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Effect of Chi Meditation on Heart Rate Oscillations: Fractal Study

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ABSTRACT
This Paper Reports On The Effect Of Chi Meditation On Heart Rate Oscillations In The Light Of Nonlinear Fractal Study. For This Purpose, Hurst Rescaled Range Analysis Method Is Applied On The Heart Rate Time Series For All The Subjects Both Before And During Chi Meditation. The Results Are Interesting. The Time Series Are Collected From MIT BIH Physionet Database. Hurst Exponent Is Found To Be Less During Meditation Than Pre-Meditation State For All The Subjects Except One. Moreover Results Show That The Heart Rate Oscillations During Chi Meditation Are Having Less Persistent Nature Than In Pre Meditation State. The Results Speak Against The Age Old Belief That Meditation Ensures A Quiescent State Of Mind.
Keywords: Chi Meditation, Heart Rate Oscillations, MIT-BIH Physionet Database, Hurst Rescaled Range Analysis

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I. INTRODUCTION

Meditation Is A Method To Bring Harmony Between Physical And Mental State Of A Person. In Today's Scenario, It Is Practiced By Anyone To Acquire A State Of Calmness. Meditation Reduces Metabolic Activity. It Enhances Emotional As Well As Physiological Stability.Meditation Practicecan Enhance Self-Regulation [1], Improvescognitive Processes Likeremembrance, Attention And Executive Functions [2]. Executive Functions Include Selective Sustained Attention [3-5], Interference Control [4,6-7], Working Memory [8-9] And Speaking Fluency[9]. Underlying Brain Structure [10-12] And Function [7,13-15] Are Also Modified By Meditation Practice. EEG Research [16-18] And Fmri Studies [19-20] Report On The Relationships Between Brain Changes And The Trainingduration Of Meditation Practitioners. EEG Correlations Of Meditative States Are Summarized In [21-22].

The Time Intervals Between Successive Heartbeatsvary Constantly And This Physiological Phenomenon Is Called Heart Rate Variability (HRV). Sympathetic And Parasympatheticnervous System Play Very Important Role In Heart Rate Variability. Such Oscillations Are Affected By Baroreflex, Thermoregulation, Hormones,Physical Activity, Stress And So On. Cardiovascular Dynamics Is Well Reflected In HRV And As Such It Has Clinical Importance [23]. First Quantitative Study On The Effect Of Meditation On Human Heart Beat Is Reported In [24]. They Utilized Spectral Analysis And Novel Analytic Technique Based On Hilbert Transform To Study These Heart Rate Oscillations. They Found Prominent Heart Rate Oscillations Were Associated With Slow Breathing During Meditation [24]. Moreover The Amplitude Of Oscillations During Meditation Was Found To Be More Than Those In The Pre-Meditation Control State. Chi Exercise Is A Traditional Chinese Meditation Trainingmethod [25]. Many Researchers Have Found That Chi Exercisecan Reduce Depression And Anxiety And It Can Improve Vitality And Mental Health [25]. Moreover, Italso Regulates Heart Rates [25]. The Heart Rate Fluctuations Are Of Highly Complex Nature And These Cannot Be Studied By Linear Methods. Autonomic Nervous System (ANS) Affects Cardiovascular System. So, Effects Of Meditation On ANS Can Be Studied In Terms Of The Effects Of Meditation On Cardiovascular System. In This Work, Chi Meditative Effect On ANS Has Been Quantitatively Studied Using Fractal Analysis Of Heart Rate Oscillation Signals. For This Purpose, Rescaled Range Analysis Method [26-29]Proposed By Hurst Has Been Applied To Heart Rate Time Series Of Subjects For Their Pre And During Chi Meditation Sessions.

II. DATA SELECTION

Heart Rateoscillation Signals Are Collected From MIT-BIH Physionet Database [30]. This Databaseis A Large Archive Of Digital Recordings Of Physiological Signals Andrelated Data.

Chi Meditation Was Taught By Xin Yan [24].The Subjects Under This Study Were All Graduate And

Post-Doctoral Students. They Were Not At All Habituated With The Practice Of Chi Meditation [24]. Most Of Them Started This Practice For About 1–3 Months. All The Subjects Were In Good Health. There Were Eight Subjects, 5 Women And 3 Men In The Age Range Of 26–35 Years. They Wore A Holter Recorder For About 10 Hours. During This Span Of Time They Used To Perform Daily Works. Each Of Them Practiced One Hour Of Meditation. Initiation And Ending Times Of Meditation Were Demarcated With Event Marks. While On Meditation, The Subjects Used To Sit Quietly And They Used To Listen To The Taped Guidance Of The Master. As Per The Instruction Of The Master, The Subjects Used To Breathe Spontaneously While Visualizing The Opening And Closing Of A Perfect Lotus In The Stomach. Data Sampling Rate Was 360 Hz [24].

III. HURST RESCALED RANGE ANALYSISMETHOD

Mean $\tilde{x}(N)$;Standard Deviation S(N) And Cumulative Departure X(N,N), Of Heart Rate Time Series Are Calculated Using The Following Eqn. (1), Eqn.(2) And Eqn.(3) Respectively [27-29]. The Rescaled Range Analysis Method Is Simple And Robust Non-Parametric Method For Fast Fractal Analysis. This Is Performed On The Discrete Time Series Data Set X_t Of Dimension N

$$\tilde{x}(N) = \sum \frac{x_t}{N} \qquad (1)$$

$$S(N) = [\frac{1}{N}\sum (x_t - \tilde{x}(N))^2]^{\frac{1}{2}} \qquad (2)$$

Cumulative Departure Is Given By

$$X(n,N) = \sum (x_t - \tilde{x}(N)), \qquad 0 \le N \le N \qquad (3)$$

Range Of Cumulative Departure Is Given By,

$$R(N)=Max[X(N,N)]-Min[X(N,N)] \qquad (4)$$

R/S Analysis For The Heartrate Signals Is Discussed In Detail In The Result Section Of This Paper. It Is Computed As

$$\frac{R}{S} = n^H \qquad (5)$$

The Fractal Dimension D [27-29] Is Determined As

$$D=2-H \qquad (6)$$

IV. RESULTS AND DISCUSSION

The Plots Ofheart Rate Oscillation Signals Of A Subject Before And During Chi Meditation Are Shown In Figure 1 And Figure 2 Respectively As Example Plots.

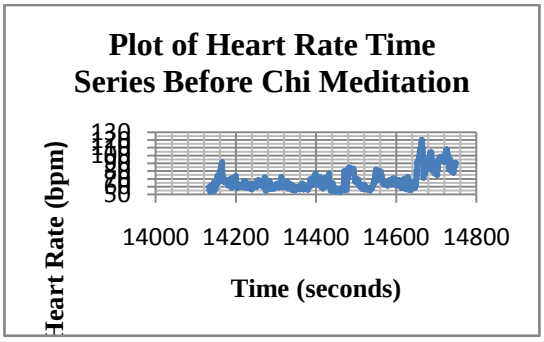

Figure 1: Heart Rate Oscillation Signal Of A Subject Before Chi Meditation

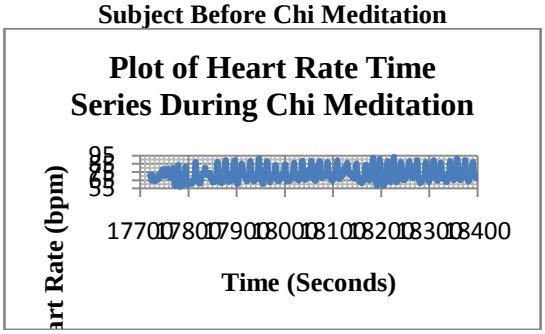

Figure 2: Heart Rate Oscillation Signal Of A Subject During Chi Meditation

Heart Rate Time Series Of All The Subjects Prior To Meditation And During Chi Meditation Are Loaded On Matlabplatform.Hurst's Rescaled Range Analysis Method As Explained Above Is Applied On These Time Series. Using This Rescaled Range Analysis, Standard Deviation S(N) And Range Of Cumulative Departure R(N) Of These Time Series Are Obtained. The Graph $Log_{10}(R/S)$ Vs. $Log_{10}(N)$ For Heart Rate Time Series Before And During Chi Meditation Are Shown In Figure 3 And Figure 4 Respectively As Example Plots. Hurst Exponent (H) And Fractal Dimension (D) For Both Before And During Chi Meditation Heart Rate Time Series Are Obtained And The Results Obtained From These Plots Are Tabulated In Table 1.

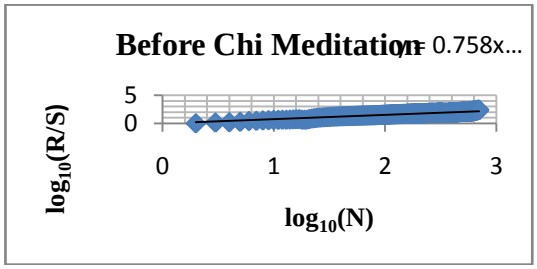

Figure 3:Log_{10}(R/S) Vs. Log_{10} (N) Of A Subject Before Chi Meditation

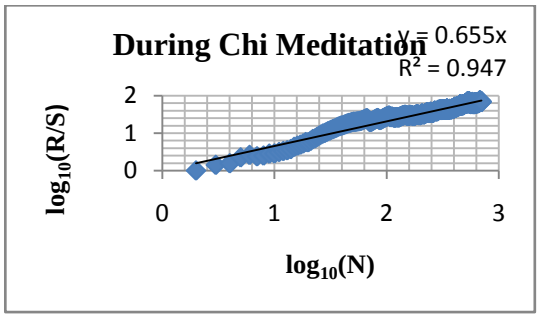

Figure 4: Log_{10}(R/S) Vs. Log_{10} (N) Of A Subject During Chi Meditation

Table 1: Hurst Exponent (H) And Fractal Dimension (D) For Heart Rate Time Series Before And During Chi Meditation

Cases	Hurst Exponent (H) Before Chi Meditation	Fractal Dimension (D) Before Chi Meditation	Hurst Exponent (H) During Chi Meditation	Fractal Dimension(D) During Chi Meditation
C1	0.722	1.278	0.651	1.349
C2	0.762	1.238	0.795	1.205
C3	0.823	1.177	0.717	1.283
C4	0.757	1.243	0.695	1.345
C5	0.761	1.239	0.685	1.305
C6	0.668	1.332	0.639	1.361
C7	0.754	1.246	0.717	1.283
C8	0.801	1.199	0.764	1.236

This Analysis Clearly Reveals The Following Interesting Features:

From Table 1, It Is Observed That Hurst Exponent (H) Values For All The Heart Rate Time Series Both Prior To And During Chi Meditation Are Greater Than 0.5. This Indicates That All The Time Series Are Persistent In Nature And They Have Positive Correlation. Subjects, C1, C3, C4, C5, C6, C7 And C8 Show That During Chi Meditation Their Heart Rate Time Series Are Persistent In Nature But The Trend Is Moving Towards Less Persistency As Compared To Their Heart Rate Time Series Prior To Chi Meditation. This Indicates Chi Meditation Has Caused Their Heart Rate Signals To Become More Complex. Chi Meditation Has Decreased The Smoothness And Increased The Irregularity And Roughness In The Time Series. This Decrease In Persistency Is Different For Different Subjects. The Subject C2 On The Other Hand Has Shown Opposite Result. Hurst Exponent Of The Heart Rate Time Series Of This Subject During Chi Meditation Is More Than That Prior To Chi Meditation. So, This Indicates, The Trend Is Moving Towards More Persistency For This Subject. This Indicates Chi Meditation Has Been Able To Bring Relaxant Effect By Bringing Smoothness And Regularity In The Time Series Of This Subject.

V. CONCLUSION

Results Of This Paper Infer Chi Meditation Has Introduced A Trend Towards Less Persistency In The Heart Rate Time Series For All Subjects Except One. This Finding Indicates Meditation Is Not Always A Stimulus That Brings Physiological And Psychological Quiescent State.

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