral brain hemisphere, providing neurocognitive benefits. Increased inter-hemispheric coherence and symmetry with yoga training has been reported in multiple studies. Yoga also seems to have a constructive effect on the anatomy of the brain.

The implementation of yoga training into the clinical treatment of certain neurological and psychosocial disorders may be beneficial to these populations because of its neuroplastic effects. Future research should focus on yoga training interventions on the neurological disorder populations. Because of the wide variety of yogic practices, research should compare different styles of yoga and assess the extent of their neurocognitive and neuroanatomical effects on neurological disordered populations. Exploring the mechanisms through which yoga improves certain brainwave powers, increase certain areas of brain activation, and produce anatomical changes in the brain may prove beneficial. With this knowledge, a specific yoga training program can be designed catering to specific neurological disorders and ailments and work to ameliorate symptoms if not treat the root cause of the disorder.

Conflict of interest statement

There was no conflict of interest.

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