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Effect of SudarshanaKriya Yoga-Meditation on Spatial-Temporal EEG Parameters

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Abstract

There is growing interest in the integration of meditation into higher education. Our work tries to review the evidence related to the use of meditation to facilitate the achievement of traditional educational goals, to help support student mental health under academic stress, and to enhance education of the "whole person." We try to determine how different types of Meditation Techniques affect the Brain Electrical Activity of a Human Being. An effort was made to analyze the cerebral electrical activity of twenty experienced SudarshanaKriya Yoga- (meditation) practitioners by means of EEG recordings. The EEG data was recorded before and after SudarshanaKriya Yoga, which is considered to be an antidote to stress. A statistical analysis was done on the data collected to analyze the changes in alpha and beta rhythms. The analysis of EEG data after the SudarshanaKriya yoga practice showed a high increase in the Alpha band amplitude and accompanied by decrease in beta band amplitude. The Experimental results clearly shows a higher level of mental and lower level of physical consciousness experienced in SudarshnaKriya Yoga.

Keywords: EEG, Alpha band, Beta band, Sudarshana Kriya, Topographic -plot.

1. Introduction

Meditation is any form of a family of practices in which practitioners train their minds or self-induce a mode of consciousness to realize some benefit. Meditation is generally an inwardly oriented, personal practice, which individuals can do by themselves. Prayer beads or other ritual objects may be used during meditation. Meditation may involve invoking or cultivating a feeling or internal state, such as compassion, or attending to a specific focal point. The term can refer to the state itself, as well as to practices or techniques employed to cultivate the state. There are dozens of specific styles of meditation practice like Zen Meditation, Transcendental Meditation, has been practiced since antiquity as a component of numerous religious traditions.

1.1. SudarshanaKriya-(meditation)
The SudarshanaKriya is a powerful rhythmic breathing technique that facilitates physical, mental, emotional and social well-being. It is an integral part of the Art of Living programs. It is today

universally acclaimed for its effectiveness in eliminating stress, and bringing one completely into the present moment. As His Highness Sri Sri Ravi Shankar Guruji puts it, SudarshanKriya bridges the gap between the worlds of inner silence, and outer expression of life.

'Su' means proper, 'darshan' means vision, and 'Kriya' is a purifying practice. Therefore, SudarshanaKriya is a purifying practice, whereby one receives a proper vision of one's true self. This unique breathing practice is a potent energizer. Every cell becomes fully oxygenated, and flooded with new life, bringing a sense of joy in the moment. And when we feel good about ourselves, love flows naturally in all our relationships with others.

In this paper the work has been done to find the effects of sudarshanakriya yoga on alpha and beta parameters of the EEG signal. Statistical parameters of interest are calculated using MATLAB Toolbox. Topo plots are plotted using the EEGLAB open source software.

2. Materials and Methods

2.1. Subject and information about the data

Twenty healthy experienced SudarshanaKriya Yoga practitioners, of age between 25 to 40 years participated in this research study assubjects.The subjects had no history of neurological or psychiatric disorders and none of them were on any medication. The experiment paradigm was explained fully and written consent was obtained from each of the participants.

2.2. EEG Recordings

EEG data was recorded from 8 electrode positions on the scalp (FP1, FP2, F3, F4, P3, P4, O1 O2,) according to the International 10-20 system of electrode placement, referenced to the linked ear lobe electrodes.

Figure 1: 10-20 Electrode Placements
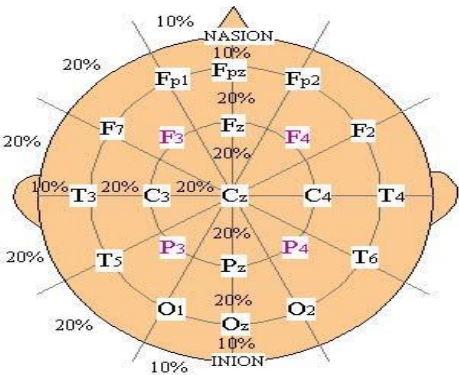
2.3. Experimental Paradigm

The Protocol was designed to perform the Trend Analysis, Group Analysis, Short term analysis, and Long term analysis and to plot Topographical Plots of the data acquired from the Subjects [2].

2.3.1 Trend Analysis

For Trend Analysis, a total of 10 subjects were considered. The data was taken for 6 consecutive days. The statistical parameters considered are Mean and Standard Deviation. The percentage change in the alpha and beta before and after meditation was calculated and compared for the same subject for all the days.

2.3.2 Group Analysis

For Group Analysis, a total of 10 subjects were considered. The data was taken for 6 consecutive days. Co-relation coefficient is calculated and compared across the subjects

2.3.3 Short Term Analysis
Subjects who have been practicing meditation for less than 3 years were considered as short term subjects. And experiment is carried out on 5 subjects for six days and Mean and Standard Deviation are computed for the comparison.

2.3.4 Long Term Analysis
Subjects who have been practicing meditation for more than 3 years were considered as long term subjects. Experiment is carried out on 5 subjects for six days and Mean and Standard Deviation are computed for the comparison.

2.3.5 Topographical Plots
EEGLAB toolbox was used to plot the Topographical plots. 10 subjects were considered and Topographical plots were plotted for the data acquired.

2.4 Data Acquisition
The EEG data was acquired using AD Instruments Power Lab equipment and Lab Chart software. System specificationswith 8channels with 16 bit Resolution, and with the filters set in Low-pass filtering: Fourth-order Bessel filter, ± 3% accuracy. EEG Notch filter: Second-order filter, −32 dB attenuation; 50 or 60 Hz frequency (automatic sensing)and a sampling frequency of 200 Hz.

The EEG data of the subjects was acquired for 6 consecutive days. Initially, the subjects were asked to be in the normal state for 2 – 3 minutes and the EEG data was acquired. This data was considered as before meditation data. Later, the subjects were instructed to perform SudarshanKriya and simultaneously the data was acquired for 8 – 10 minutes. This was considered as after meditation data. The mean and standard deviation of the alpha and beta waves was determined. The percentage increase or decrease in the mean and standard deviation of both alpha and beta waves before and after meditation was calculated. A conclusion was met on the basis of the results obtained. A graphical plotting of the mean and standard deviation before and after meditation was also performed. A conclusion was met based on the results obtained. The conclusion was whether there is a positive trend or a negative trend, that is whether there is an improvement in the data obtained or not. An improvement was considered as positive where as it was considered negative if there was no improvement.

Figure 2: AD Instruments Power Lab
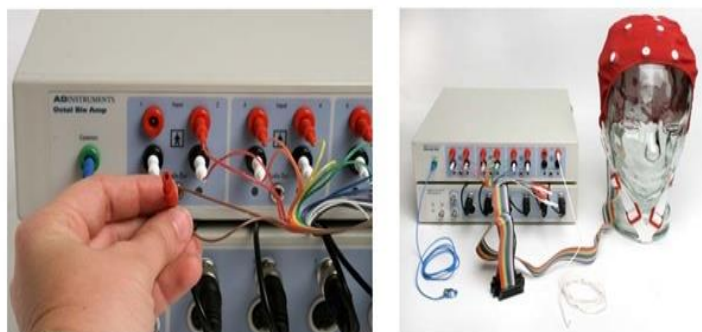
Figure 3: Sample EEG data captured by using AD Instruments Lab Chart
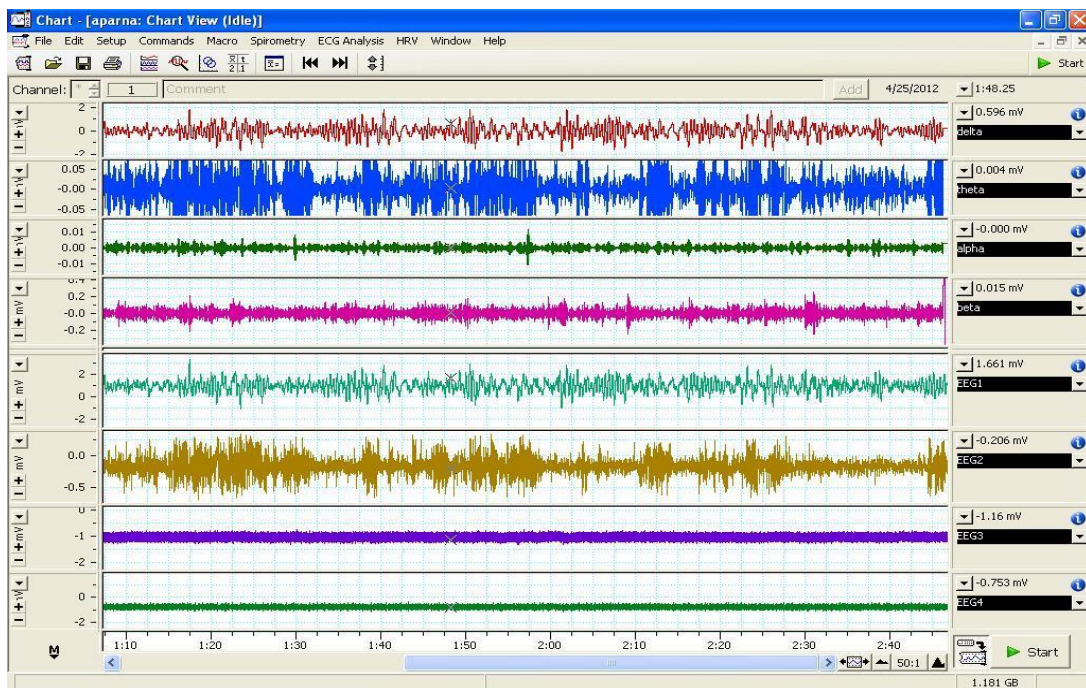
3. Results obtained

3.1. Alpha – Beta Analysis

After acquiring the data from 10 subjects for 6 consecutive days, a detailed Alpha – Beta band of frequency analysis was performed. The statistical parameters mean and standard deviation were calculated for each data set. The percentage increase/decrease in mean and standard deviation after meditation when compared to that of before meditation were calculated. A graphical plotting of the mean and standard deviation before and after meditation was also done.

The results of Alpha – Beta analysis is shown in the tables below [3-4].

	Before Kriya		After Kriya		Variation
	Mean (10^-5) V	S.D	Mean (10^-5) V	S.D	
Subject 1	2.3562	0.0021	3.2136	0.0120	26 %
Subject 2	5.1950	1.0515	10.293	0.1591	50 %
Subject 3	2.2234	0.0042	2.8448	0.0028	21 %
Subject 4	0.3606	0.0051	1.4343	0.0029	74 %
Subject 5	4.4376	0.0650	10.428	0.0025	58 %
Subject 6	5.0145	0.2486	3.9695	0.1991	-28 %
Subject 7	1.3446	0.0035	2.8508	0.0361	53 %
Subject 8	2.6034	0.0543	6.2967	0.0120	58 %
Subject 9	0.7921	0.0019	0.7286	0.0021	-9 %
Subject 10	0.4830	0.0024	2.8535	0.0038	84 %

Table 1: Analysis on Alpha Day 1

|	Before Kriya		After Kriya		Variation
	Mean (10^-5) V	S.D	Mean (10^-5) V	S.D	
Subject 1	23.5	0.0021	18.5	0.2420	- 27 %
Subject 2	5.3	0.0093	3.6	0.2534	- 47 %
Subject 3	22.2	0.0042	9.6	0.0796	- 131 %
Subject 4	3.6	0.0051	0.6	0.1091	- 500 %
Subject 5	44.3	0.0655	14.5	0.0759	- 205 %
Subject 6	5.1	0.0086	15.2	0.0515	66 %
Subject 7	13.4	0.0035	12.1	0.2393	- 11 %
Subject 8	26.3	0.0543	6.3	0.2752	- 317 %
Subject 9	7.0	0.0019	1.35	0.2537	- 418 %
Subject 10	14.3	0.0024	2.3	0.1108	-521 %

Table 2: beta Day 1   Analysis on

From the table 1 and 2 observed that after SudarshanaKriya Yoga increase in the Alpha mean values and decrease in the Beta mean Values. The values obtained over the next five days exhibited the same trend.

4. Analysis: Statistical Calculation of EEG phases

A bar graph was used to plot the mean and standard deviation of alpha and beta waves of the data acquired before and after meditation. The bar graph for the mean variations of alpha and beta waves for the data acquired on day 1 for ten subjects is shown below.

Figure 4: Bar Graph for the Mean of Alpha wave
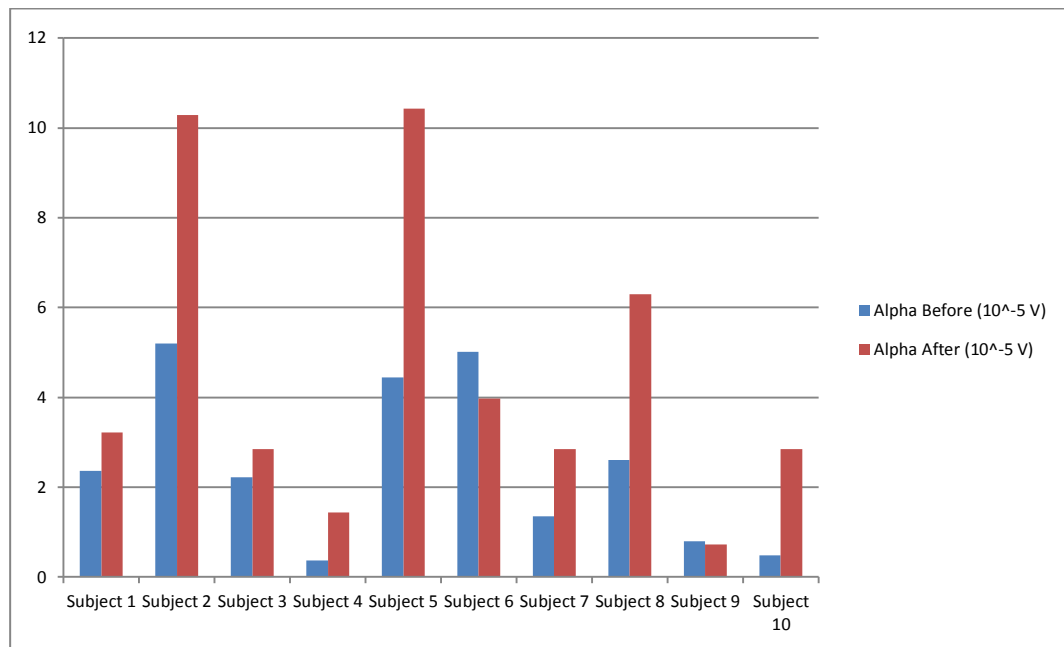
Figure 5: Graph for the Mean of Beta wave
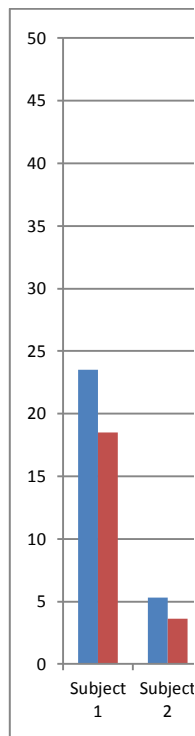
	% Increase in mean			Day to Day Variation	
	Day 1	Day 2	Day 3	1 - 2	2 - 3
Subject 1	640	74	60	Negative	Negative
Subject 2	80	100	125	Positive	Positive
Subject 3	73	32	400	Negative	Positive
Subject 4	11	266	300	Positive	Positive
Subject 5	35	117	211	Positive	Positive
Subject 6	13	-37	96	Negative	Positive
Subject 7	7	17	57	Positive	Positive
Subject 8	18	175	811	Positive	Positive
Subject 9	100	126	25	Positive	Negative
Subject 10	13	37	209	Positive	Positive

3.3 Trend Analysis

The data of the first day was compared with the data of the next 2 days. This type of analysis was performed by considering every subject individually. For example: The percentage increase/ decrease in the mean of alpha and beta waves of subject 1 on day 1 was compared with the percentage increase/decrease in the mean of the alpha and beta waves of the same subject for the next 2 days. The table below shows the Trend analysis of all the 10 subjects

Table 3: Variations of Alpha mean for short term practitioners

Table 4: Variations of Alpha mean for long term practitioners

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Subject 1	1	5.9^{-7}	1.3^{-7}	1.0^{-7}	5.5^{-7}
Subject 2	5.9^{-7}	1	1.6^{-6}	1.2^{-6}	6.8^{-6}
Subject 3	1.3^{-7}	1.6^{-6}	1	2.8^{-7}	1.5^{-6}
Subject 4	1.0^{-7}	1.2^{-6}	2.8^{-7}	1	1.1^{-6}
Subject 5	5.5^{-7}	6.8^{-6}	1.5^{-6}	1.1^{-6}	1

The results of the trend Analysis shows for few subjects it is increasing and for few subjects it is decreasing in the mean of the alpha values compared on the day wise. Trend analysis results help to find effect of the sudarshana yoga retentivity.

3.4 Group Analysis

Similarly, a co-relation coefficient is calculated for all the subjects for six days and it is found that correlation is more with long term practitioners compared to short term practitioners compared across the subjects.

A total of 10 subjects were considered. Among them, 5 subjects were considered as short term subjects and 5 subjects were considered as long term subjects. The EEG data of all the 10 subjects was acquired for 6 consecutive days. This was done by using finding the correlation coefficient between the 2 sets of alpha and beta waves. The tables below shows the Group analysis for Short term subjects on Day 1

Table 5: Correlation coefficient of the means of the Alpha activity between the subjects.

	% Increase in mean			Day to Day Variation	
	Day 1	Day 2	Day 3	1 - 2	2 - 3
Subject 1	100	25	50	Negative	Positive
Subject 2	646	50	78	Negative	Positive
Subject 3	40	67	266	Positive	Positive
Subject 4	175	500	57	Positive	Negative
Subject 5	50	200	160	Positive	Negative
Subject 6	162	- 50	110	Negative	Positive
Subject 7	120	10	13	Negative	Positive
Subject 8	131	275	386	Positive	Positive
Subject 9	492	480	7	Negative	Negative
Subject 10	308	425	45	Positive	Negative

Table 6: coefficient of the Beta between the Correlation the means of activity subjects.

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Subject 1	1	0.0907	0.0811	0.1627	0.0587
Subject 2	0.0907	1	0.0828	0.1660	0.0599
Subject 3	0.0811	0.0828	1	0.1485	0.0536
Subject 4	0.1627	0.1660	0.1485	1	0.1075
Subject 5	0.0587	0.0599	0.0536	0.1075	1

The table below shows the Group analysis for Long term subjects on day 1

Table 7: Correlation coefficient of the means of the Alpha activity between the subjects.

Table 8: Correlation coefficient of the means of the Alpha activity between the subjects
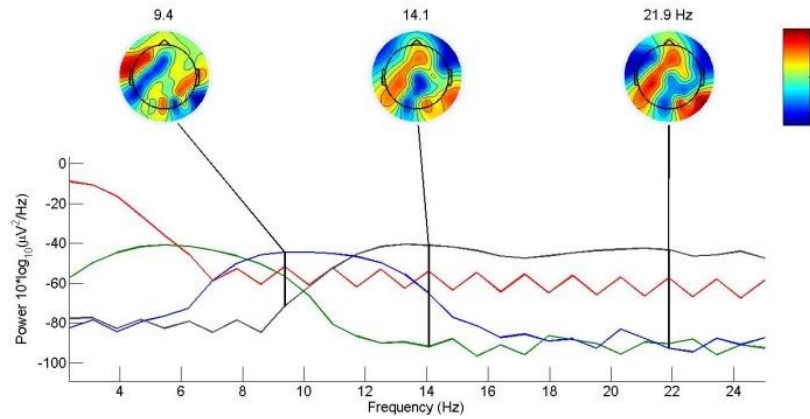
3.5 Topographical Plots

A

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Subject 1	1	3.2^{-6}	1.5^{-6}	4.0^{-5}	4.1^{-4}
Subject 2	3.2^{-6}	1	8.5^{-7}	2.1^{-4}	5.9^{-7}
Subject 3	1.5^{-6}	$8.5*10^{-7}$	1	1.0^{-4}	2.9^{-7}
Subject 4	$4.0*10^{-4}$	2.1^{-4}	1.0^{-4}	1	7.4^{-5}
Subject 5	4.1^{-6}	5.9^{-7}	2.9^{-7}	7.4^{-6}	1

topographical plotting of the acquired EEG raw data was performed in order to compare the changes that happen in the brain after performing meditation with respect to that of before meditation.
The topographical plotting was done with the help of EEGLAB Toolbox of the MATLAB software.
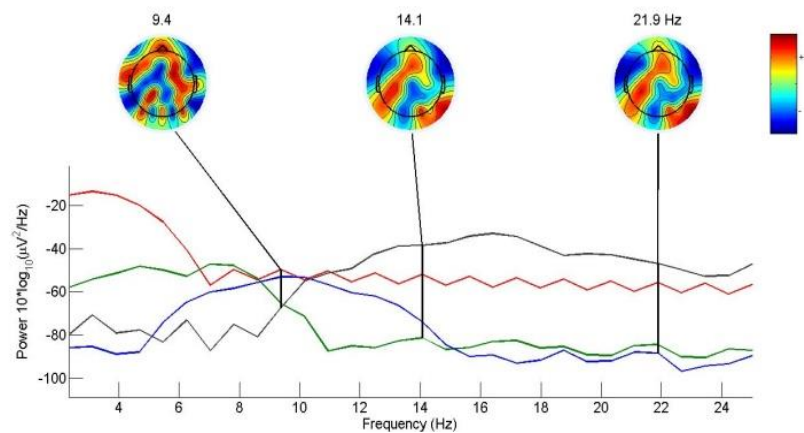
Figure 6:

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Subject 1	1	0.0214	0.508	0.038	0.0135
Subject 2	0.0214	1	0.0507	0.0238	0.0133
Subject 3	0.508	0.0507	1	0.0565	0.0317
Subject 4	0.038	0.0238	0.0565	1	0.0149
Subject 5	0.0135	0.0133	0.0317	0.0149	1

Topographical Plot of a short term subject before meditation

Figure 7: Topographical Plot of a short term subject after meditation

From the above plots it is observed that the distribution of Alpha waves is found to be more prominent in frontal and occipital lobes in the range of 8 − 12 Hz after meditation. Similarly, experimental results show that extent of distribution of alpha wave band is found to be more in long term practitioners compared to short term practitioners.

The present work has the automated detection of seizure from EEG and hence spectral analysis of detected seizure part of the signal as the two main components. The four channels right frontal (RF), right temporal (RT), left frontal (LF) and left temporal (LT) EEG time series signals are transformed to the frequency domain and from the above said method of automated seizure detection technique, we are able to detect the seizure and seizure duration. The automated detection based on ADR yielded reliable measure of seizure duration. By mapping this ADR to the EEG time series pre seizure, mid seizure and post seizure epochs of duration 6 seconds each are identified. These epochs of EEG phases are used for further analysis. The isolated three epochs in seizure condition are named as E, M and P as postfix for channel names. In the case of patient with no seizure any epoch of 6 seconds is selected from the recording. These epochs are chosen for the analysis for the comparison between normal (no seizure) EEG signal and seizure EEG signal. The discussions on the results are provided below.

In the first part of the work, the four channels RF, RT, LF and LT EEG time series signals are considered for this work. These signals are transformed to the frequency domain using Fourier transform and the power in the three bands delta (δ), alpha (α) and beta (β) are computed and the ADR is calculated. The seizure is identified by considering the peak ADR value the time duration of maximum of 10 seconds, 10 percent of ADR value and the 3 dB elevation in α and δ as threshold

values. This algorithm has been tested on EEG's of 100 segments (single channel) [4] and it has been found that the results of seizure detection coincide with the results provided by the author of the database. This algorithm is further applied on the selected data from Children's Hospital Boston database [3] for 32 non seizure EEG segments and 32 seizure segments, each of one hour duration. The present algorithm identifies all non seizure correctly and of 32 seizure segments, the algorithm is able to identify only 24 segments as seizure segments. The algorithm fails to identify 8 of the seizure segments either due to the dc drift or noise. Also in some seizure segments in children, the 3dB elevation in δ and α is not there and hence the algorithm does not detect the presence of seizure in the segment. The duration of seizure detected by this method is compared with the gold standard given in the database and the results of such few comparisons are shown in Figure 6. In the Figure, the EEG signal is not shown but only the durations of seizure are shown in red colour and those shown in blue are non seizure conditions the durations of seizure specified in the database are marked in red colour in the graph shown as A's and those identified by the proposed algorithm are shown in graphs marked as B's. This graph clearly shows that the algorithm detects correctly the presence of seizure and also the duration of seizure.

4 Discussions and Conclusion

The aim of this pilot study was to develop a protocol that can investigate whether Sudarshana Kriya Yogacan is of interest in connection with increased wellness in adult participants. As variables for wellness, a number of parameters were tested, such as degree of depression, anxiety, optimism, stress and energy.

The results suggested that the current protocol can be adopted for a full-scale trial and that the aspects of wellness measured in our study increased in the yoga group. The participants in the SK&P program had decreased level of depression and anxiety as well as increased degree of experienced optimism. There was also a decrease of stress experience in the Sudarshana KriyaYoga group compared with the control group. Furthermore, it induced an altered state of consciousness (ASC) during the practice and even after a long time [5-6].

The yoga group which is practicing it since two years showed decreased degree of depression compared to the group of short term practitioners. Studies shows that those with clinical depression can benefit from it. The current study, where only apparently healthy people without clinical depression were included, suggests that it does not only have utility as a possible therapeutic strategy for patients, but also may be a method for healthy people who would like to increase their wellness.

The strong decrease in the experienced anxiety that the Sudarshana Kriya Yoga practitioners exhibited is interesting. There was no clinical anxiety diagnosis in the participants, but the yoga group had higher degree of anxiety before the commencement of the yoga practice.

Heightened optimism is another important aspect of the wellness experience. There was an increase in the degree of optimism in the long term practitioners of Sudarshana Kriya -meditation. Whereas there is small changes in the short term practitioners.

A reduction in stress was observed in the long term practitioners compared with short term practitioners.

The increased experience of altered states of consciousness during Sudarshana Kriya is also very interesting. ASC-state is achieved during Sudarshana Kriya can be interpreted as an indication of deep rest and relaxation. During an ASC-state many different psychological changes occur compared with normal waking state, for example, very deep relaxation, the feeling that the border between body and surroundings is eliminated, and this changes the sensation of time or mindset where new and creative thoughts are generated. A mild ASC-state is often described as having the character of daydreaming.

The subjects who practiced Sudarshana Kriyafelt that they have gained a tool that can be used in stressful situations that would make it easier to relax and better handle them. Furthermore, they experienced that yoga program decreased tensions, unpleasant sensations, blocks and locked-up feelings, as well as the experience of better control over their feelings. Subjects expressed that it is easier to feel joy after they have learned it. In addition, subjects had the sense that they had more

energy and that the life force flowed through their body during the practice..Despite their verbal statements on their experience of having more energy, this was not detected by statistical analysis. One possible reason for this could be that the increased energy that they have experienced was used to assimilate all the new impressions that they have received. These new impressions consisted, among others, increased thought activity about how they live their lives, how they think, and how they feel. Furthermore, it could be that the energy was used to handle the feelings and emotions that they previously suppressed. Additional work that utilizes multiple instruments is needed to assess these possibilities [7-8].

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