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# Impact of Meditation on Mental Health: A Case Study with Two Meditation Practices using Heart Rate Variability

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**Abstract:** Heart rate variability (HRV) signals provide a non-invasive way of analyzing the functioning of the autonomic nervous system (ANS), providing important information on how mental states affect the body. This study focused on how HRV features change during meditation compared to pre-meditation states. In this work, we propose analysis of HRV signals using nonlinear features including the detrended fluctuation analysis, the Hurst exponent, the approximation entropy, the degree of distribution, and the multiscale permutation entropy. The analysis was performed on the publicly available databases [1] which consists of HRV signals of subjects before and after practice of Chi meditation and Kundalini Yoga. The proposed study shows that there is a characteristic variation in both meditation. These changes underscore the potential of HRV analysis to quantify the physiological benefits of meditative practices and their impact on mental health and well-being.

**Keywords:** Heart Rate Variability (HRV); Meditation; Mental Health; Autonomic Nervous System (ANS); Internet of Medical Things (IoMT).

#### **1. Introduction**

Mental health issues such as stress and depression are becoming more and more prevalent worldwide and have a negative influence on all aspects of people's lives. According to the World Health Organization (WHO), depression affects 280 million people globally [2]. More than 700,000 people die by suicide each year, making it the fourth most common cause of death among adults between the age range of 15 to 29 years [3]. Although early detection and continuous monitoring of mental health conditions are very crucial for effective management and timely intervention, yet in low- and middle-income nations, 75% of people do not receive any kind of care [4]. Key obstacles to obtain effective treatment include inadequate funding for mental health services, a lack of qualified healthcare workers, and the social stigma associated with mental health conditions.

From biomedical signal analysis perspective, the variations in the intervals between consecutive heartbeats also known as the heart rate variability (HRV) is a non-invasive and reliable biomarker for assessing mental health [5]. Nonlinear parameters such as the entropy, the Hurst exponent, the degree of distribution, the fluctuation, etc. [6-7] provide valuable insights into the regulation of the autonomic nervous system (ANS) and its connection to

psychological well-being. Previous study [8] shows that HRV reflects the flexibility and balance of the ANS. A decrease in HRV, along with reductions in features such as complexity and entropy, are associated with stress, anxiety, and depression, indicating diminished physiological adaptability and resilience. These measures show abnormalities in emotional and autonomic modulation, which offers important insights into mental health.

Meditation improves autonomic stability and parasympathetic activity, resulting in enhancing the HRV features, which reflects greater physiological adaptability and emotional resilience. Thus HRV analysis shows the positive impact of meditation on mental health status. The HRV-assisted mental health research is mainly based on time-domain analysis. Researchers have primarily focused on extracting statistical and geometrical parameters to assess heart rate variability [9-11]. In frequency domain analysis, the power spectral density (PSD) of HRV signals has been extensively studied to evaluate changes in characteristics in different mental states [12–15]. Recently, there has been a growing interest in utilising nonlinear analysis to investigate the complex dynamics of HRV signals.

Recent research highlights that nonlinear HRV parameters offer more accurate estimations of mental states compared to traditionally used linear parameters. These nonlinear measures capture the complex and dynamic behavior of HRV signals better, providing deeper insights into the underlying physiological and psychological processes. However, in the existing literature nonlinear analysis is not directly utilized for comprehensive mental health assessment.

Based on the above literatures, we propose the following objectives in this study

- 1. To examine meditation's impact on mental health using nonlinear HRV analysis.
- 2. To compare the effects of two different meditation techniques both during and premeditation states using nonlinear HRV dynamics.

## 2. Materials and Methods

Figure 1 presents the details of the proposed study, which mainly consists of the following procedures: data acquisition, pre-processing of data, feature extraction, and mental health analysis based on the extracted features.



Figure 1. Block diagram of impact of meditation on mental health using non-linear analysis

**Data Acquisition:** The Kundalini Yoga dataset comprises of heart rate (HR) time series data from 4 advanced practitioners (2 men and 2 women), aged 20–52 years. During meditation, participants practiced chanting and breathing techniques while sitting cross-legged, with sessions lasting approximately 8.7 to 11.5 minutes. Pre-meditation data was collected over an

average duration of 15 minutes. Similarly, the Chi Meditators dataset also includes HR time series data from 8 beginner-level (with experience of meditation of 1 to 3 months only) meditators (3 men, 5 women) aged between 26–35 years. During meditation, participants followed guided visualization exercises while breathing spontaneously, with session durations ranging from approximately 49.8 to 80.4 minutes. Pre-meditation data was collected over an average duration of 60 minutes. For both meditation types, pre-meditative and meditative data were captured once for each participant. The inclusion criteria for selecting subjects for both meditation types consist of participants in good health with no habit of any specific exercise routine.

**Data Preprocessing:** In this study, RR intervals were derived from R-peak time instants to generate the HRV signals. To handle the missing sample problem, the cubic spline (CS) interpolation method [16] is used.

**Feature Extraction:** To study the impact of meditation, nonlinear features are extracted from the preprocessed HRV data that include detrended fluctuation analysis (DFA), Hurst exponent (H), approximation entropy (AppEn), degree of distribution (DOD) for the assessment of HRV fluctuation level, and multiscale permutation entropy (MPE(1-6)) to analyze the complexity of HRV in 6 different time scales.

**Mental Health Analysis:** After analyzing these features using a signal processing tool, the effect of meditation on mental health is analyzed.

## 3. Results and Discussion

The analysis is performed using the Jupyter Notebook IDE in the Spyder environment, running Python version 3.7.12 on a personal laptop. The primary goal of this work was to analyze the variations in nonlinear HRV parameters before and during meditation practice for both Kundalini yoga and chi meditation.



Figure 2. Variation of some HRV parameters during and pre meditation states of Chi meditation and Kundalini Yoga practices

Figure 2 shows the significant changes in these nonlinear parameters during and premeditative states for both meditation types. During meditation and pre-meditation states, HRV parameter changes due to parasympathetic and sympathetic mechanisms of the ANS. During meditation, parasympathetic activation increases, enhancing vagal tone and promoting relaxation, while sympathetic activity decreases, reducing stress and autonomic arousal. This shift results in improved HRV features such as higher complexity and entropy as shown in Table 1, and the decrease in the fluctuation parameter during meditative states suggests enhanced autonomic stability. Also, this study shows greater variation of HRV parameters in Kundalini yoga compared to Chi meditation, as presented in Table 1. Chi meditation, practiced by beginners, promotes steady parasympathetic activation through slow breathing, resulting in gradual autonomic balance. In contrast, Kundalini yoga, practiced by advanced practitioners, involves dynamic techniques, like rapid breathing and chanting, causing sharper autonomic fluctuations due to initial sympathetic engagement followed by parasympathetic recovery. These findings reinforce the unique regulatory benefits of this structured meditative practice. This suggests that, while both practices exert a measurable influence on the physiological states of the participants, the underlying mechanisms or the intensity of these effects might vary.

Table 1.	HRV	parameter	variation	during and	l pre n	neditation	state on	Kundalini	Yoga and	Chi med	itation

Nonlinear HRV features during meditation	Chi Med (parameter r	litation nagnitude)	Kundalini Yoga (parameter magnitude)		
Tomment Titty reactives during incultation	During	Pre	During	Pre	
Approximation Enropy	7.10339	6.0236	7.10339	5.1236	

Hurst Exponent	0.3358	0.4631	0.2958	0.5431
Detrended Fluctuation Analysis	0.7080	0.9886	0.5781	1.0986
Degree of Distribution	0.7151	0.8904	0.6371	0.9304
Multiscale permutation entropy (MPE1)	1.7381	1.5955	1.7781	1.6455
Multiscale permutation entropy (MPE2)	1.7116	1.6339	1.8711	1.6773
Multiscale permutation entropy (MPE3)	1.7616	1.5639	1.8766	1.5336
Multiscale permutation entropy (MPE4)	1.6339	1.5339	1.7139	1.4953
Multiscale permutation entropy (MPE5)	1.6739	1.4339	1.7739	1.4339
Multiscale permutation entropy (MPE6)	1.7339	1.6239	1.8339	1.5129

### 4. Conclusions

This study has highlighted the measurable impact of Chi meditation and Kundalini Yoga on mental health using nonlinear analysis. The significant changes in HRV parameters during meditation sessions underscore the potential of these practices to induce relaxation and enhance autonomic stability. Moreover, the comparative analysis revealed distinct variations between the two meditation techniques, suggesting unique mechanisms in each practice. These findings show the role of meditation as a valuable tool for promoting mental health and provide a foundation for further exploration of its therapeutic applications such as stress management, emotional regulation etc. However, the study has certain limitations which include a small sample size (only 4 and 8 participants for Kundalini Yoga and Chi meditation), also the inclusion of only experienced Kundalini Yoga practitioners may not reflect the typical population's response to these practices. Further studies will include diverse and larger samples for broader applicability ensuring representation across different age groups, genders, fitness levels, and meditation experiences to offer a more thorough knowledge of how these practices affect mental health.

### **Multidisciplinary Domains**

This reserch covers the domains: (a) Biomedical Signal Processing, (b) Yoga, and (c) Mental Health

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### **Conflicts of Interest**

The authors declare no conflict of interest.

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