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Exploring the Neuroplastic Effects of Yoga Based Mind-Body Intervention: A Systematic Review of Brain Rewiring

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A B S T R A C T

Brain rewiring is a structural change in brain's neural connectivity. There seems to be a thin possibility of achieving synaptogenesis by using yoga-based practices in a specific and controlled environment which has been confirmed previously by multiple research studies. Neuroplasticity is brain's remarkable capacity to change, to increase structural and functional connectivity in response to mental and physical training. It is at the core of learning, memory, attention, any cognitive development and recovering from neural injuries. Brain plasticity may be influenced by modulating multiple factors like neurotransmitters, neurotrophins, gut microbiota, neuronal electrical activity etc. Enhanced connectivity between different brain regions can be attributed to increased dendritic spine density, their length, their numbers, axonal sprouting with enhanced synaptic strength. As age advances, brain's capacity to rewire gets impaired and reduction in volume of various brain regions like white matter, cortical and subcortical grey matter is found leading to cognitive and behavioral impairment.

This systematic review is based on the various previously established evidences regarding yogic approach towards neuroplasticity. For this we have reviewed around 34 research articles which have established the evidence of changes taking place in the brain network by providing constant stimulations to neurons and generating short-term potentiation (STP) which later gets converted in to long-term potentiation (LTP) which is at the core of neuroplastic changes taking place in the brain and many studies which are directing us in considering the possibility of modulations in the regulation of various factors like neurotransmitters, neurotrophins by using different yoga based practices. Yoga is an ancient practice of mind body medicine. It is a mindfulness technique which involves various restraints (Yama), observances (Niyama), various physical postures (Asana), coherent breathing (Pranayama), meditation (Dharana, Dhyana), mantra chanting. Its neuroprotective effect is well established but underlying mechanism is still unclear and yet to be explored. This review article focuses to explore the possibilities of formation of new neural connections based on available conventional and scriptural evidences.

Keywords: Yoga, Neuroplasticity, Rewiring

1. Aims and Objectives

To explore the in-depth knowledge regarding yogic mechanisms, which might be causing neuroplastic changes.

Observing the possibilities of brain rewiring through Yoga practices.

2. Literature Survey

2.1 Introduction

Neurons are brain cells which receive and send messages all over the body allowing us to do each and every complex motor task. It was believed that we are born with pre-arranged brain network containing all the neurons we are going to have throughout our lifetime, which may reduce but cannot be grown. But later on, scientists found the evidence of Neuroplasticity.

Neuroplasticity also known as brain plasticity or synaptic plasticity is a complex process involving adaptive structural and functional changes in the brain in response to repeated intrinsic or extrinsic stimuli [14]. It is possible due to an inherent characteristic of neurons to modify according to the environmental changes. Rewiring can occur at any level in the brain including axons, dendrites, synapse or tracts connecting various brain regions and spinal cord. Major changes leading to brain rewiring takes place at the level of synapse which is a microscopic gap between neurons. This includes, presynaptic axon, postsynaptic dendrites and synapse.

To perform any activity there must be generation of a stimulus which causes opening of the voltage gated sodium channels and results in change in membrane potential, eliciting an action potential. This action potential is responsible for the transmission of nerve signals. Once action potential has reached the nerve terminal it has to pass through the synapse to propagate it to succeeding neurons. A microscopic gap between two neurons is called

synapse. Human brain consists of trillions of neurons and each neuron communicates with multiple other neurons through number of synapses. Synaptic transmission takes place by release of chemical compounds called neurotransmitters. Membrane of the presynaptic terminal is called presynaptic membrane which contains large number of voltage gated calcium channels. When an action potential reaches the presynaptic terminal, it causes opening of these calcium channels and calcium flows in. Further this leads to release of vesicles containing neurotransmitter in to the synaptic cleft and these neurotransmitter gets attached to the receptor protein present on the post synaptic membrane. Depending on the type of neurotransmitter released, post synaptic neuron either gets excited or inhibited.

There are 3 types of connectomes which are the wiring present between the neurons. These are Macro-connectome, Micro-connectome and Meso-connectome. Macro-connectome is the neural network which is widely distributed between different brain regions and major changes taking place are at the level of terminal branches of long-range axons. Micro-connectome is at the synaptic level, working at the level of an individual synapse. Micro-connectome rewiring takes place by enhancing the number of synapses and dendritic spines. Meso-connectome is the neural network situated in a particular brain region, connections between neurons within a brain region. In this, rewiring changes entire connections, generating completely new connection within a brain region [3].

Yoga is the most ancient science originated in India. The antiquity of yogic tradition goes beyond 5000 years. Yoga means 'Yuj' to join. It is a union of Atma (individual self) with Parmatma (universal entity). It is a union of mind and body. In modern times yoga is considered as a well-established complimentary therapy for plethora of medical conditions as well as for general well-being.

2.2 Mechanism of Short-term and Long-term plasticity

Synaptic plasticity is the ability to make changes in the strength and number of neuronal connections based on experience, depending on frequency and duration of synaptic stimulation leading to either short term or long-term potentiation. In 1973 Bliss and Lomo introduced the concept of long-term potentiation (LTP) while studying the rabbit hippocampus. Repetitive stimulation of presynaptic fibres resulted in enhanced response of granule cells, enhanced expression of neurotransmitter receptors on post synaptic neuron, increase in post synaptic activation in response to neurotransmitter release, causing attenuation of threshold needed to stimulate postsynaptic neurons [17]. LTP induction involves calcium influx through N-methyl-D-aspartate (NMDA)receptor channels along with activation of glutamate receptors and calcium release from intracellular stores while for LTP maintenance, a stimulation of gene expression is necessary. LTP induction and maintenance are model of short and long-term memory, respectively [15]. Short term potentiation (STP) represents an unstable form of LTP that diminishes over a period of about half an hour, or develops into a sustained state of heightened neurotransmission known as LTP [29]. Short term synaptic plasticity is responsible for short-term adaptation to sensory stimuli, short term memory and transient change in the behavior which does not last long while long term synaptic plasticity is responsible for learning and memory [20]. Short term training for specific visuo-motor skill resulted in transient spatially selective increase in grey matter volume (GMV) but it reverted back to original size within few days of cessation of training along with regression of skill which suggests STP. It denotes that short term activity dependent plasticity occurs rapidly but it regresses shortly after the activity has been terminated. So long-term continuous training is necessary to maintain the learned skills and enhanced GMV [4]. Through repeated practice for certain length of time duration, same neuronal pathways are recruited and this leads to strengthening of the preexisting connections between them and generation of new connections too.

2.3 Yogic perspective of discontinuation of neuronal networks and prescriptions for reestablishment.

It has been explained by classic ancient Indian scripture called Patanjali Yoga Sutra (PYS), written by sage Patanjali about 5000 years ago.

yogaścittavṛttinirodhaḥ|| pys 1.2

It denotes the definition of yoga which is the cessation of all the Vrittis of Chitta which are functional modifications of mind. Complete removal of all the Vrittis from the mind is Yoga.

Vrittis can be considered as altered identities (apart from the actual) of a person at gross level but at the subtle level it might denote as deviation from its original state either by natural process like aging or by any pathological incursions.

At systemic level especially in nervous system any alteration in the original neuronal pathways can be considered as Vritti. To establish this relation, we see the considerations of the Patanjali as "Vrittis have few close associates like five Kleshas and thirteen Antarayas, among these Antaraya, Vyadhi or disease is the prime one. And moreover, in Vrittis he explains the Pratyaksha as the first one which includes the process of perception at different levels. Any obstruction in Pratyaksha suggests that there is an obstruction in the perception or loss of sensory connections.

tadā draṣṭu: svarupeSvasthānam|| pys 1.3

Above given is the definition of Swastha (health). It says that at that time (when Vrittis are completely removed) the seer gets established in his own form, original state. State of complete health where there is no mental or physical abnormality and even social and spiritual dimensions are perfect.

Ayurvedic definition of health given by Acharya Susrutha is as followed:

samadoṣaḥ samāgniśca samadhātu malaḳkriyāḥ|

prasannātmendriyamanaḥ svasthaitiabhidhīyate|| su.sa.15.10

One is said to be Swastha when all Doshas, Agni, Dhatus and Malas are in a state of equilibrium and Atma (soul), Indriya (senses) and Manah (mind) are in the state of optimal functioning and happiness. One who is in the ideal healthy state is called Swastha. Any deviation from the above given dimensions leads to Vikara (disease).

vṛttisārūpyam itaratra‖ pys 1.4

In the state other than explained in sutra 1.3, Purush identifies himself with Vritti present in his mind. He thinks himself according to the nature of Vritti. According to yogic philosophy these Vrittis are the cause of various pathological conditions.

vṛttayaḥ pañcatayyaḥ kliṣṭāSkliṣṭāḥ‖ pys 1.5

Vrittis are five, some are easy to remove and some are difficult to remove.

pramāṇaviparyayavikalpanidrāsmṛtayaḥ‖ pys 1.6

These five Vrittis are: Pramana, Viparyaya, Vikalpa, Nidra, Smriti.

pratyakṣānumānāgamāḥ pramāṇāni‖ pys 1.7

Pramana is an instrument of knowledge, various methods to obtain knowledge. These ways of getting knowledge are as followed.

Pratyaksha: Direct perception. Anything which is perceived through senses is Pratyaksha. To perceive anything, sensory input is must which is carried to brain through nerve fibres and is interpreted by corresponding area of the brain and in turn might cause motor activity. But if there is any hindrance in neuronal pathway then it will not be able to decode the message received and this is disruption of perception and can be called as Pratyaksha dosha. Conditions like multiple sclerosis, peripheral neuropathy may be correlated with Pratyaksha dosha due to alteration in one's ability to perceive.

Thus any such alteration in the normal functioning of the body itself is considered as Vyadhi (Rogastu dosha vaishamyam dosha saamyam arogata-A.H.S-2), and it has been prescribed by Patanjali that to reinstate the normalcy one can practice Abhyasa and Vairagya. Any action performed to reinstate the absolute normalcy is Abhyasa and to extricate from the unwanted factors is Vairagya.

This indicates that any restrictions in Pratyaksha may be correlated with the hampering of neuronal pathways and to set these things right one can perform Abhyasa and Vairagya persistently.

Anumana: It is an inference based on the previous knowledge stored in particular brain regions depending on the type of memory. If these regions are damaged or the pathway for retrieving previously stored information gets haywire then one might not be able to use Anumana Pramana effectively.

Aagama: Scriptural knowledge or words of an authoritative person, but this also depends on the stored memory, or data processing system in brain. If brain is not in the state of receiving new information and interpret it, then there is no role of this Pramana too.

viparyayo mithyājñānam atadrūpapratiṣṭham‖ pys 1.8

Viparyaya is based on false knowledge which does not correspond to its true nature. It is wrong interpretation of knowledge whether it is perceived through Pratyaksha, Anumana or Aagama. This occurs in any condition causing neuronal damage. Illusion, delusion or hallucination are the examples of Viparyaya.

śabdajñānānupātī vastuśūnyo vikalpaḥ‖ pys 1.9

Vikalpa is one of the five Vrittis in which things can only be known or explained by words, as in reality that thing does not exist. One can only imagine them, as it does not occur or does not exist in the universe.

abhāvapratyayālambanā vṛttirnidrā‖ pys 1.10

The state of consciousness which occurs by contemplating on the Tamo Guna (lethargy or inertia) is called Nidra or sleep. Sleep is one such state where repairing process of body cells which have undergone wear and tear takes place. Thus, disturbed sleep may lead to improper healing process of damaged cells.

anubhūtaviṣayāsaṃpramoṣa: smṛtiḥ‖ pys 1.11

Smriti is a memory of an experienced subject which cannot be completely removed from the mind. Initially it might retain complete details of that subject but eventually it fades off but few bits of it always remains. This is called short term memory. To retain this experience in complete details for longer duration is called long term memory. To convert this short-term memory in the long term, repeated practice is must. Whenever we experience anything, it leaves an impression in our mind in the form of Samskara (impressions). These Samskaras are rooted in our subconscious minds. Thus, whenever something related to our past experience surfaces, it might come out of subconscious mind into conscious mind. By repeated and continuous practice these Samskaras can be easily stored into conscious mind.

According to Yogic literature, presence of these 5 Vrittis is harmful for any being. During neuronal damage even these Vrittis get abnormal which are to be corrected first. Means of obtaining new knowledge gets affected, false interpretation of any signal or stimulus takes place causing delusion or illusion or hallucination. Vivid imagination, vague thoughts, insomnia or hypersomnolence and altered memory is present in any neuronal pathology.

avidyāsmitārāgadveṣābhiniveśāḥ kleśāḥ|| pys 2.3

Avidya, Asmita, Raga, Dvesha, Abhinivesha are Kleshas. Kleshas are the afflictions, which cause pain and misery. Avidya is misinterpretation of knowledge. nityānitya vastu vivekam: Lack of discrimination between eternal and non-eternal things is Avidya. In such condition person may fail to make right choices. Asmita is the 'I'ness. Raga is source of pleasure. Dvesha is source of misery. Abhinivesha is the fear of death. In any condition having disturbed neural connections, one is definitely afraid of having their life terminated earlier and their constant fear of death makes their life miserable. All five Kleshas deteriorate the condition.

vyādhistyānasaṃśayapramādālasyāvirati

bhrāntidarśanālabdhabhūmikatvānavasthitatvāni cittavikṣepāste'ntarāyāḥ|| pys 1.30

In above mentioned Sutra, are the Antaraya, obstacles present in one's life. Vyadhi is a physical and mental ailment. It starts in mind in Manomaya kosha level and ultimately comes to Annamaya kosha level which is at the level of physical body.

To come out of above-mentioned problems below given prescription and proscription should be followed.

abhyāsavairāgyābhyāṃ tannirodhaḥ|| pys 1.12

Complete cessation of Vrittis is achieved through Abhyasa and Vairagya. In this Sutra they have shown two ways for removal of these Vrittis. To achieve this all abnormal Vrittis have to be brought to their normal state and then be eliminated.

tatra sthitau yātno'bhyāsa|| pys 1.13

Here, Patanjali has given the definition of Abhyasa (practice). It is an effort to get the steadiness in a specific state. It is a repetition of a particular state to eventually get stabilised in it. Thus, it is like a continuous effort which can be of anything either yoga practice or any task you are willing to do. By the Abhyasa of various yoga-based practices, one should get stabilised in generating STP followed by LTP in brain and reestablishment of a normalcy. Next sutra denotes the method of firmly grounding that Abhyasa.

sa tu dīrghakāla nairantaryasatkārāsevito dṛḍhabhūmi:|| pys 1.14

Firm establishment of any path or channel may be attained by long term and uninterrupted practice (stimulation) along with great devotion. Three essential conditions to firmly establish the practice are: longer duration and uninterrupted practice with complete dedication.

dṛṣṭānuśravikaviṣayavitṛṣṇasya vaśīkārasaṃjñā vairāgyam|| pys 1.15

Vairagya is to have mastery over all the desires of subjects which are seen or heard. One is aware of his desires and has total control over it. Vairagya is like proscription, things which should not be done, things which one should avoid during neuronal damage. They should not deviate from yogic lifestyle. Late night sleeping, reduced hours of sleep, intake of junk food, lack of physical exercise, stress, anxiety, irregular eating habit, anything which is against yogic routine should be avoided.

By following these prescription and proscription one can go from abnormal to normal and from normal to towards the higher dimensions of health and spirituality. At which rate one will get better depends on the intensity of practice.

tīvrasaṃvegānāmāsanna:|| pys 1.21

Those who have intense urge can achieve it easily. To achieve success in any field one must be having an intense desire for that. Higher the keenness, faster the goal can be achieved. Yoga based practices performed with impulsivity to get back to normalcy will allow one to achieve it quickly.

mṛdumadhyādhimātratvāt tato'pi viśeṣaḥ|| pys 1.22

Even though one has an intense urge, degree of efforts made by one also plays a significant role. Unless one puts on a suitable effort he may not succeed only by intense desire. These efforts are of 3 degrees: mild (Mridu), medium (Madhya) and extreme (Adhimatra). Chances of success vary according to the degree of effort. Success in reestablishing healthy neural network depends on the degree of efforts made by a person along with its intense desire to practice and get back to previous normal state.

Thus, according to above two sutra two dimensions are needed: One is the intensity of urge and another is degree of efforts made by a practitioner. Each dimension has three different levels making total of nine levels. For those with mild conviction it may be either mild practice-mild conviction or moderate practice-mild conviction or intense practice-mild conviction. For those with medium conviction, mild practice-medium conviction or medium practice-medium conviction or intense practice-medium conviction. For intense conviction, it may be mild practice-intense conviction or medium practise-intense conviction or intense practice-intense conviction. To achieve maximum success at faster rate intense practice with intense conviction is necessary.

For brain to undergo functional and structural changes at the level of presynaptic axon, synapse and postsynaptic dendrites, it has to modulate dendritic length, their density, their number, axonal length and their myelination, eventually leading to enhanced nerve conduction and connections causing more complex neural network. Due to this dense neuronal connection if any region of the brain gets damaged, adjacent dendrites take over the action of lost part or by dendritic sprouting and lengthening it might form new connections with healthy neurons and eventually take over the function of damaged part. For this, the practices adopted should be done for an appropriate length of time with each practice done with proper breathing and awareness which eventually leads to learning and activity dependent plasticity**.**

2.4 Evidence regarding yogic effect on neuroplasticity

Yoga is a movement-based activity synchronised with breathing. It involves interoceptive awareness and focused attention towards alignment of postures and breathing which modulates variety of neurobiological alterations in different brain regions. During the practice of yoga there is direct, simultaneous stimulation of muscles and corresponding brain regions and repetitive practice of those yoga postures causes recurrent activation of them leading to enhanced communication between them and improved functional and structural connectivity and this is experience dependent or action dependent plasticity. By increasing communication between various brain centres and through their repetitive stimulations, new anatomical pathways are built and already existing connections get strengthened resulting in promotion of interhemispheric and intrahemispheric neural networks. Thus, our aim is to recruit wide range of pre-existing neurons and these neurons act as a precursor for generation of new neuronal pathways.

One study found greater resting state functional connectivity between the caudate and a variety of brain regions in experienced yoga practitioners and meditators as compared to controls [7]. A study investigated GMV differences between yoga meditation practitioners and a matched control group found that yoga meditation practitioners exhibited greater GMV in frontal, limbic, temporal, occipital, and cerebellar regions and GMV was positively correlated with the duration of yoga practice and reported significantly fewer cognitive failures suggesting that the practice of Hatha yoga promotes neuroplastic changes [5]. One study used magnetic resonance imaging to compare age-related GM decline in yogis and controls and found that controls had reduction in GM in correlation with age while this was not same for yogis and the number of years of yoga experience was also positively correlated with GMV [28].

2.5 Probable mechanism

Yoga promotes enhanced neural oscillations through various mechanisms leading to neuroplasticity. Proposed mechanisms are as followed.

1. Neurotrophic factors

Ample of research studies have proven the role of yoga in upregulation of neurotrophins release. Neurotrophic factors are key proteins secreted to promote neural growth, their differentiation, survival and neurogenesis, playing major role in neuronal plasticity. Their synthesis and release are activity dependent. The neurotrophic factors which are thought to be important are: Brain Derived Neurotrophic Factor (BDNF), Vascular Endothelial Growth factor (VEGF), Insulin like Growth factor -1(IGF-1), Glial Cell Derived Neurotrophic Factor (GDNF), Nerve Growth Factor (NGF) and Fibroblast Growth Factor (FGF2) [18]. 8 weeks of yoga-based lifestyle intervention was found to be beneficial in elevation of markers associated with neuroplasticity like BDNF, serotonin and β-endorphins along with decrease of depression measuring scale [11]. 12-week yoga- and meditation- based lifestyle intervention (YMLI) on patients with major depressive disorder found significant increase in BDNF, Sirtuin 1, and telomerase activity levels, and decreased cortisol, and IL-6 levels along with decreased level of oxidative stress [25]. Study conducted on Sudarshan Kriya, which involves rapid cyclical breathing along with slow controlled breathing found elevated levels of BDNF, also called the "fertilizer of neuroplasticity'' [34]. BDNF is highly expressed in central nervous system, regulating activity dependent synaptic plasticity and provides neuroprotection against excitotoxicity and regulates anti-apoptotic effect [1]. It acts by promoting NMDA receptor plasticity which are glutamate receptors and also upregulates genes essential for rapid formation of dendritic connections. We can hypothesise that rapid cyclical breathing promotes neuroplasticity as rapid breathing leads to CO2 washout causing transient hypocapnia which increases Glutamate release, a major excitatory neurotransmitter of brain and reduces the threshold for neuronal excitation allowing activity dependent long-term increase in signal transmission and strengthening of synapses [9]. Signalling cascade for BDNF involves receptor tyrosine kinase (TrkB) and mTOR activation. It was found that vagal activation leads to rapid stimulation of TrkB and this vagal tone is at the core of parasympathetic activation which is improved by yogic practices. Thus, yoga has an impact on TrkB and BDNF signalling. Along with TrkB, mTOR signalling is also one of the major factors as it promotes synthesis of synaptic proteins necessary for synapse formation and maturation [25]. Regular practice of yoga is also associated with heightened circulating IGF-1 [18]. It may also increase the level of GDNF, VEGF but it is yet to be explored [18]. These neurotrophins initiate a rise of intracellular calcium which plays a key role in neurotransmitter release.

2. Neurotransmitters

Neurotransmitters are signalling molecules which hold significant role in brain development, enhancing memory, learning, attention, behaviour, motor skills. Various neurotrophins are known to regulate Dopaminergic, Serotonergic, Glutaminergic and Cholinergic system and they in turn cause expression of genes controlling BDNF and GDNF in brain [16,24]. Yoga downregulates hypothalamus-pituitary-adrenal (HPA) axis and serum cortisol and causes increase in alpha wave activity, GABA levels, serotonin, dopamine, acetylcholine and glutamate [2]. GABA is considered the main inhibitory neurotransmitter responsible for the regulation of cortical excitability and it modulates dendritic spine turnover. Dopamine, Serotonin, Acetylcholine causes neuronal migration, dendritic differentiation, arborization, increase in length and number of dendritic spines. Glutamate is considered an important excitatory neurotransmitter causing elongation of dendritic spines [13].

3. Mitochondria

Synaptogenesis also depends on metabolic requirements of mitochondria. Mitochondria are concentrated in axonal presynaptic terminals. In response to repetitive neuronal depolarisation increase in mitochondrial content or activity in dendrites was found leading to enhancement of synaptic plasticity [12]. Post-yoga practise, increase in mitochondrial membrane potential, mitochondrial copy number and expression of genes that maintain mitochondrial integrity and promote their biogenesis was found. Through enhanced mitochondrial expression yoga might increase dendritic length and brain connectivity [8].

4. CSF

Cerebrospinal fluid (CSF) acts as a medium for supplying nutrients to neuronal cells, transporter for hormones, neurotransmitters, neuropeptides and remover of waste metabolic products throughout the brain. Deep and longer breathing as a part of Pranayama practice has well-established role in CSF flow modulation. Deep inspiration causes enhanced flow of CSF towards brain while exhalation causes CSF outflow into the spinal canal. Due to its cleansing and nourishing property towards brain cells, it can reduce age related neuronal degeneration as well as influence neuroplasticity [32].

5. Diet (Mitahar)

According to Hatha yoga pradipika,

susnigdhamadhurāhāraścaturthāṃśavivarjitaḥ|

bhujyate śivasaṃprītyai mitāhāraḥ sa ucyate || hyp 1.58

Mitahar is a concept in yoga which means one should eat sweet and palatable food leaving one fourth of the stomach free. It is a habit of eating in moderation.

Studies done with calorie restriction showed prominent improvement in adult neurogenesis and showed upregulated BDNF and dendritic spine density [30]. Gut brain axis is a bidirectional communicating system working through modulation of enteric nervous system of gut and HPA axis with vagus at the centre of this communication. Yoga and aerobic exercise have potential to upregulate parasympathetic tone through vagal modulation which alters the diversity and expression of gut flora [27]. Cyclic meditation (CM)—a technique of yoga involving meditation combined with physical postures (asanas) and relaxation improves cognitive function via vagal tone modulation and alters serotonin synthesis suggesting an impact of gut microbiota on GABA-glutamate levels. We can hypothesise that by various yogic practices vagal oscillations are regulated which improves gut microbial flora which in turn causes release of neurotransmitters necessary for synaptogenesis [33].

6. Chanting

Chanting Sanskrit words and aphorisms is an integral part of yoga practice. OM chanting and Sanskrit reading was correlated with increase in alpha activity [26], theta power and reduced heart rate, respiratory rate and skin resistance suggesting increased attentional arousal and reduction in anxiety and cortical arousal [10,21]. Above findings suggest greater range of the mind activation along with relaxation and higher functional connectivity of brain during chanting. By repeated chanting one can generate specific vibrations in specific regions of brain invoking resonance which may be a probable mechanism for healing and for synaptogenesis.

7. Pranayama

Pranayama is a coherent breathing practice involving repeated breathing at a particular frequency and fixed duration of inhalation, exhalation along with breath holding. Ample of research studies have shown that yoga-based breathing practices improve performance in psychomotor task [22,23]. These improvements were seen immediately after the pranayama practice suggesting the development of STP which might prolong and develop LTP or gradually decline over a period of time. Probable mechanism may be respiration mediated neural oscillations. During inhalation, air entering into our nostrils trigger mechanoreceptors present in nose which are connected with olfactory bulb and initiates neural oscillations which are closely related with the respiratory rate. These electrical oscillations get propagated to adjacent brain areas at a frequency matched with respiratory frequency and larger area of brain starts oscillating creating high amplitude waves in entire neural network. These brain entrainment via respiratory stimulation leads to neuroplasticity. Humming involved in Bhramari pranayama produces nitric oxide (NO) which is a potent vasodilator [31] taking part in modulation of cell division and synaptic plasticity [19].

3. Conclusion

Above evidences suggest that yoga has a potential to modulate neuroplasticity through various mechanisms. As age advances, reduction in brain matter especially grey matter volume reduction is inevitable but this may be slowed down by following yogic lifestyle. Various pathological conditions like Multiple sclerosis, ALS, GBS, MND, Alzheimer's disease, Stroke, Parkinsonism can lead to brain degeneration and damage. As of now these conditions don't have any specific treatment and cannot be cured completely and even if cured, brain damage cannot be reversed. Current treatment modalities are insufficient to regenerate the lost connections. So along with conventional medicine, Yogic approach acts as a boon in these conditions and promotes healthy aging. During the practice of yoga repetitive direct stimulation of muscles and corresponding brain regions take place and they form new neuronal circuits leading to healthy brain. Yogic practices give sensory followed by motor stimulation to brain which eventually generate activity dependent plasticity. Due to any pathology if any function of part of brain is hampered then remaining part of brain has capacity to take over the function of damaged part by generating new neuronal connections if proper enriched environment is provided. Thus, by inculcating yoga-based lifestyle, rewiring is harnessed and lost motor skills either accidental or pathological may be improved or recovered. Further RCTs with good sample size are greatly warranted.

Conflict of interest

There are no financial relationships with any entities nor any have influenced the content of the submitted work.

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