Effect of Ekagrata Meditation on Sympatho-Vagal Balance-An Auto-Regression Model Approach

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Abstract—The ekagrata meditation state pertains to channelizing the thoughts in one direction. In the present work the effect of meditation state of ekagrata on heart rate variability dynamics have been analyzed. For this, the electrocardiogram (ECG) was recorded in thirty ($n=30$) experienced male yoga practitioners (mean age $\pm 32$ years, range 22-38 years, mean height $\pm 164$ cms) in pre, during and post-sessions of ekagrata meditation. The heart rate variability was evaluated using optimized autoregressive technique. The sympatho-vagal balance (LF/HF ratio) became sympathetic tone (LF power) dominant, while vagal tone (HF power) was observed to be significantly low ($p<0.01$) under meditation state of ekagrata. The total variability ($P_{total}$ (ms$^2$)) is significantly high ($p<0.05$) and mean heart rate (HR (bpm)) is lowered under this meditation state.

Index Terms—heart rate variability, ekagrata meditation, optimized AR model, LF power, HF power.

I. INTRODUCTION

The previous studies on yoga therapy, breathing exercises and meditation have demonstrated their therapeutic potential to influence the autonomic nervous system dynamics. Howorka K. et al. (1995) demonstrated an immediate decrease of sympathetic and increase of parasympathetic activity after yoga in a preliminary study [1]. The heart rate variability study by Raghuraj P. et al. (1998) in two selected breathing techniques, viz. Kapalabhati (breathing at high frequency) and nadisudhi (alternate nostril breathing) exhibited significant increase in low frequency (LF) power and LF/HF ratio while high frequency (HF) power was significantly lowered following kapalabhati, but there were no significant changes following nadisudhi [2]. Peng C. K. et al. (1999) reported extremely prominent heart rate oscillations during Chinese Chi and Kundalini yoga meditation techniques with slow breathing, which challenged the very notion of meditation as only an autonomically quiescent state [3]. Peng C. K. et al. (2003) in their later study on heart rate variability in three forms of meditation observed increased coherence between heart rate and breathing during relaxation response and segmented breathing when compared to baseline. The third form of meditation i.e. breath of fire was marked by increase in mean heart rate with respect to baseline and a significant decrease in coherence between heart rate and breathing [4]. Vladimir S. and Ofer B. (2005) emphasized the sympathetic nervous system dynamics to counter mental stress and other external or internal disturbances effecting visceral homeostasis [5]. Jovanov E. (2005) during very slow yogic breathing found increased VLF frequencies, respiratory sinus arrhythmia, LF/HF ratio and decreased breathing frequency after exercise in comparison to state before exercise [6]. Patil S. and Telles S. (2006) in their study on two yogic based relaxation effects on HRV in cyclic meditation (CM) and supine rest (SR), showed decrease in LF power and LF/HF ratio during and after CM, whereas HF power decreased. The heart rate increased during CM but decreased after CM. However, there was no change in SR state [7]. Travis F. et al. (2008) tested the advantageous effect of transcendental Meditation (TM) technique in overcoming stress in college students [8]. Sunkaria et al. (2010) observed high HRV in yogic practitioners in comparison to non-yogic practitioners [9].

The present study evaluates heart rate variability dynamics during meditation states of ekagrata. The effect of this meditation state on autonomic control dynamics may enhance the therapeutic utility in relevant cardiac health conditions.

II. METHODS

A. Subjects

Thirty four experimental volunteers for electrocardiogram (ECG) recording were selected from Swami Vivekanand Yoga Research Foundation, Bangalore, India. The selected volunteers were regular yoga practitioners having 3-12 twelve years of meditation experience and were used to practice 3-5 times/week. They were in excellent health condition and were not having even history of any cardiac or vascular disease. This was also ascertained by a thorough medical examination. The subjects were explained the experimental procedures and that the recorded ECG signal would be used for academic and research purpose alone. An informed written consent was obtained from each subject prior to recording. The lead-II ECG was recorded in each of the thirty four male volunteers having age in the range of 22-to -38 years (mean age $\pm 32$ years,
mean height $\equiv 164$ cms) under ekagrata state. The signal quality in four recorded signals was contaminated by artifacts especially due to subject’s movements, so in total, good quality ECG data of thirty subjects were used for analysis.

B. Inclusion/Exclusion Criteria

The normal and healthy yoga practitioners were included in the present study after a thorough medical examination and fulfilling certain physiological requirements. Subjects having pulse rate $> 100$ bpm, blood pressure $> 160/100$ and subjects suffering from severe breathlessness were left out of the recording process. The ECGs were checked and none of the subjects had extra systoles.

C. Intervention of Ekagrata Meditation State and Recording Protocols

Each of the selected yoga practitioners underwent ECG recording protocol as per Table I under ekagrata state of meditation with total duration of more than thirty minutes comprising of pre, during (D1, D2, D3 and D4) and post session with conditioning gaps. The interventional meditation states of ekagrata are channelizing the thoughts in one direction. All recording sessions of pre, D1, D2, D3, D4 and post were of duration five minutes each. The recording was made on subsequent days between 05:00 and 08:30 hours in the morning or 05:00 and 08:30 hours in the evening to avoid outside disturbance to cover all the subjects. The instructions to all subjects were as per given in the Table I.

<table>
<thead>
<tr>
<th>Sessions</th>
<th>EKAGRATA RECORDING PROTOCOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre (5 min)</td>
<td>Sit and relax</td>
</tr>
<tr>
<td>Gap (2 min)</td>
<td>Viewing slides of pictures pertaining to mountains, rivers etc. with logical linking among pictures.</td>
</tr>
<tr>
<td>D1 (5 min)</td>
<td>Play of logical lecture on cyclic meditation</td>
</tr>
<tr>
<td>D2 (5 min)</td>
<td>Play of logical lecture on cyclic meditation</td>
</tr>
<tr>
<td>D3 (5 min)</td>
<td>Play of logical lecture on cyclic meditation</td>
</tr>
<tr>
<td>D4 (5 min)</td>
<td>Play of logical lecture on cyclic meditation</td>
</tr>
<tr>
<td>Post (5 min)</td>
<td>Sit and relax</td>
</tr>
</tbody>
</table>

D1-D4 are sessions of interventional ekagrata meditation state

D. Data Acquisition and Analysis

The lead-II ECG signal of each subject was recorded at sampling frequency of $250$ Hz using 4-channel RMS polyryte ECG recorder (Chandigarh, India) in all sessions as elaborated above. The acquired ECG data was visually inspected and only visibly artifact free data were used. The ECG signal was filtered using FIR band-pass (0.5 Hz-100 Hz) filter to remove any high frequency noise and base wander, while retaining the diagnostically useful frequency range. The R-peaks were detected using highly efficient new wavelet transform function based QRS detection algorithm [10]-[12]. This resulted into highly accurate RR-tachogram (HRV signal), which leads to evaluation of highly reliable HRV indices.

E. Heart Rate Variability Measurement

1) Spectral domain HRV indices using optimized AR model

The heart rate variability evaluated using FFT with improved windowing technique gives highly accurate spectral HRV indices magnitudes as window bias caused by windowing of data is removed in this algorithm. So HRV indices with this technique have been taken as reference. The AR model has smooth PSD curve and easy identification of central frequencies in spectral bands corresponding to intrinsic oscillators. Moreover, the spectral resolution in case of AR technique is mostly affected by order of the model because time resolution is independent of frequency resolution, so even a shorter window length can be used. Further, the order of model affects the spectral band (VLF, LF & HF) powers and other HRV indices. So, a criterion is chosen for model order selection, such that variance of the prediction error is minimized. The Akaike’s FPE (finite prediction error) criteria for model order selection has the disadvantage that magnitude of HRV indices differs from those evaluated with fast Fourier transform (FFT) technique [13]. In the present study, this model order has been optimized and evaluated on the basis of total prediction error (TPE). It was observed experimentally, that if the highest order of model is evaluated corresponding to total prediction error (TPE) of $+1\%$ more than least square error computed with FPE criteria or till the trend of least square error starts increasing, then this model order provides HRV indices which are closely same to those evaluated with FFT technique, without sacrificing the inherent advantages of AR model. However, if model order is evaluated corresponding to more than this $+1\%$ of least square error, then the HRV indices again starts deviating from those evaluated with FFT [14]-[17].

The R-peaks were detected using highly efficient detection algorithm and RR-interval tachogram was formed. This RR-tachogram was resampled at $4$ Hz and HRV indices were evaluated using above elaborated optimized autoregressive (AR) model for all four meditation states in their pre-during-post sessions. Three frequency bands were considered as per the task force guidelines: very low frequency (VLF, $\leq 0.04$ Hz), low frequency (LF, $0.04$ Hz-0.15 Hz) and high frequency (HF, $0.15$ Hz-0.40 Hz). The spectral band powers were evaluated by summation of power in each of these frequency bands. The physiological processes attributed to the VLF band are not well defined, but it is believed to be associated with thermoregulatory mechanisms and rennin-angiotensin variations. LF signifies sympathetic tone and parasympathetic tone is related to the HF. The VLF, LF and HF power components may be computed in absolute (millisecond square) or normalized units (n.u.). The LF/n.u. HF/n.u. indicates proportion of autonomic control by sympathetic and parasympathetic branches of autonomic nervous system [18]-[21]. The time domain HRV measures of mean heart rate (HR, bpm)) was also evaluated from RR-interval series in the present study for further supporting the spectral based analysis. The mean
heart rate indicates the heart rate dynamics in the meditation state.

2) Statistical analysis

The group values of various HRV indices for all four meditation states are summarized as mean ± S.D. in pre, during and post sessions in Table II. Since, the recordings were made on subsequent days, so pre-session values of HRV indices differs slightly under all four states. Therefore each pre-session HRV indices values have been taken as baseline and their percentage change in magnitude during ekagrata meditation state and in post-sessions with pre-session values as baseline indicates the effect of ekagrata meditation state. The significance of change during and in post-sessions were determined by one way ANOVA test with pre, during and post session group values formulating group values. The 'p-values' and 'Fisher F-values' determined by one way ANOVA test have been quoted in Table II.

### TABLE II. HEART RATE VARIABILITY DYNAMICS IN PRE- AND DURING EKAGRATA MEDITATION

<table>
<thead>
<tr>
<th>HRV measure</th>
<th>Subjects</th>
<th>Baseline (Pre-session)</th>
<th>During ekagrata meditation state</th>
<th>Post-session</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF (ms²)</td>
<td>30</td>
<td>348.59 ± 132.57</td>
<td>540.92 ± 264.39</td>
<td>612.68 ± 297.30</td>
<td>9.54</td>
<td>0.000</td>
</tr>
<tr>
<td>HF (ms²)</td>
<td>30</td>
<td>289.42 ± 55.25</td>
<td>251.39 ± 67.79</td>
<td>253.63 ± 66.22</td>
<td>3.40</td>
<td>0.038</td>
</tr>
<tr>
<td>LF/HF ratio</td>
<td>30</td>
<td>1.89 ± 1.69</td>
<td>2.57 ± 1.22</td>
<td>2.96 ± 1.64</td>
<td>3.75</td>
<td>0.027</td>
</tr>
<tr>
<td>LF n.u.</td>
<td>30</td>
<td>58.13 ± 14.91</td>
<td>68.43 ± 9.40</td>
<td>70.36 ± 12.32</td>
<td>8.41</td>
<td>0.000</td>
</tr>
<tr>
<td>HF n.u.</td>
<td>30</td>
<td>41.87 ± 14.91</td>
<td>31.57 ± 9.40</td>
<td>29.64 ± 12.32</td>
<td>8.41</td>
<td>0.000</td>
</tr>
<tr>
<td>Ptotal (ms²)</td>
<td>30</td>
<td>1010.72 ± 448.59</td>
<td>1353.73 ± 557.69</td>
<td>1298.03 ± 510.70</td>
<td>3.94</td>
<td>0.023</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>30</td>
<td>77.47 ± 7.45</td>
<td>75.52 ± 6.93</td>
<td>75.94 ± 6.43</td>
<td>0.65</td>
<td>0.522</td>
</tr>
</tbody>
</table>

LF = power in low frequency; HF = power in high frequency; ms²=absolute units; n.u. = normalized units; LF/HF ratio = sympatho-vagal balance; Ptotal=total power; HR= mean heart rate.

*HRV indices in terms of mean and standard deviation calculated for all thirty subjects (n=30) participating in the study in pre, during and post sessions of ekagrata meditation state.

*Pre-session values were considered as baseline.

*Values were averaged over D1-D4 sessions of meditation states.

### III. RESULTS

The typical effect of ekagrata meditation state on heart rate variability dynamics is shown in Fig. 1 for one of the representative subject in pre and during ekagrata meditation state for one of the session (D4). The result for session D4 has been shown as the subject will effectively transit into ekagrata meditation by the session.

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**Figure 1. Heart rate variability of a representative subject in pre-and during one of the ekagrata session (D4).** The power spectral density (PSD) (Fig. 1(b) and 1(d)) in pre-and during ekagrata meditation state are shown alongside with their corresponding RR-interval series (Fig. 1(a) and 1(c)). The RR-interval series and their PSD curve are shown for session D4 such that the effect of meditation states is clearly observable. Only 200 numbers of RR-intervals are shown in above figure for clear visibility, although these are more in any 5-minutes duration session.

**A. Comparison of HRV in Pre- and During Ekagrata Meditation State**

To determine the mean effect of ekagrata meditation state on heart rate variability dynamics the mean value of HRV indices during multiple sessions of D1, D2, D3 and D4 have been calculated for all thirty (n=30) subjects. The quantitative results for these thirty subjects (n=30) showing effect of ekagrata on heart rate variability dynamics are summarized in Table II. The results are presented in terms of mean and standard deviation (for all thirty subjects) in pre, during and post sessions. The variations in frequency domain HRV indices in pre- and during ekagrata states are either significant or very significant. However the time domain indices of rMSSD (ms) do not show the consistency in results.
B. Comparison of Ekagrata Meditation States with Baseline

The HRV indices during and in post-sessions were compared with their baseline (pre-session) values. The indices were differently affected and their magnitude of variations in comparison to the baseline is shown in Table III in terms of percentage change with respect to baseline value.

<table>
<thead>
<tr>
<th>Variables</th>
<th>During ekagrata meditation</th>
<th>Post-session</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF (ms²)</td>
<td>55.17</td>
<td>75.76</td>
</tr>
<tr>
<td>HF (ms²)</td>
<td>-13.14</td>
<td>-12.36</td>
</tr>
<tr>
<td>LF/HF ratio</td>
<td>35.92</td>
<td>56.61</td>
</tr>
<tr>
<td>LFn.u.</td>
<td>18.92</td>
<td>21.02</td>
</tr>
<tr>
<td>HFn.u.</td>
<td>-24.61</td>
<td>-29.22</td>
</tr>
<tr>
<td>Ptotal (ms²)</td>
<td>33.91</td>
<td>28.4</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>-2.50</td>
<td>-1.91</td>
</tr>
</tbody>
</table>

*+ve value = increase in reference to pre-session; -ve value = decrease in reference to pre-session

*Percentage change was calculated for change in mean value (for thirty subjects) of particular HRV indices during and in its post-session in reference to baseline.

Compared to baseline, the percentage increase in LF power was very significantly higher during ekagrata ($p<0.01$) and this persists even in post-session. The HF power is lowered very significantly ($p<0.01$) during ekagrata and it remains lowered in post-ekagrata session. The autonomic balance (LF/HF Ratio) is sympathetic tone dominant during and even in post-ekagrata session. The normalized LF and HF have shown the same trend as the absolute LF and HF does. The total power (Ptotal (ms²)) increases very significantly during ekagrata ($p<0.05$). The mean heart rate (HR (bpm)) is lowered during ekagrata and remains lowered in post-session.

IV. DISCUSSIONS

The meditation state of ekagrata used as an intervention for the present study is one of the meditation states towards the path of attaining final state of Samadhi as per yoga literature. The results pertaining to heart rate variability dynamics during this meditation state has revealed interesting autonomic control dynamics as observed in Table II. The quantitative variations in HRV measures in reference to baseline during and in post-sessions shown in Table III comprehend the effect of interventions. It was observed that there is increased power in LF during ekagrata, which indicates that sympathetic tone is markedly enhanced under ekagrata.

The vagal tone is markedly reduced under ekagrata. This is indicator of the fact that heart rate variability is reduced under ekagrata. The sympatho-vagal balance (LF/HF ratio) is sympathetic tone dominant, thus autonomic control become more responsive to peripheral variations i.e. meditation state of ekagrata. The normalized indices of LF and HF show the percentage contribution of sympathetic and vagal tones in autonomic control. The reduced mean heart rate (HR (bpm)) in ekagrata is similar to other studies undertaken previously. The above trends of various heart rate variability dynamics related measures, such as sympathetic tone (LF), sympatho-vagal balance (LF/HF ratio), total variability (Ptotal (ms²)), normalized LF, HF sustains even in their post-sessions.

This study assessed effect of meditation state of ekagrata on heart rate variability in selected middle aged male volunteers, who were having training in meditation practices. Inclusion of female subjects would have added wider applicability of the study. However, the subjects taking part in the present study were regular yoga practitioners and taking pre-session values of each HRV measure as baseline or control is well justified as the trained yoga practitioner has the ability to be in particular meditation state at a given time. Future studies may help to elucidate effect of ‘Om’ meditation over other forms of meditation and how the autonomic control is regulated.

V. CONCLUSIONS

This study reveals very interesting autonomic control dynamics under intervention of ekagrata meditation state. The sympathetic tone is increased, where as the vagal tone is reduced under ekagrata. The increased sympatho-vagal balance under this meditation state further supports this fact. Thus, the heart rate variability is reduced under ekagrata meditation state. The increased total spectral power Ptotal (ms²) may be due to increased visceral dynamics due to interventional meditation state.

ACKNOWLEDGMENT

The authors are highly thankful to Department of Electronics & Communication Engineering and Director, Dr. B.R. Ambedkar National Institute of Technology, Jalandhar for providing all necessary help to carry out the present work. The authors are also highly thankful to Electrical Engineering Department and administration of Institute of Technology Roorkie, India for their all administrative and technical assistance in providing the various facilities for this work. The help in clinical aspects of Yoga and interpretation of results in this study rendered by research and support staff of Yoga Research Centre at Patanjali Yogpeeth, Haridwar, India is highly appreciated.

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