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Original Research Article

A Study on the Effect of Deep Breathing Exercise on Heart Rate Variability (HRV) in Healthy Subjects

Bhupendra Buda[1], Silvi Banerjee[2], Susajit Kumar Pradhan[3]

[1]MD Physiology, Assistant Professor, Department of Physiology, SCB MCH Cuttack, Odisha, India

[2]MD Physiology, Assistant Professor, Department of Physiology, SCB MCH Cuttack, Odisha, India

[3]Assistant Professor (Anaesthesiology), ECMO Unit, Department of Cardio Thoracic and Vascular Surgery, SCB MCH Cuttack, Odisha, India

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Corresponding author: Dr. Silvi Banerjee
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Abstract

Background: Cardiac Autonomic Dysfunction is reported in several cardiac pathologies. Heart Rate Variability (HRV) is a standard tool reflecting the Cardiac Autonomic status. Respiration is an important modulator of Heart Rate Variability. So as Physiologists, we designed a research plan to study the effect of a Physiological Intervention (ie Deep Breathing Exercise) on Heart Rate Variability.

Hypothesis: Our hypothesis was Deep Breathing Exercise Training for a considerable duration leads to improvement in HRV.

Aim: We conducted our research plan to study the effect of Deep Breathing Exercise on Heart Rate Variability (HRV) in healthy subjects.

Methodology: This is a prospective case-control study conducted for 1 year (November 2014 to October 2015) including 70 non-smoking healthy men. Control Group (n=35) - No intervention. Study Group (n=35) – Intervention (Deep Breathing Exercise Training). Initial and Final Assessments (Including HRV Analysis) of all subjects were done.

Results: The baseline parameters of the two groups were similar. Time Domain Components of HRV Analysis showed a significant increase ($p < 0.05$) in the Study Group as compared to the Control Group. Frequency Domain Component of HRV Analysis (LF: HF Ratio) showed a significant decrease ($p < 0.05$) in the Study Group.

Conclusion: Our study shows that Deep Breathing Exercise Training at a rate of 06 (six) breaths per minute for 30 minutes per day for one month either in supine or sitting position is an Effective Physiological Intervention for improvement of HRV and maintenance of Normal Sympatho-Vagal Balance.

Keywords: HRV, Deep Breathing Exercise, Cardiac Autonomic Status, Sympatho-Vagal balance.

Introduction

The human heart is not an ideal metronome with fixed interbeat intervals or zero beat-to-beat variations. [1] Rather, a healthy heart exhibits a complex pattern of interbeat variations in terms of interbeat intervals, spectral power, and other non-linear components. These Cardiac interbeat variations equip healthy heat to cope with sudden physical changes and stressful situations. And are very important for the maintenance of homeostasis. Several physiological conditions where interbeat variations are markedly evident like physical exercise, playing, singing, change in body posture, fear, mental stress, etc. The interbeat variations are greatly influenced by cardiac inputs from the Autonomic Nervous System. These interbeat variations reflect the functional integrity of the Cardiac Autonomic System. [1]

Cardiac Autonomic Dysfunction is reported in several cardiac pathologies. [2,3,4] Thus, it became imperative to develop a standardized tool to estimate the Cardiac Autonomic status of an individual. Researchers and scientists had developed Heart Rate Variability (HRV) as a challenging tool to satisfactorily mirror the Cardiac Autonomic status of an individual. Heart Rate Variability (HRV) is a non-invasive and non-pharmacological tool that measures the interbeat variations among successive R-R intervals caused by oscillations in the autonomic inputs (Sympathetic and Parasympathetic supply) to the Cardiac Pacemaker, ie Sino-Atrial node (SA node). Heart Rate Variability reflects an individual's Cardiac Autonomic status or Sympatho-vagal balance. The other commonly used terms for Heart Rate Variability are 'Cycle Length Variability' or 'R-R interval Variability'. [5,6]

Thus, Heart Rate Variability (HRV) is a standard tool to measure Interbeat Variations reflecting the Cardiac Autonomic status. Abnormal Heart Rate Variability (HRV) or Cardiac Autonomic Dysfunction is reported in several cardiac pathologies like Congestive Cardiac Failure, Coronary Heart diseases, Increased risks of Sudden Cardiac deaths, etc. [2,3,4] So, it's important to conduct scientific studies to develop various physiological or pharmacological interventions focused on the maintenance of Heart Rate Variability (HRV) within an optimal level. [1,7] Extensive studies are continuing on various Pharmacologic Interventions like ACE Inhibitors, Bradycardiac agents, etc, targeting the improvement of Heart Rate Variability (HRV). [8,9] Extensive studies are also continuing on different Physiological procedures or maneuvers like changes in respiratory frequency, posture changes, High-stress activity (Public speaking), High Energy Expenditure activity (Exercise), affecting Heart Rate Variability (HRV). [10,11]

Respiration is an important modulator of Heart Rate Variability. [17]. So as Physiologists, we designed a research plan to study the effect of a Physiological Intervention (ie Deep Breathing Exercise) on Heart Rate Variability. We hypothesized that Deep Breathing exercise training for a considerable duration leads to improvement in Heart Rate Variability (HRV). Hence, we conducted our research plan with an aim to study the effect of Deep Breathing Exercise on Heart Rate Variability (HRV) in healthy subjects.

Material and Methods

Study Design: This is a Prospective case-control study designed to study the effect of Deep Breathing Exercise on Heart Rate Variability (HRV) in young healthy subjects.

Study Approval: Our study approval was obtained from the Institutional Ethics Committee of SCB MCH, Cuttack. Informed written consent was mandatorily obtained from the participants before participating in the study.

Study Duration: The study was conducted for a period of 01 (One) year (November 2014 to October 2015).

Study Place: This is a monocentric study conducted in only one center i.e., Department of Physiology, S.C.B Medical

College and Hospital, Cuttack, Odisha, India.

Study Population: The study participants were healthy males recruited from Cuttack city, Cuttack, Odisha, India.

Inclusion Criteria: The eligible participants were lifetime non-smoking healthy males in the age group of 21 to 35 years with a Body Mass Index of 19-25 kg m-2. The participants must be performing sedentary to moderate levels of physical activity.

Exclusion Criteria: Subjects with respiratory diseases, Cardiovascular diseases, Diabetes Mellitus, or any other neurological illness were excluded from the study. Subjects involved in a high level of physical activities or practicing any type of breathing exercises, or any type of Yoga were excluded from the study. Also, subjects involved in playing mouth organ (Harmonica) or Flute or Trumpet blowers were excluded from the study.

Sample Size: A total of 70 eligible participants participated in the study. The study participants were placed in two groups:

- Control Group (n=35)
- Study Group (n=35)

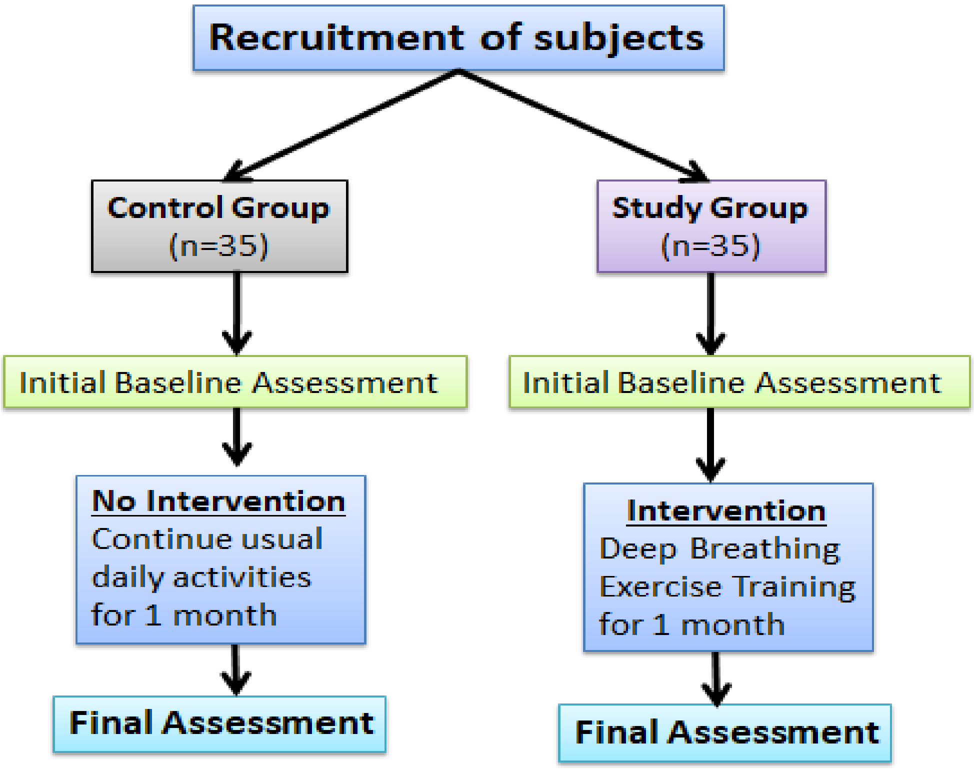

Figure 1: Study Procedure

Study Procedure:

Recruitment of subjects: Advertisements in the form of public notices were posted at different prime locations of Cuttack City. Public meetings were conducted with a focus on sensitizing youth mass regarding Cardiac illness, Heart Rate Variability (HRV), the significance of deep breathing exercise training, and its expected impact on HRV. Followed by recruitment of subjects for the study. Finally, Eligible participants were randomly placed in two groups:

- Control Group (n=35): No Intervention for 01 (one) month.
- Study Group (n=35): Physiological Intervention [Deep Breathing Exercise Training for 01 (one) month.]

Assessments of the subjects: It involved two steps

1. **Initial Baseline Assessment:** It was done at the beginning of the study in the Department of Physiology, SCB Medical College and Hospital, Cuttack between 9:00 am to 11:00 am to avoid diurnal fluctuations. It included the collection of Behavioral and Socio-Demographic profiles (Name, Age, Sex, Contact number, Educational Status, Socio-Economic Status, Occupation, Level of Physical Activity, etc.). Anthropometric measurements including Weight, Height, Body Mass Index (BMI), etc. Clinical and Laboratory Examinations including Blood Pressure, Respiratory Rate, 5-minutes ECG, Heart Rate Variability (HRV). Blood Pressure was recorded manually with a sphygmomanometer.
2. **Final Assessment:** It was done in the Department of Physiology, SCB Medical College and Hospital, Cuttack between 9:00 am to 11:00 am after one month from the beginning of the study. The same parameters were again assessed in the Final assessment.

Physiological Intervention: In the Control Group, subjects were not given any intervention. They were advised to continue their usual day-to-day activities without the inclusion of any new exercise protocol. In the Study Group, subjects were given a Physiological Intervention (Deep Breathing Exercise Training). Deep Breathing Exercise Training is a programmed Breathing Exercise Protocol. It included slow and deep breathing at a rate of 06 (six) breaths per minute for 30 minutes per day for a period of one month either in a supine or sitting position. As the breathing rate was 6 breaths per minute, the duration of one complete breath was 10 seconds (Maintaining Inspiration- 04 seconds and Expiration- 06 seconds). Subjects were guided by pre-recorded Audio commands in an Audio CD indicating the time of Inspiration and Expiration. Such pre-recorded Audio CDs were distributed to the subjects of the Study Group. Again, the subjects needed to perform the deep breathing exercise for a period of 30 minutes per day which can be done in one compact session of 30 minutes or two divided sessions of 15 minutes each at any suitable time of the day. Subjects were given a small pocket diary to note their regular deep breathing exercise schedule. Routine follow-up of the subjects was done by making a telephonic call to their registered mobile number.

Heart Rate Variability (HRV): HRV Indices were obtained from supine 5-minute ECG during Initial Baseline Assessment and Final Assessment of all the subjects (Both Control Group and Study Group). Subjects were asked to reach the Physiology Laboratory, Department of Physiology, SCB Medical College and Hospital, Cuttack between 9:00 am to 11:00 am. Subjects were advised to refrain from Caffeinated and alcoholic beverages for 12 hours prior to the Assessment. After 30 minutes of rest in the supine position, a 5-minute ECG recording was done in the supine position followed by Signal amplification, Data Analysis, and recording of HRV Indices.

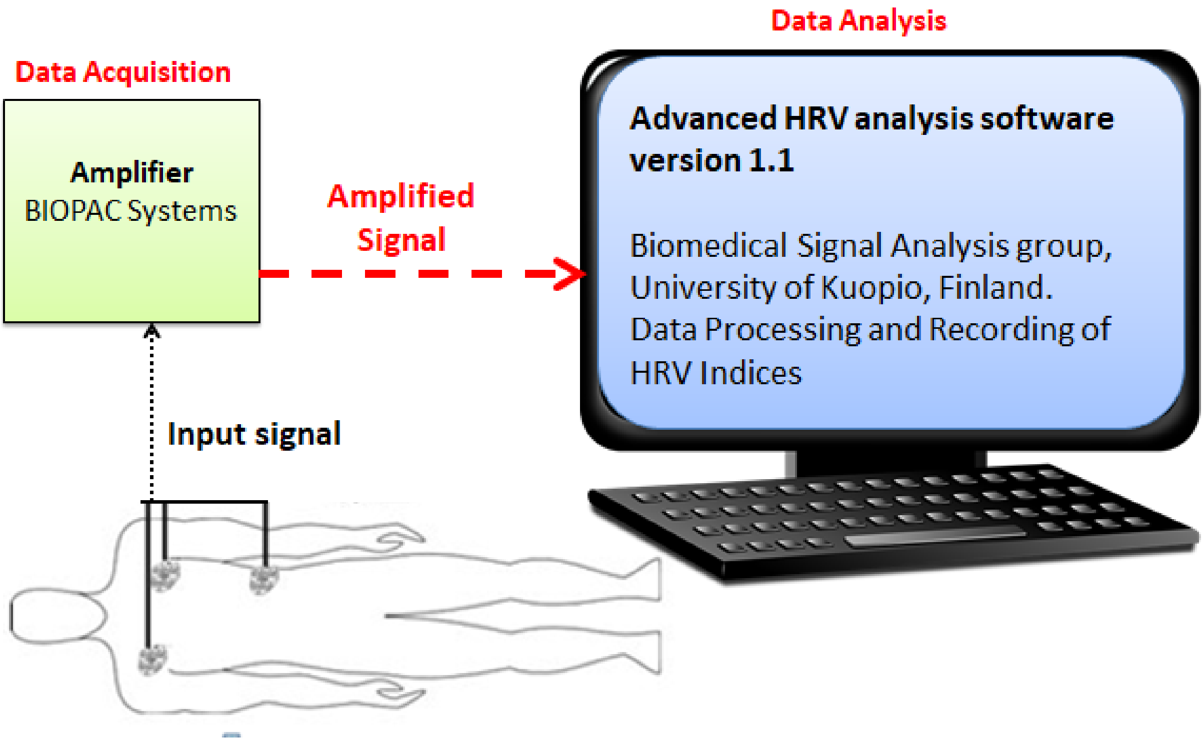

Figure- 2 : Schematic Representation of Data Acquisition and HRV Analysis

Signal amplification was done by Amplifier (Manufactured by BIOPAC SYSTEMS, Inc., CA 93117, USA.) The input ECG signals were received by the Amplifier and Amplified signals were directed to the computer. In the computer, incoming data were processed and HRV Analysis was done by the Advanced HRV Analysis Software of Version 1.1 (Manufactured by Biomedical Signal Analysis Group of University of Kuopio, Finland.) [Figure- 2.]

The Time Domain component of HRV Analysis represented quantification of Interbeat Interval (IBI) variations among successive heartbeats. Time Domain Components of HRV analyzed in our study are Standard Deviations of Normal-to-Normal intervals (SDNN), Root Mean Squared Standard Deviation (RMSSD).

The frequency Domain component of HRV Analysis represented quantification of Intrabeat Power variations or Intrabeat signal energy variations. Frequency Domain of HRV Analysis involved decomposition of input ECG signal or power into its constituent frequency bands. Just like a Glass Prism scatters a white light into its constituent frequency bands from Red to Violet. Similarly, HRV Analysis software (By Fast Fourier Transformation) decomposes input ECG signal or power into the following major broad Frequency Bands: High-Frequency Power (HF), Low-Frequency Power (LF), Very Low-Frequency Power (VLF).[Figure- 3.] In this study, Frequency Domain Components of HRV Analyzed are Low-Frequency Power (LF Power in ms^{-2}), High-Frequency Power (HF Power in ms^{-2}), and Ratio of Low-Frequency Power to High-Frequency Power (LF/HF ratio). [1,13]

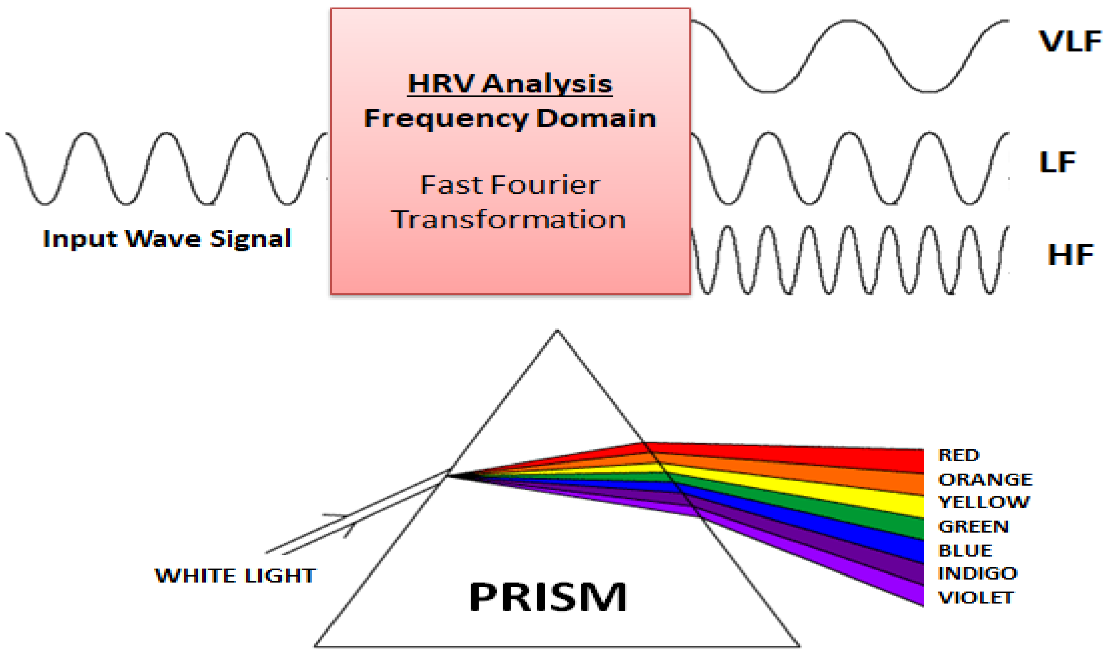

Figure- 3. Schematic Representation of HRV Analysis: Frequency Domain.

Statistical Analysis: Data entry was done in Microsoft Excel 2016 and Statistical Software version **SPSS 22.0.** $p < 0.05$ was considered statistically significant. Frequency, Percentage, Descriptive Statistics, and Chi-Square tests were applied to analyze the data.

Results

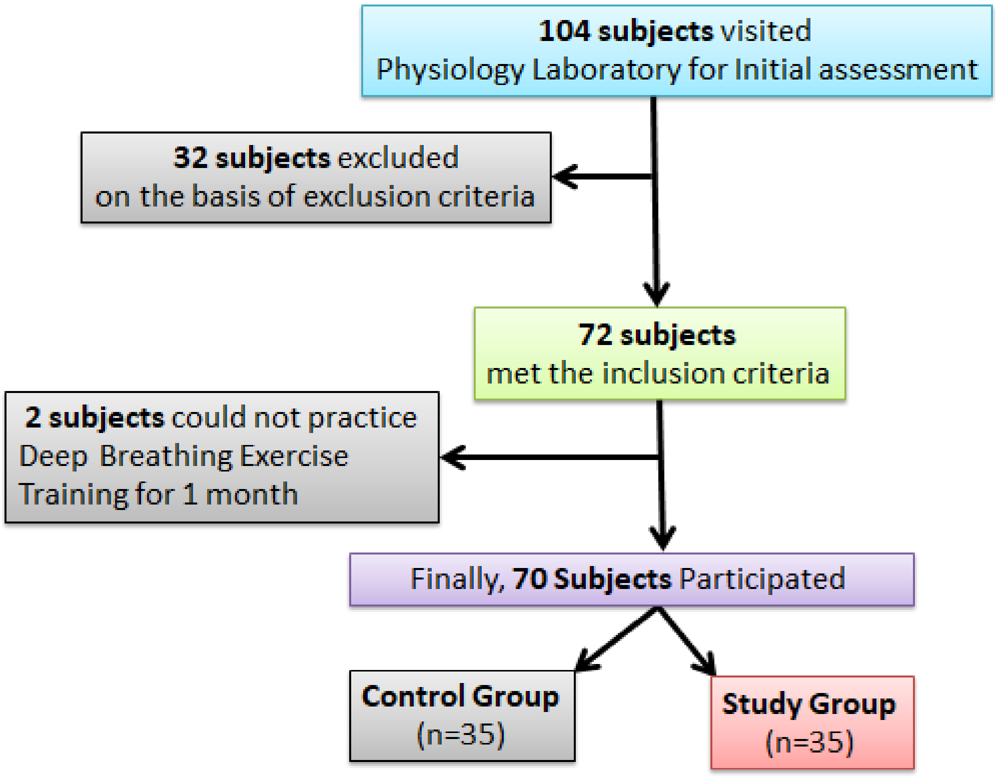

Figure- 4 : Selection of Eligible Participants

Following advertisements and public meetings, a total of 104 men showed interest to participate in this study and attended for baseline assessment in the Department of Physiology, SCB Medical College and Hospital, Cuttack between 9:00 am to 11:00 am. But 72 subjects were eligible participants for the study and 32 men (02 men– Asthma; 04 men - Hypertension; 01 man-Cardiac diseases; 8 men– Obesity, 7 men- Already practicing Yoga, 8 men- Involved in Heavy Physical Exercise, 2 men- Trumpet Blowers) were excluded based on the exclusion criteria. Informed written consent was obtained from 72 eligible participants. Again, 02 eligible participants were unable to continue the Deep Breathing Exercise Training. Finally, 70 subjects [Control Group (n=35) and Study Group (n=35)] participated in the study, and their data were considered for analysis. [Figure- 4.]

Table 1: Baseline Characteristics and Socio-Demographic variables

Variables		Control Group (n=35)	Study Group (n=35)
Age (years)		26.6 ± 3.42	26.8± 3.34
Weight (kg)		59.12± 4.92	58.96 ± 4.88
Height (cm)		165.1± 4.34	164.96 ± 4.68
BMI		21.68± 1.68	21.62 ± 1.84
Levels of Physical Activity	Sedentary	6	5
	Mild	15	13
	Moderate	14	17
	Severe	Nil	Nil
Socio-Economic Status (Based on Modified Kuppuswamy's Socioeconomic scale 2012)	Upper	6	6
	Upper Middle	14	13
	Lower Middle	8	7
	Upper Lower	6	7
	Lower	1	2

*p<0.05 Significant

Data are expressed either as mean±SD or number of subjects.

There was no significant difference between the Control Group and Study Group for Baseline Characteristics and Socio-Demographic variables (Age, Weight, Height, Body Mass Index BMI, Levels of Physical Activity, Socio-Economic status). [Table- 1.] All the subjects in the Control Group and Study Group had Blood Pressure and Respiratory Rate within normal range without any significant inter-group difference. (Table-1.)

Table 2: Heart Rate Variability Indices

Parameters	Control Group (n=35)	Study Group (n=35)
SDNN (ms)	41.18±13.38	50.82±20.42*
RMSSD (ms)	41.58±21.32	63.02±30.96*
LF Power (ms^{-2})	898.86±642.55	830.98±625.06
HF Power (ms^{-2})	782.02±699.98	1479.02±1218.92
LF: HF Ratio	1.45±1.18	0.65±0.40*

*p<0.05 Significant

Data are expressed as mean±SD

Time Domain Components of Heart Rate Variability HRV Analysis (ie SDNN, RMSSD) showed a significant increase ($p < 0.05$) in the Study Group as compared to the Control Group. (Table- 2.) This indicated that there is an increase in HRV Indices following Deep Breathing Exercise Training in the Study Group.

Frequency Domain Components of Heart Rate Variability HRV Analysis showed the following results. The Low-Frequency Power (LF Power) showed a decrease in the Study Group as compared to the Control Group, but the decrease was not significant. The High-Frequency Power (HF Power) showed an increase in the Study Group as compared to the Control Group, but the increase was not significant. However, The LF: HF Ratio showed a significant decrease ($p<0.05$) in the Study Group as compared to the Control Group. (Table- 2.) This showed shifting of balance towards Parasympathetic Dominance favorable for rest, psychological resilience, adaptability to environmental changes, and behavioral flexibility. Thereby resulting in improvement of HRV Indices towards the maintenance of an overall stable Sympatho-vagal balance (Cardiac Autonomic Status) following Deep Breathing Exercise Training in the study group.

Discussion

Young healthy non-smoking subjects were included in the study. Smokers were excluded from the study because several studies had observed the negative effect of cigarette smoking on Heart Rate Variability. [13,14] Obese subjects with high BMI were also excluded from the study to avoid the effect of obesity on HRV. Studies have already shown the profound effects of obesity on HRV. [15,16]

Physiological Intervention:

Deep Breathing Exercise: Respiration modulates HRV both by Neural and Non-Neural Mechanisms. Neural control includes Autonomic Nervous System via Arterial Baroreflex. Respiration alters venous return to the heart, thereby affecting stroke volume. Alteration in Stroke Volume is reflected as changes in blood pressure leading to activation of baroreceptors. Stimulation of baroreceptors further causes a Fast Vagal response and a Slow Sympathetic response thereby producing new oscillations and resulting in Beat-to-Beat fluctuations ie HRV. Thus, Changes in respiratory rate via Baroreceptors affect Sympatho-vagal balance and Heart Rate Variability. Again, studies have shown that slow and deep breathing at a rate of 6 breathes per minute (0.1Hz), had maximum Cardio-Vascular variability. [17,18] Hence, in this study, we had included Deep Breathing Exercise Training at a rate of 06 (six) breaths per minute for 30 minutes per day for a period of one month either in a supine or sitting position as a Physiological Intervention to study the effect of Deep Breathing Exercise on Heart Rate Variability. [19]

Heart Rate Variability (HRV)

The intrinsic heart rate of a denervated human heart at the time of heart transplantation is 100 beats per minute. Denervated heart had no sympathetic or parasympathetic supply. Heart rate below 100 beats per minute shows Parasympathetic Dominance and Heart rate above 100 beats per minute shows Sympathetic Dominance. The average 24-hour heartbeat of a normal healthy human is 72 beats per minute. It shows Parasympathetic dominance in healthy subjects. [11]

There exists a significant relationship between Heart Rate (HR) and Heart Rate Variability (HRV). When Heart Rate increases, the time between heartbeats decreases, and less time is available for variability to occur. Thus, Heart Rate Variability decreases with an increase in Heart Rate. Conversely, When Heart Rate decreases, the time between heartbeats increases and more time is available for variability to occur. Thus, Heart Rate Variability increases with a decrease in Heart Rate. This is referred to as “Cycle

Length Dependence of Heart Rate Variability". [11]

LF/HF ratio of HRV is a reflection of the Sympatho-Vagal balance. [10] LF power is mainly produced by the Sympathetic Nervous System. HF Power is generated by Parasympathetic Nervous System. Low LF/HF ratio indicates Parasympathetic Dominance seen in conditions like relaxing and resting. A high LF/HF ratio indicates Sympathetic Dominance seen in conditions like Fear, Fight, or Flight. [1]

Thus, it is observed that during parasympathetic dominance, LF/HF ratio decreases, and Heart Rate Decreases. As HR decreases, Heart Rate Variability increases (Cycle Length Dependence of Heart Rate Variability).

In our study, Time Domain Components of HRV Analysis (ie SDNN, RMSSD) showed a significant increase ($p< 0.05$) in the Study Group as compared to the Control Group. (Table- 2.) This indicated that there is an increase in HRV Indices following Deep Breathing Exercise Training in the Study Group.

Frequency Domain Components of Heart Rate Variability HRV Analysis showed the following results. The Low-Frequency Power (LF Power) showed a decrease in the Study Group as compared to the Control Group, but the decrease was not significant. The High-Frequency Power (HF Power) showed an increase in the Study Group as compared to the Control Group, but the increase was not significant. However, The LF: HF Ratio showed a significant decrease ($p<0.05$) in the Study Group as compared to the Control Group. (Table- 2.) This showed shifting of balance towards Parasympathetic Dominance favorable for rest, psychological resilience, adaptability to environmental changes, and behavioral flexibility. Thereby resulting in improvement of HRV Indices towards the maintenance of an overall stable Sympatho-vagal balance (Cardiac Autonomic Status) following Deep Breathing Exercise Training in the study group.

Limitations of the study:

Our study had the following important limitations:

1. In this study, we have done short-term HRV (5-minutes). But, 24-hour HRV recording is the "GOLD STANDARD" which includes the effect of Circadian rhythms, Sleep cycle, metabolism, Core Body temperature, and Renin-Angiotensin System. [1]

2. In our study only young healthy males were taken as subjects. The inclusion of female subjects would have further given a better-generalized result.

Conclusion

Heart Rate Variability (HRV) is a standard tool to measure Interbeat Variations reflecting the Cardiac Autonomic status. Abnormal Heart Rate Variability (HRV) or Cardiac Autonomic Dysfunction is reported in several cardiac pathologies like Congestive Cardiac Failure, Coronary Heart diseases, Increased risks of Sudden Cardiac deaths, etc. [2,3,4] So, it's important to conduct scientific studies on various physiological or pharmacological interventions focused on the maintenance of Heart Rate Variability (HRV) within an optimal level. [1,7] Our study shows that Deep Breathing Exercise Training at a rate of 06 (six) breaths per minute for 30 minutes per day for a period of one month either in supine or sitting position is an Effective Physiological Intervention for improving Heat Rate Variability (HRV) and maintenance of normal Sympatho-Vagal balance. Further studies are needed to develop a Standard Physiological Intervention Design like a Deep Breathing Exercise Training Protocol for improvement Heat Rate Variability (HRV) and maintenance of normal Sympatho-Vagal balance in Health and disease.

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