A Study of Meditation Effect on The Brain and Emotional Happiness by MiRi Scan

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Abstract

The objectives of this study are as follows: 1) to measure and compare the cerebral cortical thickness (CT) at straight gyrus of the frontal lobe in three eligible groups: a) Long-term meditation practitioners, b) Short-term meditation practitioners, and c) Non-meditation practitioners; 2) to measure and compare physiological changes of neurons in the putamen (the part of basal ganglia) of all eligible groups by advanced MRI technique, called "Fractional Anisotropy (FA)"; and 3) to measure and compare the Happiness score (HS) among three eligible groups. The study was an experimental research in nature. Population of the study comprised 256 healthcare providers in Kasemrad International Hospital by randomized interview for those eligable of the study from October to December 2015. The samples of the study included 30 eligible cases divided to three groups, namely, 10 cases of Long-term meditation practitioners (LTM), 10 cases of Short-term meditation practitioners (STM), and 10 cases of Non-meditation practitioners (NM). Tools of data collection were MRI and questionnaire. Statistics used for analyzing data composted of Percentage, Mean, Standard Deviation and Pearson correlation.

Keywords: Meditation Effect on the Brain and Emotional Happiness, MRI SCAN

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Results of the Study

1. With respect to the measurement and comparison of the cerebral cortical thickness (CT) at straight gyrus of the frontal lobe in three eligible groups: a) Long-term meditation practitioners, b) Short-term meditation practitioners, and c) Non-meditation practitioners, it was found that there existed no significant changes of cerebral cortical thickness (CT) within the each group and across the three groups. While comparing the cerebral cortical thickness (CT) at straight gyrus of the frontal lobe among three eligible groups with standard value of cerebral cortical thickness there was no change with a statistical significance.

2. In respect of the measurement and comparison of physiological changes of neurons in the putamen (the part of basal ganglia) of all eligible groups by advanced MRI technique, called "Fractional Anisotropy (FA)" it revealed that there were no significant changes of fractional anisotropy (FA) within the group and across the three groups. When comparing the standard values of FA there were no statistically significant changes.

3. Regarding the measurement and comparison of the Happiness score (HS) among three eligible groups it revealed that there was a high mean happiness score (HS) in the group of Long-term meditation practitioners. While comparing the mean happiness score (HS) of Long-term meditation practitioners with Short-term meditation practitioners and Non-meditation practitioners it was found that the mean happiness score of the latter two groups statistical similar.

Background and Significance of the Problem

Many years ago, meditation was a well-known cognitive therapy incorporating enhanced mindfulness. Many researches emphasized meditation as an important process as curative & palliative therapy. They suggested that improvement of complex emotional control and attention regulation increases in meditators. Recently, the therapeutic use of meditation, including mindfulness-based techniques, has become increasingly important in the treatment of physiological and psychological conditions[4]. Furthermore, the neuroscientific evidence suggests that meditation alters the structure and function of the brain including neural

[4]D.S. Ludwig, J. Kabat-Zinn , **Mindfulness in Medicine**.. The Journal of the American Medical Association**,** 2008*,* Vol.300 No.11, Pp.1350-1352.

processes, underlying attention, and emotion[5]. One of many researches, *Goto et al*,[6] shows altered synaptic structure of the brain circuits associated with attention and emotion might be the one of the essential pathophysiological conditions underlying some major psychiatric disorders such as schizophrenia and depression. In the details of the research of *Goto*, the Prefrontal cortex (PFC) mediates an assortment of cognitive functions including working memory, behavioral flexibility, attention, and future planning.

Unlike the hippocampus, where induction of synaptic plasticity in the network is well-documented in relation to long-term memory, cognitive functions mediated by the PFC have been thought to be independent of long-lasting neuronal adaptation of the network. Nonetheless, accumulating evidence suggests that prefrontal cortical neurons possess the cellular machinery of synaptic plasticity and exhibit lasting changes of neural activity associated with various cognitive processes. Moreover, deficits in the mechanisms of synaptic plasticity induction in the PFC may be involved in the pathophysiology of psychiatric and neurological disorders such as schizophrenia, drug addiction, mood disorders, and Alzheimer's disease.

In Thailand, there are many meditation practitioners of the Thai style Theravada tradition, such as "breathing training" with Brikornrnam "pút-toh" There does not seem to be any research of brain structures using MRI of practitioners of Thai meditation by Diagnostic Radiologist (specialist doctor). This is an important and interesting issue in the field of medical evidence based experimental study in Thailand, when we compare data of international meditation research with MRI scans. However, there are many researches about meditation in Thailand but most of these are not related with medical equipment.

This study wants to utilize evidence-based medical science applied to Theravada meditation in Thailand. This will be attempted by identifying anatomical and physiological brain changes in meditation practitioners under detection and measurement by MRI scan.

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[5] J.A. Brefczynski-Lewis, A. Lutz, S. Schaefer, D.B. Levinson, R.J. Davidson, **Neural Correlates of Attentional Expertise in Long-Term Meditation Practitioners.** Madison: The Wisconsin Press, 2007, Pp.11483-11488.

[6] Y. Goto, C.R. Yang, S. Otani, **Functional and Dysfunctional Synaptic Plasticity in Prefrontal Cortex: Roles in Psychiatric Disorders.** Biological Psychiatry, 2010, Vol.67 No.3, Pp. 199-207.

Objectives of Research

1. To measure and compare the cerebral cortical thickness (CT) at straight gyrus of the frontal lobe in three eligible groups; a) Long-term meditation practitioners, b) Short-term meditation practitioners, and c) Non-meditation practitioners.

2. To measure and compare physiological changes of neurons in the putamen (the part of basal ganglia) of all eligible groups by advanced MRI technique, called "Fractional Anisotropy (FA)".

3. To measure and compare the Happiness score (HS) between groups.

Hypothesis in Research

1. Increased cerebral cortical thickness (CT) in meditation group
2. Increased value of fractional anisotropy (FA) in meditation group
3. High happiness score (HS) in a long term meditation group.

Definition of the Term used in the Research

A long-term meditation is an at least 3 years meditation experience that has a routine meditation of at least 20 minutes a day at least five days per week.

A short-term mediation is a short duration of meditation experience of less than 3 months.

A control is a case of no experience in meditation in recent 3 years.

MRI[7] is a medical machine with magnetic generation. MRI stands for Magnetic Resonance Imaging. Magnetic resonance imaging (MRI) was used in radiology to form pictures of the anatomy and the physiological processes of the body in both health and disease. MRI scanners use strong magnetic fields, radio waves, and field gradients to generate images of the inside of the body.

The cerebral cortex [8] is the outer covering of gray matter over the hemispheres. This is typically 2- 3 mm thick, covering the gyri and sulci. Certain cortical regions have somewhat simpler functions, termed the primary cortices. These include areas directly receiving

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[7] American Society of Neuroradiology. **"A CR-ASNR Practice Guideline for the Performance and Interpretation of Magnetic Resonance Imaging (MRI) of the Brain**. 2013, Boston: Pp. 26 -28

[8] Swenson Rand, Chapter 11-Cerebral Cortex. **Review of Clinical and Functional Neuroscience**. E-book, Boston: 2006.

sensory input (vision, hearing, somatic sensation) or directly involved in production of limb or eye movements. The association cortices subserve more complex functions. Regions of association cortex are adjacent to the primary cortices and include much of the rostral part of the frontal lobes also regions encompassing areas of the posterior parietal lobe, the temporal lobe and the anterior part of the occipital lobes. These areas are important in more complex cortical functions including memory, language, abstraction, creativity, judgment, emotion and attention. They are also involved in the synthesis of movements.

Cerebral cortical thickness (CT) [9] is a thickness of gray matter, typically 2-3 mm. This study measured CT at "straight gyrus" of the frontal lobes. For mammals, species with larger brains (in absolute terms, not just in relation to body size) tend to have thicker cortices. The range, however, is not very great; only a factor of 7 differentiates between the thickest and thinnest cortices. The smallest mammals, such as shrews, have a neocortical thickness of about 0.5 mm; the ones with the largest brains, such as humans and fin whales, have thicknesses of 2.3–2.8 mm. There is an approximately logarithmic relationship between brain weight and cortical thickness.

Fractional anisotropy (FA)[10] is a value of anisotropy of a diffusion process. A value of zero means that diffusion is isotropic, i.e. it is unrestricted (or equally restricted) in all directions. A value of one means that diffusion occurs only along one axis and is fully restricted along all other directions. FA is a measure often used in diffusion imaging where it is thought to reflect fiber density, axonal diameter, and myelination in white matter. The FA is an extension of the concept of eccentricity of conic sections in 3 dimensions, normalized to the unit range

Happiness is a mental or emotional state of well-being defined by positive or pleasant emotions ranging from contentment to intense joy[11]. Happy mental states may also reflect judgements by a person about their overall well-being-A variety of biological, psychological, economic, religious and philosophical approaches have striven to define happiness and identify its sources. Various research groups, including positive psychology and happiness economics are employing the scientific method to research questions about what "happiness" is, and how it might be attained.

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[9] R. Nieuwenhuys, H.J. Donkelaar, C. Nicholson, **The Central Nervous System of Vertebrates,** Volume 1, New York: Rockefeller University Press, Pp. 2011–2012.

[10] P.J. Basser & C. Pierpaoli, Microstructural and Physiological Features of Tissues Elucidated by Quantitative-Diffusion-Tensor MRI. Journal of Magnetic Resonance, 1996, Boston: Pp. 209-219.

[11] Darrin M. McMahon, "From the Happiness of Virtue to the Virtue of Happiness", Daedalus, 2004, California: Pp. 5–17.

Meditation[12] is a practice where an individual trains the mind or induces a mode of consciousness, either to realize some benefit or for the mind to simply acknowledge its content without becoming identified with that content, or as an end in itself. The term *meditation* refers to a broad variety of practices that includes techniques designed to promote relaxation, build internal energy or life force (*qi*, *ki*, *prana*, etc.) and develop compassion, love, patience, generosity, and forgiveness. A particularly ambitious form of meditation aims at effortlessly sustained single-pointed concentration meant to enable its practitioner to enjoy an indestructible sense of well-being while engaging in any life activity.

Expected Benefits (Outcomes)

1. To explored scientific evidence of MRI study in the human brain with meditation
2. To know relationship between anatomical brain changes and meditation
3. To know relationship between emotional happiness and meditation.

Research Methodology

The discourse of this study is about social experimental design and scientific measurement to evaluate the result of meditation of three groups of population by the method of cross sectional study. Statistical analysis of variables with Pearson correlation was performed for study effect of meditation on the brain and emotional happiness. The population of this study is healthcare providers: 256 persons, in the Kasemrad International Hospital. The research was done from June 1, 2014 to Jan 31, 2015. There is a wide range of age: 24 to 64 years.

Population and Samples

We selected 30 persons from 256 persons to interview about their history of meditation. Samples are divided to three groups as follows: 1) Ten cases of Long-term meditation practitioners, 2) Ten cases of Short-term meditation practitioners, and 3) Ten cases of Non-meditation practitioners.

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[12]Daniel Goleman , The Meditative Mind: The Varieties of Meditative Experience. 2008, New York: Tarcher, Pp 86-88

We employed cortical thickness (CT) analysis and fractional anisotropy (FA) based on advanced MRI technique to quantify white matter integrity and structural change in the brains. All cases of our study would receive psychological questionnaires of happiness score (HS) assessment.

Research Tools

All data were acquired using a 1.5-Tesla Essenza MRI scanner (Siemens, Erlangen, Germany). T1-weighted structural images covering the whole brain using a 3D magnetization-prepared rapid gradient echo sequence were acquired with the following parameters: TR/TE=1160/4.76ms, field of view=23cm, flip angle=15egrees, voxel size=0.45x0.45x0.90mm^3, slice thickness=0.9mm. Diffusion-weighted images (DWIs) were acquired with diffusion gradients (b-factor 1000s/mm^2) along 12 non-collinear directions. Ten images were acquired with no diffusion gradient (B0 images) to increase the signal-to-noise ratio. Other parameters were as follows: TR/TE=9200/83ms, 75 slices, field of view=256mm, voxel size=2x2x2mm^3. All scans were judged by a diagnostic radiologist (T.W.) to be visually excellent without obvious artifacts, signal loss or gross pathology.

Scope of Contents

To study for the changes of cerebral cortical thickness (CT), Fractional anisotrpy (FA), and Happiness score (HS).

Data collection and Steps of Research

A total of 30 cases (10 long-term meditators, 10 short-term meditation practitioners and 10 controls) with Age-Sex matching participated in the study. The mean duration of long term meditators was calculated and noted. Control subjects had no previous experience with meditation or similar practices. The non-patient version of the Structured Clinical Interview for DSM-IV was used to assess psychiatric disorders in all participants. All subjects were right-handed (Annett, 1970). Exclusion criteria included a life-time history of psychosis, bipolar disorder, major depressive disorder, substance abuse or dependence, significant head injury, seizure disorder or mental retardation. The present study was approved by the Research Institutional Review Board of Bangkok Chain Hospital (BCH) and informed consent was obtained from all subjects following the explanation of the procedures. The questionnaires for assessment of happiness score was used in all participants after MRI scan. (See diagram 1)

Statistics and Data analysis

The statistical analysis was corrected for multiple comparisons using a Pearson correlation (2-tails). The correlation coefficient (r) was calculated between factors of 1) mediation duration, 2) cortical thickness (CT), 3) fractional anisotroy (FA) and 4) happiness score (HS). (See diagram 2)

Diagram 1: Steps in research and data collection

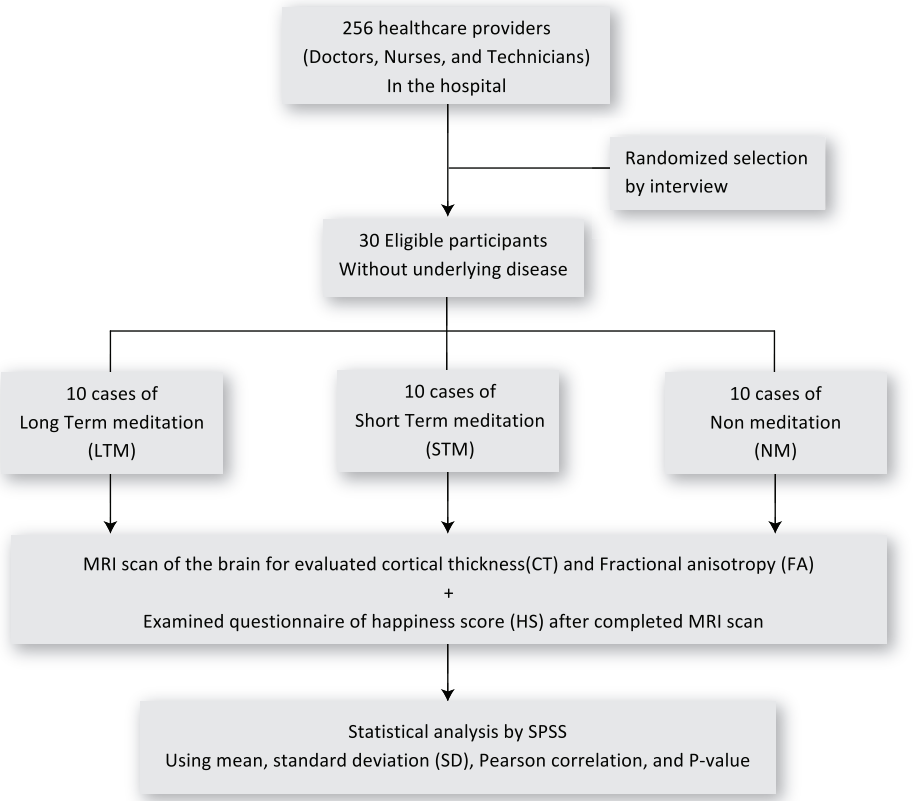
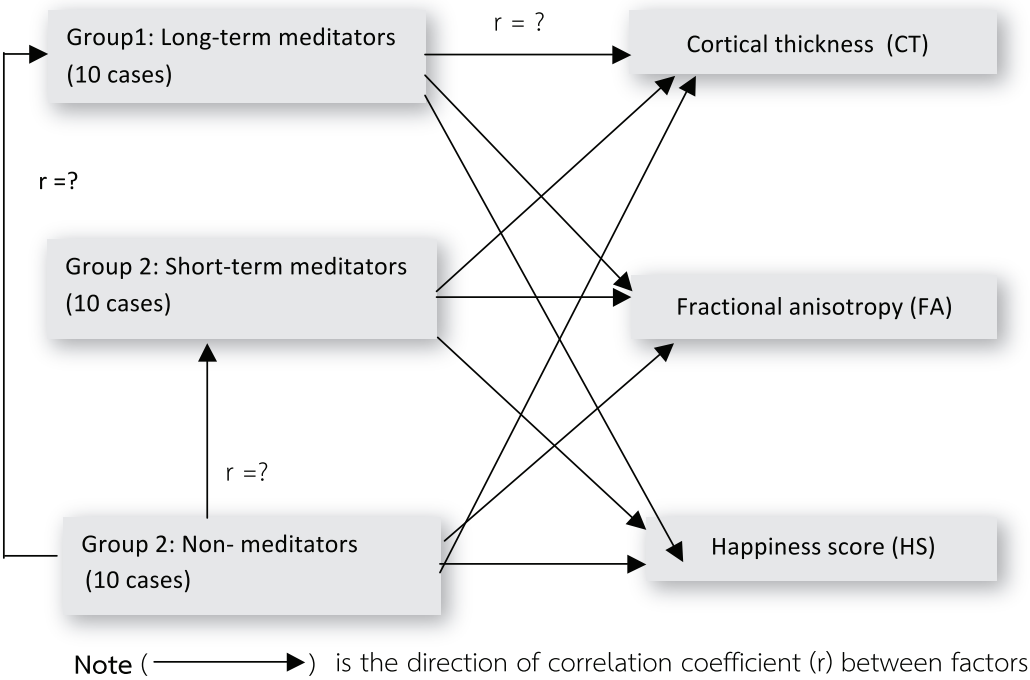


Diagram 2: Statistical correlation between three eligible meditation groups and three dependent variables (CT, FA, and HS)



Results

Thirty participants were eligible in the study. There are divide to three groups as 1) Long term meditation (LTM), average 4.4 years for duration of mediation, 2) Short term meditation (STM), average 1.6 months for duration of meditation and 3) Non meditation (NM). The mean age of LTM group = 31 years, STM group = 34 years, and NM group = 33.3 years. Twenty-two cases had graduated Bachelor degree. The mean duration of meditation in LTM group = 4.4 years, and STM group = 1.8 months.

Measurement of Cortical Thickness (CT) and Fractional Anisotropy (FA)

The measurement of cerebral cortex, this study selected on the axial T1W view at skull base, used direct measurement at mid part of lateral cortex of the straight gyrus under work station of PACS. The reason for using lateral cortex of the straight gyrus was due to: 1) The medial cortex usually has wavy contour in contrast to lateral cortex which is straight and smooth contour, 2) The straight gyrus is easily identified on MRI scan without confusion rather than other temporal gyri and frontal gyri.

The measurement of Fractional anisotropy, the study used FA map with b = 1000, TR 3300, TE 107, axial view of whole brain, and also select at basal ganglia level. The hand-free regional of interest (ROI) was put on the right & left putamen. The measurement value in each side was recorded.

The MRI's image & measurement of CT and FA of LTM case, STM case and NM case are shown in Figure 1 (a,b), Figure 2(a,b) and Figure 13(a,b).

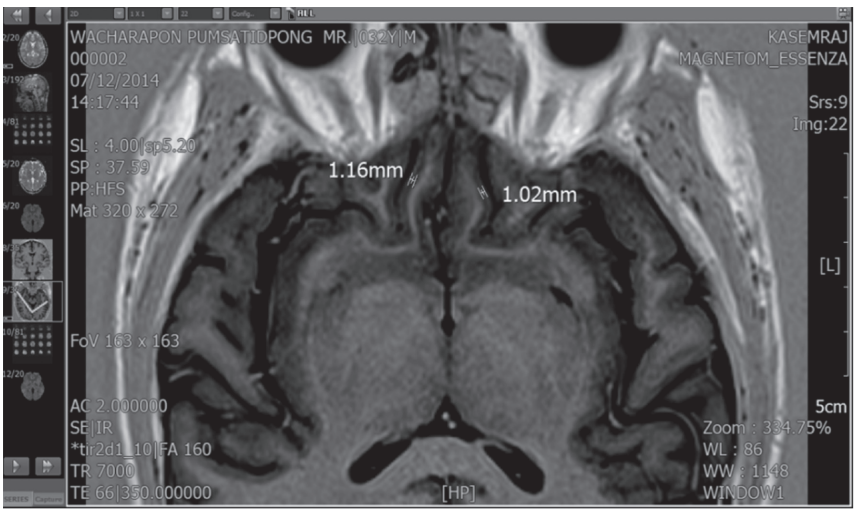


Figure 1a: Measurement of cortical thickness (CT) in the case of LTM, using axial 3D T1W technique. The direct measurement (in millimeters) was performed perpendicular to the white matter at mid part of the right straight gyrus (1.16mm) and left straight gyrus (1.02mm), under workstation. The average value measurement (1.09mm) was recorded.

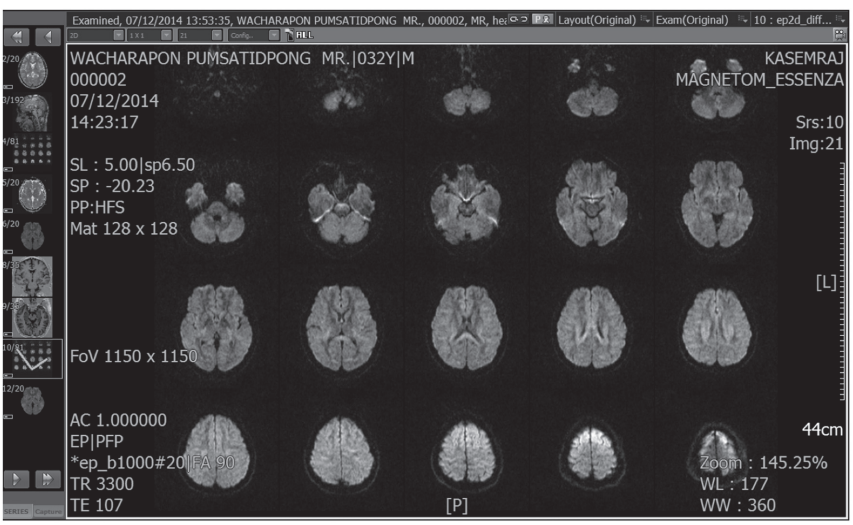


Figure 1b: Fractional anisotropy (FA) map in the case of LTM, using b = 1000, TR 3300, TE 107, the FA value of the right putamen = 0.24, the FA value of the left putamen = 0.20

Figure 2a: Measurement of cortical thickness (CT) in the case of STM, using axial 3D T1W technique. The direct measurement (in millimeters) was performed perpendicular to the white matter at mid part of the right straight gyrus (1.31mm) and left straight gyrus (1.32mm), under workstation. The average value measurement (1.31mm) was recorded.

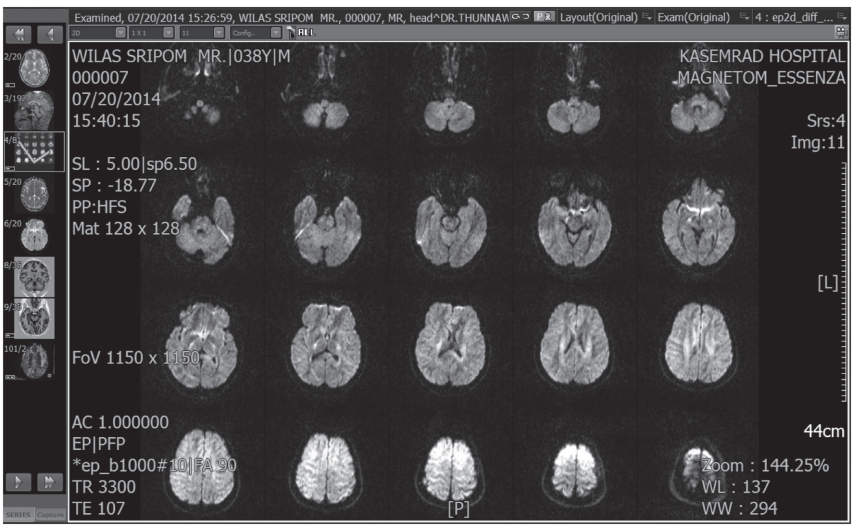


Figure 2b: Fractional anisotropy (FA) map in the case of STM, using b = 1000, TR 3300, TE 107, the FA value of the right putamen = 0.21, the FA value of the left putamen = 0.26

Figure 3a: Measurement of cortical thickness (CT) in the case of NM, using axial 3D T1W technique. The direct measurement (in millimeters) was performed perpendicular to the white matter at mid part of the right straight gyrus (1.16mm) and left straight gyrus (1.00mm), under workstation. The average value measurement (1.08mm) was recorded.

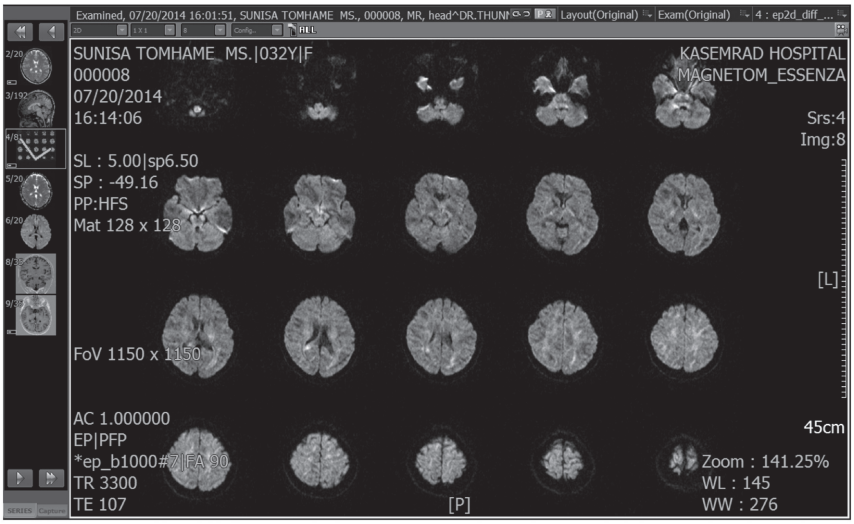


Figure 3b Fractional anisotropy (FA) map in the case of NM, using b = 1000, TR 3300, TE 107, the FA value of the right putamen = 0.24, the FA value of the left putamen = 0.24

The means of value's measurement of cortical thickness (CT), fractional anisotropy (FA) of the right putamen (FAR) and the left putamen (FAL) are summarized on Table 1, below

Table 1: Summarization of the means of CT, FAR, and FAL in each group.

	Mean CT	Mean FAR	Mean FAL
Long Term Meditation (LTM)	1.205 mm	0.2418	0.2268
Short Term Meditation (STM)	1.143 mm	0.2417	0.2266
Non-Meditation (NM)	1.221 mm	0.2413	0.2264
Total 30 cases	1.1897 mm	0.2426	0.2266

From this table, there is no significant difference of the mean value of CT and FA between LTM, STM and NM groups. No difference in neuronal density and white matter arrangement, which reflects from FA, of the right and left putamen are seen between groups.

The standard reference value of the cerebral cortical thickness (CT)[13]is about 2mm in overall average. Various values of cerebral cortical thickness depend on age, region of the brain, race, underlying disease, etc. However, Cortical thickness values reported in the literature mostly range from a mean thickness over the whole brain of around 2.5 mm up to 3 mm.[14] The cortical thickness of straight gyrus is thinner than the average value of whole brain.

For the standard reference of Fractional Ansiotropy (FA), the study of Cheng Luo and colleague[15] shows normal range of FA in putamen of the control group about 0.21 to 0.31. For this study, the mean FA of right and left putamen in LTM group is 0.2418 and 0.2268, respectively. The mean FA of right and left putamen in STM group is 0.2417 and 0.2266, respectively. The mean FA of right and left putamen in NM group is 0.2413 and 0.2264,

[13]Chloe Hutton, V**oxel based cortical measurements in MRI.** Neuroimage. Bethesda MD: 2008, Vol. 40, Pp 1701–1710.

[14]J.P. Lerch, A.C. Evans, **Cortical thickness analysis examined through power analysis and a population simulation.** Neuroimage. Bethesda MD: 2005, Vol. 24, Pp 163–173.

[15]Cheng Luo, et al., **Diffusion and volumetry abnormalities in subcortical nuclei of patients with absence seizures.** Epilepsia, 2011, Vol 52, Pp 1092-1099.

respectively. The overall mean FA of total thirty cases at the right putamen is 0.2416, and also the left putamen is 0.2266.

Measurement of Happiness Score (HS)

All cases of three groups were had to examine happiness score by answers of questionnaires, after received MRI scan. The mean of HS of LTM group = 5.188, STM group = 3.630, NM group = 3.480.

The meaning of mean happiness score = 5.188 is "**Very happy".** Being happy has more benefits than just feeling good. It's correlated with benefits like health, better marriages, and attaining goals.

The meaning of mean score = 3.630 and 3.480 is "**Not particularly happy or unhappy".** This score would be an exact numerical average of happy and unhappy responses. Some of the exercises mentioned just above have been tested in scientific studies and have been shown to make people happier longer.[16]

Conclusion

After collecting data, MRI scans, examining questionnaires and statistical analysis, the conclusion of the study with respect to the three objectives of research and hypothesis of research was summarized as follows;

(1) With respect to the measurement and comparison of the cerebral cortical thickness (CT) at straight gyrus of the frontal lobe in three eligible groups: a) Long-term meditation practitioners, b) Short-term meditation practitioners, and c) Non-meditation practitioners it found that there existed no any significant changes of cerebral cortical thickness (CT) within the group and among three groups, while comparing the cerebral cortical thickness (CT) at straight gyrus of the frontal lobe among three eligible groups with standard value of cerebral cortical thickness there were no changes with a statistical significance.

[16]P. Hills and M. Argyle, **The Oxford Happiness Questionnaire**: **a compact scale for the measurement of psychological well-being**. Personality and Individual Differences, Oxford: 2002, Vol.33, Pp.1073–1082.

(2) In respect of the measurement and comparison of physiological changes of neurons in the putamen (the part of basal ganglia) of all eligible groups by advanced MRI technique, called "Fractional Anisotropy (FA)" it revealed that there were no any significant changes of fractional anisotropy (FA) within the group and among three groups, when comparing with standard value of FA there were no statistically significant changes.

(3) Regarding the measurement and comparison of the Happiness score (HS) among three eligible groups it revealed that there was a high mean happiness score (HS) in the group of Long-term meditation practitioners. While comparing the mean happiness score (HS) of Long-term meditation practitioners with Short-term meditation practitioners and Non-meditation practitioners it was found that the mean happiness score of the latter two groups were not significantly different.

Discussion

Unless this study shows no significant change of cerebral cortical thickness (CT) and Fractional anisotropy (FA) of LTM, STM and NM group, at point of time (cross-sectional study), the study give a new body of knowledge as follow;

1) Long-term meditation effects emotional happiness significantly.

2) Meditation in the study does not improve cerebral cortical thickness, that means no effect on the natural progression of senile aging or degeneration of the human brain, corresponding with "The three marks of existence" (Trilaksana – Anicca, Dukka, Anatta), and the research of Sergio Elías Hernández [17] , which shows increased Gray Matter (neuronal density) in the Long-Term Sahaja Yoga Meditation, using by a Voxel-Based Morphometry MRI Study. This study is one of several researches which discloses the differentiation between neural density and volumetric thickness of cerebral cortex. The results of the study show the direct effect of meditation to neurons (increased neural density and neuroplasticity). Some cases of the study showed no change of the cortical thickness (CT), but all cases of Long-term Meditation have an abundance of neuronal density of gray matter.

[17] Sergio Elías Hernández, and et al, **Increased Grey Matter Associated with Long-Term Sahaja Yoga Meditation: A Voxel-Based Morphometry Study.** Plos Journal, 2016, Plos organization, E-book. (Search on Apr 1, 2016)

Suggestions for research methodology

1) Prospective longitudinal studies may give more information between three mediation groups.

2) Increased number of case studies may be helpful to the study.

3) Choosing more regional cerebral areas for measurement in further studies may give more information and more extended discussion.

Suggestions for meditation practitioner and beginner

1) Long-term meditation with regular self-training of at least 20 minutes per day for an average 4.4 years seems to improve emotional happiness.

Suggestion for proposed policy

1) The government, public organizations, or private organizations should promote meditation of at least 15 to 20 minutes per day as a daily routine for all age groups, especially adult or working person, for the benefit of happiness and decreased stress in the workplace, home, and social relationships.

2) Schools, colleges, and university should have the activity of meditation and emphasize the important relationship between meditation and happiness.

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