Journal of
Yoga and Physiotherapy
ISSN: 2476-1303

Review Article
Volume 6 Issue 2 - September 2018
DOI: 10.19080/JYP.2018.06.555681

J Yoga & Physio

Neuroimaging Studies on Yoga Practice in Healthy Population

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Submission: December 22, 2017; **Published:** September 04, 2018

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Introduction

Yoga comprises various domains of practices but practically we can divide yoga into three categories: poses exercise (asana), breathing (pranayama), and meditation (dhyana). Asana is usually considered as a form of exercise through actions of the body. Breathing-based practice involves purposeful inhalations and exhalations that can be designated at a specific speed and intensity. Breathing exercise can be practiced in a seating, standing or lying position (savasana). Previous studies have shown various mental and physical health benefits related to yoga. For example, studies examining mental health outcomes have reported decreased feeling of anxiety and depression Streeter et al. [1]. Cognitive benefits of yoga in healthy subjects have also been demonstrated with improved spatial and verbal memory Naveen et al. [2], increased executive functions Gothe et al. [3] and better psychometric abilities Sharma et al. [4].

Mental health and cognitive benefits of yoga are now well accepted by the community, but the neuronal changes in the brain associated with these benefits mostly remain to be investigated. Changes in behavior are often associated with changes in neuronal activity within the brain. Understanding what can elicit brain modulations that lead to improved cognition can give insight into the development of cognitive interventions in both healthy and clinical populations. In this article, we will review studies on neural changes detected by neuroimaging techniques that occur because of yoga practice, which may influence mental health and overall wellbeing in healthy population. For each section, we will first describe the technique and then report findings related to yoga intervention and practice.

Neuroimaging Techniques and Yoga Findings

Positron emission tomography (PET)

PET studies measure resting regional cerebral metabolic rates for glucose or changes in regional cerebral blood flow as an indirect measure of the neural synaptic activity (Figure 1). For example, a PET scan using fluorodeoxyglucose (18F) summates approximately 30 minutes of cerebral glucose metabolism and allows assessment of regional variations. PET scanning is invasive because it involves the injection of positron-emitting radionuclides with short half-lives (Figure 2). As the radioactive compound accumulates in different regions of the brain and positron annihilations occur, the scanner detects the coincident rays produced at all positions outside the head and reconstructs an image that displays the location and concentration of the radioisotope within a plane of the brain. PET is combined with CT imaging to co-register the functional PET image with an anatomic resolution image Boly et al. [5].

Figure 1: Positron emission tomography (Liege Hospital, Belgium).

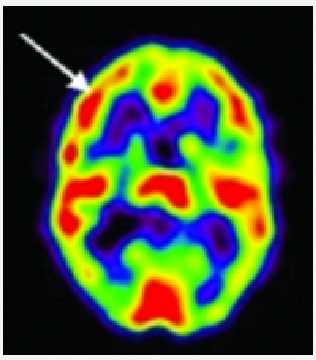

Figure 2: The cerebral blood flow is greater in the right prefrontal cortex (arrow) after the yoga program, which suggests a training effect that enhances the activation in that brain area. Cerebral blood flow is represented as red > yellow > green > blue. Taken from Cohen et al. [6].

Regarding yoga, decreased blood flow has been measured in the amygdala whereas increased blood flow has been observed in the frontal lobes, because of three months of Iyengar yoga training practice in fours subjects Cohen et al. [6]. This result suggests that yoga training may prevent negative feelings as the amygdala is thought to regulate emotions, being especially active during negative emotions. Moreover, prolonged focus and attention may have been developed throughout the training as the frontal cortex is involved in these processes.

Magnetic resonance imaging (MRI)

Functional MRI can detect an increase in blood oxygen concentration that occurs in an area of heightened neuronal activity (Figure 3). The basis for this capacity comes from the way neurons make use of oxygen. Functionally induced increases in blood flow are accompanied by alterations in the amount of glucose the brain consumes but not in the amount of oxygen it uses. Additional blood to the brain without a concomitant increase in oxygen consumption leads to a heightened concentration of oxygen in the small veins draining the active neural centers Boly et al. [5]. The reason is that supply has increased, but the demand has not. Therefore, the extra oxygen delivered to the active part of brain simply returns to the general circulation by way of the draining veins. The commonest form of fMRI is blood oxygenation level dependent (BOLD) imaging. The BOLD signal depends on the ratio of oxygenated to deoxygenated hemoglobin. In regions of neuronal activity this ratio changes as increased flow of oxygenated blood temporarily surpasses consumption, decreasing the level of paramagnetic deoxyhemoglobin.

Figure 3: Magnetic resonance imaging (Liege hospital, Belgium).

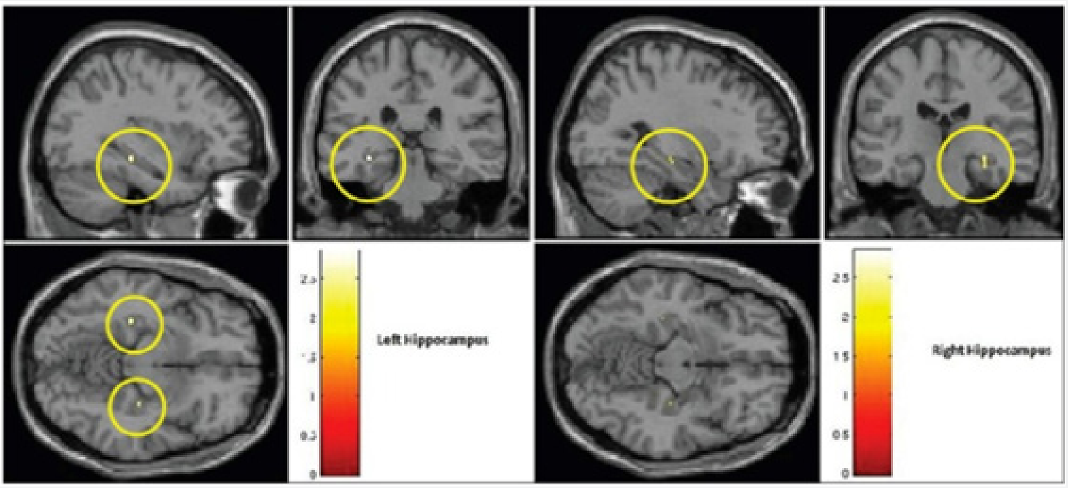

Figure 4: Increased hippocampus gray matter volume after yoga practice in healthy elderly (difference before and after training using voxel based morphometric analysis). Taken from Hariprasad et al. [8].

These localized changes cause increases in magnetic resonance signal, which are used as markers of functional activation. So far, only a few MRI studies have investigated the benefit of yoga on brain function. Froeliger et al. [7] showed that while viewing negative emotional images and when presented with distracters, seven practitionersof hatha yoga and meditation presented less activation in the dorsolateral prefrontal cortex as compared to seven non-practitioners. This finding suggests that yoga training may decrease negative emotional stimuli from distracting working memory, and thus improve negative emotional response to incoming sensory information. The authors also reported a correlation between amygdala activation and decay of positive affect in non-practitioners, which was not the case for the yoga trainees. More specifically, non-practitioner showed a decreased positive affect that could be predicted by the magnitude of the activation of the amygdala. Additionally, a positive correlation was found between gray matter volume in the frontal lobe and yoga experience, which suggests that long-term practice of yoga increases gray matter volume. Another study on fourteen yoga practitioners found that asana-based yoga practitioners with six to eleven years of experience (doing four to ten practices a week) also presented increased gray matter, mostly in the insular cortex, area involved in the pain matrix. This increase in gray matter volume correlated with larger pain thresholds during thermal and pain threshold tasks. Gray matter volume was also increased with yoga experience in this study.

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Another study measured the volume of the hippocampus in seven healthy elderly adults before and after an extensive 6-month yoga intervention with asana-based and breathing-based training (including "OM" chanting) Hariprasad et al. [8] (Figure 4). The hippocampus (brain region involved in memory formation and vulnerable to loss of grey matter with aging) was found to increase substantially after the yoga intervention. The increase in gray matter was observed in bilateral hippocampus but not in the occipital gray matter (see figure below), which suggests that yoga may have the potential to reduce neuronal senescence. Note, however, that the sample size of this study (as well as all the studies mentioned so far) is small and there is no control group for comparison, so the results should be taken with caution.

Finally, in another fMRI study of twelve subjects (four with formal training in yoga including meditation, and eight naïve), the audible "OM" chanting, which produces a sensation of vibration, induced deactivation in the amygdala, anterior cingulate gyrus, hippocampus, insula, orbitofrontal cortex, parahippocampal gyrus and thalamus, as compared to the brain at rest (see below) Kalyani et al. [9] (Figure 5). These brain regions are part of the limbic system, which controls emotions and drives. In contrast, deactivation did not occur in these brain regions during a control condition (i.e., enunciating "sss", which does not have the vibratory property). This study thus shows the direct effect of "OM" chanting on brain modulation. This is however not strictly related to yoga practice (as naïve subjects were included), and it rather shows the brain experience of audible "OM" per se.

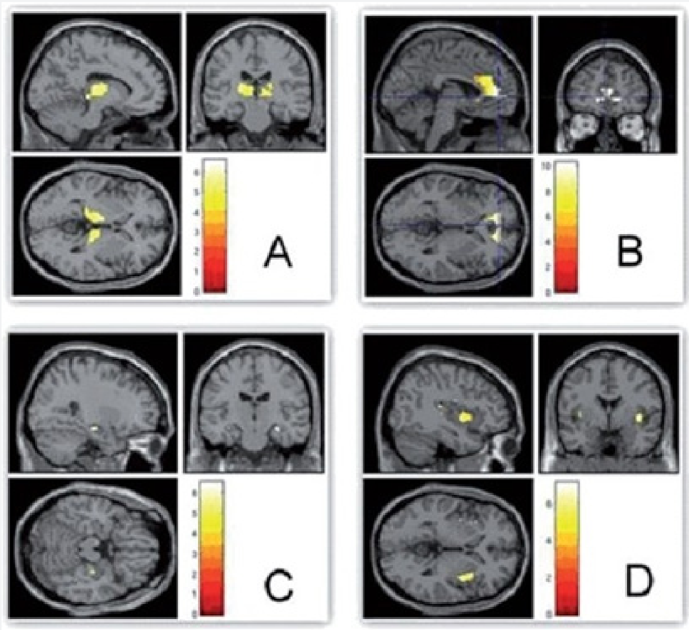

Figure 5: Increased hippocampus gray matter volume after yoga practice in healthy elderly (difference before and after training using voxel based morphometric analysis). Taken from Hariprasad et al. [8].

Electroencephalography (EEG)

EEG is a non-invasive technique that allows the detection of spontaneous brain electrical activity from the scalp. It provides temporal resolution in the millisecond range. However, traditional EEG technology provides insufficient spatial detail to identify relationships between brain electrical events and structures and functions visualized by fMRI. Recent advances help to overcome this problem by recording EEG from more electrodes (see below), by registering EEG data with anatomical images, such as structural MRI, and by reducing the distortion caused by volume conduction of EEG signals through the skull and scalp. In addition, statistical measurements of sub-second interdependences between EEG time-series recorded from different locations can help to generate hypotheses about the instantaneous functional networks that form between different cortical regions during mental processing Boly et al. [5].

Desai & colleagues [10] recently reviewed the current literature on EEG and yoga. Based on 15 articles, they conclude that yoga increased overall brain electrical activity, which include increases in alpha, beta and gamma band activity. Alpha band neural oscillations are in the frequency range of 7.5–12.5Hz and are predominant in the occipital brain areas during periods of eyes closed. In an old study on eight healthy subjects, an increase in alpha activity has been measured over 30 consecutive days of breathing and relaxation yoga training of 50 minutes Satyanarayana et al. [11]. More specifically, increases in alpha wave activity were observed in occipital and prefrontal cortices. Another old study reported increased alpha band and beta band (12-30Hz) activation during pranayama practice (i.e., alternate nostril breathing) in eight long-term practitioners Stancak et al. [12]. On the other hand, a recent study looked at the effects of yoga asana training, pranayama training and a combination of both on brain activity in 80 healthy subjects

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Trakroo et al. [13]. The authors found a significant increase in alpha wave activity in asana group and in the combination group, but not in the pranayama group. Another study found that Kriya yoga and pranayama yoga practitioners presented larger beta waves and spurts of alpha waves, indicating relaxation with the co-occurrence of alertness (Bhatia et al, 2003). Kriya-based yoga practice has also been shown to elicit theta activity (slower activity than alpha and beta), with an increase of 40%, mostly in parietal regions Satyanarayana et al. [11]. This finding suggests that the brain was more deeply relaxed after a session of yoga with reduced feelings of anxiety and better emotional control. Moreover, the effects on gamma wave activity were also investigated after a pranayama practice and showed again an increase in high frequency patterns during pranayama in eight healthy subjects Vialatte et al. [14].

Yoga Research, What Is Next?

In summary, the results from the reviewed articles were all in favor of yoga practice. Among yoga practitioners and after a yoga intervention, the three subdivisions of yoga (i.e., asana, meditation and breathing) produced changes in behavior, cognition and the brain. Indeed, we have seen that yoga training has been correlated with decreased amygdala activation and decreased negative emotion in response to emotional distracter images. Yoga also seems to have a constructive effect on the anatomy of the brain, with for instance an increase of grey matter in the hippocampus in elderly subjects. Yoga also seems to have positive effects on brainwave activity in terms of increasing alpha, beta, and theta electrical activity, which have been associated with improvements in cognition, memory, mood, and anxiety.

We are still however at the beginning of yoga research and most findings come from small sample size, uncontrolled and non-randomized studies. Comparing different groups are crucial for accurate testing and interpretation of yoga intervention experiments. Selecting appropriate comparison groups can however be difficult because yoga includes a heterogeneous set of practices, as we have seen in the previous section. To isolate the specific mechanisms of yoga's effects, using an active control group seems to be the best option, for example a physical exercise or an education control group Park et al. [15]. Yoga intervention is another good option and in an ideal world, one wants to do both: group comparison (between experienced and naïve subjects) and yoga intervention (before and after, within subject). Further research should examine the effects of yoga training into the clinical treatment of neurological and psychosocial disorders [16]. Because of the extensive variety of yoga practices, more studies should also directly compare the different styles of yoga and evaluate the extent of their neurocognitive and neuro-anatomical properties on healthy and pathological populations.

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