RESEARCH ARTICLE

TO STUDY AND CORRELATE THE EFFECT OF INTEGRATED APPROACH OF YOGA THERAPY ON FREQUENCY DOMAIN PARAMETERS AND POINCARE PLOT OF HEART RATE VARIABILITY AMONG PREDIABETICS

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Introduction-
Prediabetes is demarcated as an intervening stage amongst normal glucose tolerance and type 2 diabetes mellitus. The present study aimed to evaluate the effects of the integrated approach of yoga therapy on linear and nonlinear dynamics of heart rate variability and correlate between a linear component that was frequency domain and nonlinear dynamics that was Poincare plot of heart rate variability.

Method-
The study was conducted in the Department of Physiology, Rajasthan University of Health Sciences, Jaipur in association with RDBP Jaipuria hospital. Group A was involved in the integrated approach of yoga therapy (IAYT) including Prayer, Omkar recitation, yoga postures, breathing techniques, Shavasana, counseling, and dietary modification and Group B was not involved in any yoga sessions.

Result-
In this study, an attempt has been made to assess specifically the nonlinear dynamics of HRV using Poincare plot after the integrated approach of yoga therapy and compare it with that of the frequency domain of HRV assessed by linear measures. The high-frequency power (46.04 ± 11.75 to 67.56 ± 13.06) and SD1 (28.75 ± 3.15 to 45.66 ± 2.15) were increased and low-frequency (LF) power (66.67 ± 11.87 to 40.67 ± 13.9) and the SD2 (55.76 ± 1.15 to 44.88 ± 2.15) of the Poincare plot decreased compared to baseline in subjects who followed the integrated approach of yoga therapy. Additionally, significant correlations were found between high frequency (HF) and SD1 (p < 0.05), LF and SD2, (p < 0.05), and LF/HF and SD2/SD1 (p < 0.01).

Conclusion-
Integrated approach of yoga therapy practiced regularly can emerge as one of the important non-pharmacological tools for primary prevention of cardiovascular disease and restoring sympathovagal balance. Poincare plot analysis is easier and more sensitive in evaluating the sympathovagal balance and observing the variation in heartbeats.

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and stress. Classically, there transpires the failure of the body to metabolize the carbohydrates, proteins, and fats properly, henceforth, presents with hyperglycemia that is elevated blood sugar level. Hypertension, dyslipidemia, chronic inflammation, hypercoagulation said to be metabolic abnormalities are the co-morbidities to prediabetes. The physiological abnormality of prediabetes starts with the pancreas.

Heart rate variability (HRV) is the time interval between two successive heartbeats which is a non-invasive method to assess the dominance of the autonomic nervous system.

Cardiac autonomic dysfunction (CAF) is associated with metabolic abnormalities including obesity, insulin resistance, metabolic syndrome, diabetes, and is measured by heart rate variability. Yogasinghasana and breathing practices (pranayama). Hence the regular practice of this, the autonomic system shifted to parasympathetic dominance. The parasympathetic system is conserved for the retention and restoration of physical and energy resources. This is achieved by decreasing cardiac and digestive function, promoting secretions. Heart rate variability (HRV) has been used as a noninvasive marker of cardiac autonomic activity and cardiovascular risk assessment. HRV is an index of vagal tone and reflects the balance between the sympathetic and parasympathetic systems. Sympathetic nervous system activation increases heart rate and decrease variations in variability, whereas parasympathetic nervous system activation decreases heart rate and increases variation in variability.

Conventionally, there were linear and nonlinear dynamics for assessment of heart rate variability. In linear dynamic time and frequency domain analysis in time domain using the various statistical measures and in the frequency domain analysis using the spectral analysis by Fast Fourier transformation. However, time and frequency domain methods have got some technical limitations and in some cases, these methods are insensitive and more susceptible to interference by ectopic rhythm.

In nonlinear dynamics, heart rate variability was assessed by Poincare plot and histogram. The analysis of Poincare plots of RR intervals was an emerging method of nonlinear dynamics applied in HRV analysis. The Poincare plot analysis was a nonlinear and geometric method to assess the nonlinear dynamics of heart rate variability. It is a plot in which each R-R interval was denoted as a function of the previous R-R interval where the values of each pair of subsequent R-R intervals represent a point in the plot. Poincaré plots have evaluated in a qualitative way using their visual pattern whereby the shape of the plot is categorized into functional classes that had a prognostic value in cardiovascular disease and can be evaluated quantitatively through the computation of the Standard deviation indexes of the plot. Hence, Poincare plot analysis may be a better way to monitor the nonlinear dynamic variation of autonomic function after the integrated approach of yoga therapy. Genesis of HRV also involves the nonlinear phenomena, which are determined by complex interactions of hemodynamic, electrophysiological, and humoral variables, as well as by autonomic and central nervous regulations. Hence, the analysis of the nonlinear dynamics of heart rate variability would enable a better physiological interpretation of the variation in heart rate. Poincare plot of RR intervals was an important visual tool, which was capable of analyzing whole RR time series derived in one frame, and a quantitative technique which gives information on short and long-term HRV. However, studies on the nonlinear component of HRV after the integrated approach of yoga therapy were not well documented. Therefore, in this study, an attempt has been made to assess the nonlinear dynamics of HRV by using the Poincare plot after an integrated approach of yoga therapy and comparing it with that of the linear parameters. Using Poincare plot analysis may be a better way to assess dynamic changes of autonomic functions during meditation.

Methods:
The purpose of this study was to assess specifically the nonlinear dynamics of HRV using Poincare plot after the integrated approach of yoga therapy and compare it with that of the frequency domain parameters of HRV assessed by linear measures. The study was designed as cross-sectional pilot study conducted in a research yoga lab at the department of physiology, RUHS College of Medical Sciences & Associated Hospitals, Jaipur.

The sample size was calculated by using the formula \( z^2 pq/d^2 \) where \( p \) and \( q \) were taken as .08 and .92 to get the sample size with 5% precision and 10% non-response rate. The sample size was 250 with a 95% confidence interval. Subjects were divided into Group A and Group B. Group A was control and Group B was a study group that engaged in an integrated approach of yoga therapy. Participants included have fasting blood glucose level of 110 to 125 mg/dL and glycated hemoglobin 5.7 to 6.4 (ADA criteria).
of medications. Subjects who have Fasting blood glucose less than 100 mg/dL and greater than 126 mg/dL, Liver disease, renal dysfunction, alcoholic individuals, interstitial fibrotic disease, spinal injury, retinopathy & nephropathy those being treated with anti-inflammatory medication were excluded.

The Integrated Approach of Yoga Therapy included Prayer, Omkar recitation, yoga asanas, pranayama, Shavasana, Counselling, and dietary intervention. In dietary intervention, each participant received a diet plan from a qualified dietician as per dietary guidelines for Asian Indians. In brief, guidelines the recommended nutrient composition for daily diet included 50%–60% carbohydrates, less than 30% total fat, less than 10% saturated fat, 10%–15% monounsaturated fat, 5%–8% polyunsaturated fat, less than 200–300 mg cholesterol, 10%–15% protein, 25–40 g dietary fiber, and less than 5 g salt. Subjects were instructed to record their daily food intake in a dairy. Asanas and posture that included Sukhasana, Bhujangasana, Suryanamaskar, Pashimottanasana, Tadasana, Padmasana, Ardhamatsyendrasana, Nataryangasana, Pawanmuktasana, Vajrasana, Dhanurasana, Shavasana. Yoga asanas were supervised and demonstrated by certified yoga instructors. Yoga sessions were approximately 45 minutes six days per week for six months. To facilitate home practice, participants were given video clips of the yoga asanas recorded under the direction of the certified yoga instructor, compliance of subjects was checked by daily messages on WhatsApp and weekly telephonic conversions with subjects and family members. The evaluation was done baseline and after six months of integrated approach of yoga therapy, then after three and six months of post-intervention. After obtaining ethical clearance from the institutional ethics committee, participant information sheet and written informed consent form were obtained. A detailed history was taken and a detailed general physical examination was conducted. Anthropometric measurements were taken and baseline ECG was recorded for 5 minutes.

Analysis of heart rate variability-

The electrodes were placed on the pressure pad of the Finger Pulse Transducer. The HRV analysis is in the frequency domain reflects the speed variation in heart rate. Further, this method also gives information about different frequency components of the N-N intervals and their power, or variance. ECG signals were recorded by a digital physiograph (AD instruments). The signals were filtered digitally and processed to extract QRS peaks which determine the R-R intervals. These QRS peaks were automatically detected and were reviewed visually for R-wave determination and ectopic beats. Areas of ECG in which identification of beats was poor or ectopic beats were present were excluded. The time and frequency domain indices were computed from 5-minute segments.

Frequency domain analysis:

Frequency domain analysis was done by power spectral analysis using fast Fourier transformation. The frequency-domain indices included low frequency (LF; 0.04–0.15 Hz), high frequency (HF; 0.15–0.4 Hz), LF/HF ratio. Nonlinear dynamics:

assessed by Poincaré plot which is a graphical representation in which each R-R interval of tachogram is plotted against the previous R-R interval. It is a two-dimensional graphic representation of the correlation between consecutive RR intervals, in which each interval is plotted against the following interval and its analysis can be done qualitatively, by assessing the shape formed by its attractor, which shows the degree of complexity of RR intervals, or in a quantitative way. The quantitative analysis is done by fitting an ellipse to the shape formed by the plot and measuring the dispersion along the major and minor axis of the ellipse. There are two standard descriptors of the Poincaré plot namely: Standard deviation 1: The length of the transverse line is defined as the SD1 of the plot data in a perpendicular direction. It is the standard deviation (SD) of the instantaneous (short-term) beat-to-beat R-R interval variability (minor axis of the ellipse or SD1).

Standard deviation 2: The length of the longitudinal line is defined as the SD2 of the plot data. It is the SD of the long-term R-R interval variability (major axis of the ellipse or SD2).

Furthermore, additional parameters were computed which included: Area of the ellipse (S): It is given as the amount of area covered by the ellipse. It is calculated by doing the product of π, SD1, and SD2. It represents total HRV. A normal configuration of the plot was defined as a fan of comet shape. Abnormal forms were a random pattern characterized by asymmetrical RR-interval clusters; a torpedo-shaped pattern with narrow configuration that lacked RR-interval dispersion.
Statistical Analysis:
Mean and standard deviations are calculated for each parameter. The appropriate tool for comparing the change in the level of a variable is the student’s paired t-test for Intragroup comparison before applying this test the Smirnov-Kolmogorov test is conducted to confirm the normality of each parameter. For all the variables normality is confirmed. The level of significance is taken at 5%. Tables are constructed to show the mean and standard deviation for the various parameters. Inference of significance is drawn on the value of p. Apart from comparing the various parameters of the data concerning before and after the integrated approach of yoga therapy, the comparison is made concerning a control group. There are 125 people in this group. To show that initially, the two groups are on the same platform for each parameter, the student’s unpaired t-test is conducted for Intergroup comparison. If the value of p is more than 5%, for any parameter, that shows there is no significant difference between the two groups.

Results:

Table 1: Age and Gender distribution of Prediabetic Subjects.

| Age group   | Male | Female | Total |
|-------------|------|--------|-------|
| 30-40 years | 35   | 65     | 100   |
| 41-50 years | 50   | 100    | 150   |
| Total       | 85   | 165    | 250   |

Table 1 depicts the Age and Gender distribution of the prediabetic population. In “Age group of 30-40 years out of 100 subjects males was 35 and female was 65 &In the age group between 41-50 years Out of 150 subjectmale was 50 and female were 100, majority of subjects were females belongs to 41-50 years age group. The mean age in the control group was 44.5 ± 3.8 years and in the study group was 45.8±4.1 years.

Table 2: Base Line Parameters Before and after Integrated approach of yoga therapy.

| S.No | Baseline parameters | Control Pre | Control Post | Study Pre | Study Post | p-value |
|------|---------------------|-------------|--------------|-----------|------------|---------|
| 1.   | BMI                 | 28.6±3      | 28.7±2       | 27.8±7    | 26.8±4     | <.001   |
| 2.   | Waist hip Ratio     | 90 ±6       | 92 ±6        | 91 ±7     | 85 ±4      | <.05    |
| 3.   | Blood pressure SBP  | 152±8.3     | 153±8.4      | 154±7.3   | 130.7±10.1 | <.002   |
|      | DBP                 | 90.8±4.2    | 90.7±4.3     | 92.8±4.2  | 88.3±3.9   | <.001   |
| 4.   | Pulse Rate          | 90.2±9.8    | 90.1±8.8     | 89.2±9.7  | 82±8.6     | <.05    |

Table 2 depicts that baseline parameter like body mass index, waist-hip ratio, blood pressure systolic and diastolic and pulse rate before and after the integrated approach of yoga therapy and results were about p-value significant.

Table 3: Intragroup Comparison of Results of Heart Rate variability.

| Parameters            | Pre (Baseline) | Post (After six months) | p VALUE |
|-----------------------|----------------|-------------------------|---------|
| Frequency domain      | Control        | Study                   |         |
| LF                    | 65.72±11.44    | 67.82±12.44             | .876    |
|                       | 66.67±11.87    | 40.67±13.9              | <.001   |
| HF                    | 45.90±11.79    | 36.85±12.08             | .689    |
|                       | 46.40±11.75    | 67.56±13.06             | <.001   |
| LF/HF Ratio           | Control        | Study                   |         |
|                       | 2.18±1.09      | 2.20±1.05               | .8862   |
|                       | 2.19±1.09      | .57±0.54                | <0.0001 |
| Poine care plot       | Control        | Study                   |         |
| SD1                   | 16.92±1.15     | 15.88±1.29              | .577    |
|                       | 28.75±3.15     | 45.66±2.15              |         |
| SD2                   | 30.45±1.15     | 36.45±1.15              |         |
|                       | 55.76±1.15     | 44.88±2.15              |         |
Table 3 depicts Mean and standard deviations of LF, HF, LF/HF Ratio & Poine care plot variables SD1 & SD2 in control and study groups at baseline and after six months of integrated approach of yoga therapy. The appropriate tool for comparison of the change in the level of a variable is the student’s paired t-test for intragroup comparison before applying this test the Smirnov-Kolmogorov test is conducted to confirm the normality of each parameter. For all the variables normality is confirmed. The level of significance is taken at 5%.

In the control group, pre and post results were not significant whereas study group there was a significant reduction in, LF and (LF/HF ratio), SD2, and a significant increase in HF and SD1 after six months of integrated approach of yoga therapy.

Figure 1: Poine care plot in the study group (baseline).

Figure 1 depicts the baseline shape as a narrower torpedo-like shape. An elongated, torpedo-like shape with decreased SD1/SD2 ratio is denotes increased sympathetic tone.

Figure 2: Poine care plot in the study group (After IAYT).

Figure 2 depicts a more oval, fan-shaped configuration resulting from increased SD1/SD2 ratio represents increased parasympathetic tone.
Table 4:- Correlation of power spectral indexes (LF, HF, LF/HF) and Poincare plot indexes (SD1, SD2, SD1/SD2) during meditation.

|       | LF  | HF  | LF/HF Ratio | SD1  | SD2  | SD2/SD1 |
|-------|-----|-----|-------------|------|------|---------|
| LF    | 1.00| 0.796* | 0.687*     | 0.429* | 0.561* | 0.556   |
| HF    | 1.00| −0.24 | .626        | −.684 | −.495 |         |
| LF/HF | 1.00| 1.08  | .674        | .811  |       |         |
| SD2   |    | −.884 | 1.0         | .874  |       |         |
| SD1   |    |      |             | −.753 |       |         |
| SD2/SD1 |    |      |             | 1.0    |       |         |

Results show there is a strong correlation b/w LF and SD2, HF and SD1, and LF/HF ratio and SD2/SD1.

Figure 4 depicts the results of correlation between spectral and Poincaré analysis shows LF/HF has a positive correlation with the SD2/SD1 ratio. HF was positively correlated with SD1 & HF, SD2 & LF.

Discussion:--

Studies on linear and nonlinear components of heart rate variability are not well documented. Hence, in this study, an attempt has been made to assess and correlate linear components that were frequency domain and nonlinear component like Poincaré plot after the integrated approach of yoga therapy.

The frequency-domain parameters like the High-frequency component (HF) reflect parasympathetic activity, the Low-frequency component (LF) reflects sympathetic modulation, and LF/HF ratio indicates sympathovagal balance. In this study, it was observed that in the spectral analysis, after the integrated approach of yoga therapy, which is show parasympathetic activity is stimulated after the integrated approach of yoga therapy with concomitant sympathetic withdrawal the outcome of the study has been found similar to studies undertaken by Meshram et al, Vinay et al, An H et al, Sarang et al.

The Poincaré plot is a geometrical representation that allows the identification of the presence of non-linear HRV components. In the Poincaré plots, the SD1 width reflects the parasympathetic activity; and the SD2 length reflects the sympathetic modulation. The shape of the Poincaré plot can be used to visually evaluate the sympathovagal balance. An elongated, torpedo-like shape with decreased SD1/SD2 ratio is denoted increased...
sympathetic tone, and a more oval, fan-shaped configuration resulting from increased SD1/SD2 ratio represents decreased sympathetic tone. In this study after six months of integrated approach of yoga therapy in Poincaré plots variables SD1 increases, the SD2 decreases, and SD1/SD2 ratio increases with a concurrent change of shape that was a narrower torpedo-like shape and after six months of integrated approach of yoga therapy fan shape. Results of the present study are in concurrence to studies done by Karmakar CK et al, Guzik P et al. In this present study results of correlation between spectral and Poincaré analysis shows LF/HF has a positive correlation with the SD2/SD1 ratio. HF was positively correlated with SD1 & HF, SD2 & LF results were similar with previous studies done by Bootsma M et al, Silke B et al, CarrascoS et al.

Poincaré plot may identify abnormalities that were not easily detectable with frequency domain measures. Poincaré plot analysis of R-R intervals provides prognostic information in various cardiovascular diseases. The Poincaré plots which use the unfiltered data have the advantage of being able to identify beat-to-beat cycles and patterns in the data. It has the advantage of being able to identify beat-to-beat cycles and patterns in the data. Moreover, the Poincaré plot may be better in the use of dynamic analysis than spectral analysis.

Hence, we assessed that the findings of the nonlinear dynamics of HRV are corroborative with linear dynamics. It was able to summarize an entire RR time series derived from an ECG in one frame, and a quantitative technique, which gives information on short and long-term HRV. The advantage of nonlinear analysis was that it does not require any preprocessing of data, which is needed in linear analysis. Nonlinear methods such as the Poincaré plot, entropy analysis, detrended fluctuation analysis (DFA) & heart rate complexity analysis were newly developed tools used for identifying nonlinear patterns within electrocardiogram.

Limitations of the study:
Studies should be conducted in larger sample sizes and analysis by logistic regression and multicentric to further establish the predictive and investigatory importance of Poincare plot analysis and its predictive role in the assessment of cardiovascular risks.

Conclusion:-
In the control group, pre and post results were not significant whereas study group there was a significant reduction in (LF/HF Ratio) after six months of integrated approach of yoga intervention. HF power spectrum showed an increasing trend in the short-term practice of yoga. The decrease in LF/HF ratio in this study was likely to be predominated by sympathetic withdrawal and increasing parasympathetic activity. This study depicts the effect of the long-term practice of yoga can help in shifting the autonomic nervous system towards parasympathetic dominance. The Poincaré plot is visually more discernible to detect this autonomic change, showing the potential to evaluate the dynamic change associated with the integrated approach of yoga therapy. For better dynamic monitoring the Poincaré plot provides a qualitatively and quantitatively visual measure of sympathovagal activity.

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