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Heart Rate Variability in Gym - Goers and Response to Paced Breathing

[1]Ibtihal Abdulsalam Yousef Aldawood, [2]Dr. Nusrat Aziz

[1]Dept. of Medical Education, Medical Laboratory Technician, Umm Al-Qura University Makkah Saudi Arabia

[2]Dept. of Physiology, Associate professor Dr. VRK Women's Medical College Teaching Hospital and Research Center, Kaloji Narayana Rao University of Health Sciences, Hyderabad, Telangana, India

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Corresponding Author: Dr. Nusrat Aziz, Dept. of Physiology, Associate professor Dr. VRK Women's Medical College Teaching Hospital and Research Center, Hyderabad, Telangana, India

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ABSTRACT

Objective

In recent days more incidence of sudden cardiac deaths among young and visibly fit exercisers at gyms has been observed. Regular exercise meditation mindfulness and resonant breathing have been known to increase heart rate variability, a sign of parasympathetic dominance and an indicator of wellbeing and longevity. We attempted to analyze the acute response in HRV to paced breathing of 6 breaths per minute in regular gym goers and those who do not do any regular exercise routine.

Methods

ECG was recorded using limb leads for duration of 5 minutes with spontaneous breathing pattern followed by another 5 minutes with paced breathing of 6 breaths per minute. HRV was analyzed for their time domain frequency domain and Poincaré plot standard deviation.

Results

The results showed significantly increased RMSSD, SDRR, LF/HF and SD2 during paced breathing from spontaneous breathing in gym-goers. Significant increase in SDRR, RMSSD, LF, SD1, and SD2 from those of spontaneous breathing was also seen in participants who do not do regular exercise.

Conclusion

Both of the responses indicate enhanced baroreceptor reflex activity during paced breathing as seen with parasympathetic dominance. The effects of regular exercise are additive and can be used in conjunction with paced breathing to promote health, increase

longevity enhance performance and protect against the detrimental effects of stressful modern life.

Keywords

Baroreceptor reflex sensitivity, exercise, heart rate variability, paced breathing, respiratory sinus arrhythmia

INTRODUCTION

The autonomic nervous plays a critical role in body function by which it controls the heart rate blood pressure respiratory and gastrointestinal tract keeping the balance between the energy requirement and the energy supply. A recording of the resting heart rate and its variations from moment to moment gives a reliable index of autonomic adjustments occurring in our body. Heart rate variability has gained much significance since the last few decades as predictors of health and longevity. The time interval between one heart beat and the other is not fixed and keeps on changing under the influence of autonomic system to match the needs of the body. It was first observed by Rev. Stephen Hales in 1733 that pulse rate was changing with respiratory phase which was followed by recording of respiratory sinus arrythmia by Carl Ludwig in 1847[1]. In 1895 Einthoven successfully recorded the first electrocardiogram (ECG) or the electrical activity of heart[2]. This new development helped scientist to study the heart beat and heart rate in depth and analyze it critically. Holter developed a small portable recorder for 24 hours recording thus he could observe the variation of heart rate with daily activities including respiratory influences[3]

Thus, heart rate variability is a marker for your internal body functions. It is an indicator of visceral functions and overall health. It utilizes the variation in time interval between beat to beat that is interbeat intervals (IBI) to analyze the sympathetic and parasympathetic activity and the balance between them. A bad HRV may indicate disease, stress, injury, cancer, diabetes mellitus (where autonomic nervous system dysfunction is common), fibromyalgia, and neurologic and psychiatric disorders such as anxiety, depression, and posttraumatic stress disorder (PTSD) etc. and may be an of indicator increased mortality. Heart rate variability as a biofeedback tool is increasingly used to promote health.

The sympathetic and parasympathetic systems exhibit antagonist actions on many organs. The sympathetic stimulation increases heart rate and blood pressure while the parasympathetic decrease the heart rate and blood pressure. The sympathetic actions show prolonged latency with changes occurring much slower compared to parasympathetic whose latency is less and therefore show rapid changes in HR and BP [4].Thereby decreasing the heart rate variability and in contrast a condition of parasympathetic dominance allows higher heart rate variability.

HRV can be measured periods of 24 hours (long term duration) 5-10 minutes (short term duration) and < 5 minutes that is ultrashort term duration. Heart rate variability is a measured in the form of variables of frequency domain, time domain and linear variables.

Time Domain analysis: Time domain analysis shows the short term and long-term variability in heart beats by evaluating the R-R intervals between consequent heart beats. The short-term variability indices analyze the changes in heart beat intervals occurring with the respiratory sinus arrythmia. The long-term indices help in understanding the changes in heart rate and thereby the heart beat intervals with baroreceptor and thermoreceptor mediated changes which are much slower compared to that of respiratory. Time domain

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indices analyze the HRV by using statistical analysis. The time domain indices studied are

1. SDNN- Standard deviation for all N-N It is the mean of the 5-minute standard deviations of NN intervals calculated over 24 hours.
2. SDANN- Standard deviation of average of all N-N. SDANN <50ms is poor health, 50 – 100ms is compromised and >150ms over a 24-hour recording indicates good health for cardiac health specially for individuals with cardiac morbidity.
3. RMSSD- Root mean square of successive differences between normal heart beats. It is good for analyzing short duration of recordings. It bestows good information about respiratory sinus arrythmia.
4. SDSD- Standard deviation between differences between adjacent N-N intervals
5. NN50 count – Number of pairs of adjacent N-N intervals differing by more than 50%
6. pNN50- it is the NN50 after dividing by total number of all N-N intervals

RMSSD, NN50 and pNN50 measure high frequency variations in heart rate.

Frequency Domain: the indices of frequency domain are the following

1. Very low frequency (VLF): units- ms^2 , Power of 0-0.04 Hz
2. Low frequency (LF): units- ms^2 , Power of 0.04-0.15 Hz
3. High frequency (HF): units- ms^2 , Power of 0.15-0.4 Hz
4. LF Norm: units- nu, LF power in Normalized units

   LF/ (Total power-VLF) * 100
5. HF Norm: units- nu, HF power in Normalized units

   HF power/ (Total power-VLF) *100
6. LF/HF ratio: LF (ms^2)/ HF (ms^2)

Frequency domains help in spectral analysis which indicate variability as a function of magnitude of oscillation frequency.

Non-linear measurements: SD1 and SD2

1. SD1 ms Poincaré plot standard deviation perpendicular the line of identity
2. SD2 ms Poincaré plot standard deviation along the line of identity
3. SD1/SD2 % Ratio of SD1-to-SD2

Heart Rate Variability Biofeedback (HRVB) (also called Resonance Frequency Biofeedback) is based on the respiratory sinus arrhythmia (RSA), which is the variation in heart rate (HR) corresponding to phase breathing. Slow breathing at rates of about 4.5-7 per minute has been found to be of resonant frequency to most people [5]. A respiratory rate of 6 breaths per minute has been found to show highest oscillations of heart rate variability [6] in majority of people. Resonant breathing produces autonomic resetting, enhances sympathovagal balance and increase vagal tone. Respiratory rate and heart rate are linked to each other via the oscillations of respiratory sinus arrythmia (RSA) and the baroreceptor reflex from carotid and aortic baroreceptor discharge through Vagus nerve creating Meyer waves. Manifestation of RSA has been linked to better cardiovascular health [7]. It produces a phase shift of 0 degrees between heart rate and breathing and increases the moment-to-moment variations of heart rate [8]The R-R interval varies with the phase of respiration such as inspiration decreases the R-R interval and expiration increases R-R interval with increase and decrease of heart rate respectively. Decreased heart rate variability has been seen to be significantly associated with all-cause death

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and cardiac events in patients with coronary vascular disease [9]

MATERIAL AND METHODS

Participants include 133 human subjects of age group 15-65 years old. 18 of them male and 115 of them were female. 85 were doingregular exercise in different gymnasium across the Makkah city and 48 were of control group not involved in any regular exercise. The data for not regularly exercising participants/ controls was taken from general population. The participants were explained about the procedure and informed consent was taken. They were given an electronic questionnaire in the form of google drive form. This questionnaire included personal data such as age, sex, social statues, occupation, hight, Wight, calculated BMI, chronic disease, and menstruation. Informed consent was taken from the participants. The study was approved by the biomedical research ethics committee of Umm Al-Qura University. Approval No. (HAPO-20-K-012-2022-04-1066)

The participants were explained in detail the method for ECG recording to measure heart rate variability. The data was collected with spontaneous breathing for 5 minutes and with paced breathing for another 5 minutes. ECG recording was done with subjects in sitting position using limb leads. 5 minutes ECG with spontaneous breathing followed by recording of 5 minutes of ECG recording with resonant breathing of 6 cycles per minute was done. A video was played to assist the participants for regular paced the breathing pattern. ECG recording and HRV analysis was done with Labchart-8 AD instruments. The participants were sitting comfortable in a quiet room with comfortable temperature of 20-25ºC. They were instructed to keep calm and relaxed and not to talk or move during recording.

DATA PROCESSING AND STATISTICAL ANALYSIS

Collected data were analyzed using the Statistical Package for Social Sciences (IBM, SPSS version 28.0). Descriptive statistics were applied (i.e., frequency and percentage for qualitative variables). Kolmogorov Smirnov test and Shapiro Wilk test were applied to assess the normality of HRV parameters and showed that all variables were non-parametrically distributed. Therefore, median, and interquartile range (IQR) were used for descriptive statistics of HRV parameters rather than the mean and standard deviation. Moreover, Mann Whitney U test was applied rather than unpaired t-test to compare differences in HRV parameters between exercised and non-exercised participants, and Wilcoxon rank-sum test was applied, rather than paired t-test to compare HRV parameters during spontaneous and paced breathing. Differences were considered statistically significant at $p<0.05$.

RESULT

The descriptive statistics and HRV parameters of frequency, time domain, SD1, SD2 and their ratios were analyzed and presented in the table during spontaneous breathing and during paced breathing for subjects who do regular exercise and those who don’t taken as controls.

The age gender and BMI characteristics of the132 participants including 115 of female participants and 18 of male participants are presented in Table I.

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Table I: Personal characteristics of study sample

	Regular gym-goersgroup (n=85)		Control group (n-48)		Total (n=133)		P
Personal Characteristics	**No.**	**%**	**No.**	**%**	**No.**	**%**	**Value**
Age groups							
• <30 years	41	48.2	14	29.2	55	41.4	
• 30-40 years	27	31.8	21	43.8	48	36.1	0.100
• >40 years	17	20.0	13	27.1	30	22.6	
Gender							
• Male	16	18.8	2	4.2	18	13.5	
• Female	69	81.2	46	95.8	115	86.5	0.018†
BMI class							
• Normal	36	42.4	25	52.1	61	45.9	
• Overweight	17	20.0	12	25.0	29	21.8	0.218
• Obese	32	37.6	11	22.9	43	32.3	

† Statistically significant

Table I shows that 41.4% of participants were less than 30 years old, while 36.1% were 30-40 years old. There was no significant difference between participants' age groups according to their group. Most participants were females (86.5%). However, the percentage of control/sedentary females was significantly higher than that for regularly exercising females gym-goers (95.8% and 81.2%, respectively, p=0.018). About one-third of participants were obese (32.3%), with no significant difference between participants' body mass index class according to their group.

Table II: Participants' heart rate variability during spontaneous breathing according to their group

Parameters of Heart rate Variability	Regular gym-goersgroup(n=85)				Control group (n=48)				
	Median	IQR	Mean Rank	Sum of Ranks	Median	IQR	Mean Rank	Sum of Ranks	P Value
SDRR	49.79	31.93	65.98	5608	52.58	47.63	68.81	3303	0.684
Average rate	85.03	13.55	71.46	6074.5	80.33	11.58	59.09	2836.5	0.075
RMSSD	36.15	35.86	65.81	5594	42.08	67.36	69.1	3317	0.636
PRR50	7.48	21.50	66.74	5672.5	10.68	26.23	67.47	3238.5	0.916
VLF	657.90	780.00	66.44	5647	619.50	1118.78	68	3264	0.822
LF	48.89	35.34	67.45	5733	47.71	40.30	66.21	3178	0.859
HF	48.62	31.65	66.84	5681	49.71	35.72	67.29	3230	0.948
LF/HF	1.01	1.71	67.19	5711	0.95	2.07	66.67	3200	0.940
SD1	25.59	25.52	65.84	5596	29.80	43.56	69.06	3315	0.643
SD2	60.41	29.18	65.38	5557	66.61	56.56	69.88	3354	0.518
SD1/SD2	0.42	0.34	65.98	5608	0.45	0.38	68.81	3303	0.684

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Table II shows that during spontaneous breathing, regular exercisers had higher median values for their average heart rate, VLF, LF and LF/HF ratio. On the other hand, participants not involved in regular exercise had higher median values for their SDRR, RMSSD, PRR50, HF, SD1, SD2 and SD1/SD2. However, differences in participants' HRV parameters according to their groups did not differ significantly

Table III: Participants' heart rate variability during paced breathing according to their group

Parameters of heart rate variability	Regular gym-goers group (n=85)				Control group(n=48)				
	Median	IQR	Mean Rank	Sum of Ranks	Median	IQR	Mean Rank	Sum of Ranks	P Value
SDRR	68.71	52.96	65.22	5544	77.17	77.26	70.15	3367	0.479
Average rate	84.42	12.35	71.33	6063	81.57	11.58	59.33	2848	0.085
RMSSD	45.01	52.30	65.26	5547	51.02	98.15	70.08	3364	0.488
PRR50	12.69	22.74	67.29	5719.5	13.76	20.04	66.49	3191.5	0.909
VLF	752.70	1216.45	67.61	5747	596.40	1500.40	65.92	3164	0.808
LF	68.87	31.23	69.71	5925	67.09	37.15	62.21	2986	0.281
HF	30.63	25.95	64.99	5524	31.71	30.29	70.56	3387	0.423
LF/HF	2.21	3.04	69.43	5901.5	2.10	2.74	62.7	3009.5	0.333
SD1	31.92	37.97	64.2	5457	36.39	96.57	71.96	3454	0.265
SD2	93.28	64.22	65.76	5589.5	104.75	82.81	69.2	3321.5	0.621
SD1/SD2	0.32	0.21	62.58	5319	0.38	0.48	74.83	3592	0.078

IQR: Interquartile range

Table III shows that during paced breathing, exercised participants had higher median values for their average heart rate, VLF, LF and LF/HF ratio. On the other hand, non-exercised participants/ control group had higher median values for their SDRR, RMSSD, PRR50, HF, SD1, SD2 and SD1/SD2. However, differences in participants' HRV parameters according to their groups did not differ significantly.

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Table IV: Regular exerciser's HRV parameters during spontaneous breathing compared with those during paced breathing (Wilcoxon Rank Sum Test)

Parameters of HRV		No.	Mean Rank	Sum of Ranks	P-value
SDRR	Negative	16§	29.63	474.00	<0.001†
	Positive	69‡	46.10	3181.00	
	Ties	0#			
Average rate	Negative	40§	42.24	1689.50	0.545
	Positive	45‡	43.68	1965.50	
	Ties	0#			
RMSSD	Negative	37§	36.92	1366.00	0.043†
	Positive	48‡	47.69	2289.00	
	Ties	0#			
PRR50	Negative	32§	40.52	1296.50	0.061
	Positive	50‡	42.13	2106.50	
	Ties	3#			
VLF	Negative	44§	38.30	1685.00	0.532
	Positive	41‡	48.05	1970.00	
	Ties	0#			
LF	Negative	26§	30.35	789.00	<0.001†
	Positive	59‡	48.58	2866.00	
	Ties	0#			
HF	Negative	59§	48.75	2876.00	<0.001†
	Positive	26‡	29.96	779.00	
	Ties	0#			
LF/HF ratio	Negative	24§	38.35	920.50	<0.001†
	Positive	61‡	44.83	2734.50	
	Ties	0#			
SD1	Negative	38§	36.84	1400.00	0.061
	Positive	47‡	47.98	2255.00	
	Ties	0#			
SD2	Negative	10§	22.90	229.00	<0.001†
	Positive	75‡	45.68	3426.00	
	Ties	0#			
SD1/SD2 ratio	Negative	85§	43.00	3655.00	<0.001†
	Positive	0‡	0.00	0.00	
	Ties	0#			

† Statistically significant

§ Spontaneous>Paced ‡ Spontaneous<Paced # Spontaneous=Paced

Table IV shows that regularly gym-goersgroup's HRV parameters were significantly higher during spontaneous breathing than paced breathing regarding HF, and SD1/SD2, while HRV parameters were significantly higher during paced breathing than spontaneous breathing regarding SDRR, RMSSD, LF, LF/HF and SD2. On the other hand, HRV parameters did not differ significant regarding average heart rate, VLF and SD1.

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Table V: Control group's HRV parameters during spontaneous breathing compared with those during paced breathing (Wilcoxon Rank Sum Test)

Parameters of HRV		No.	Mean Rank	Sum of Ranks	P-value
SDRR	Negative	9§	21.89	197.00	<0.001†
	Positive	39‡	25.10	979.00	
	Ties	0#			
Average rate	Negative	20§	25.65	513.00	0.442
	Positive	28‡	23.68	663.00	
	Ties	0#			
RMSSD	Negative	16§	24.25	388.00	0.040†
	Positive	32‡	24.63	788.00	
	Ties	0#			
PRR50	Negative	15§	29.27	439.00	0.376
	Positive	30‡	19.87	596.00	
	Ties	3#			
VLF	Negative	21§	26.76	562.00	0.790
	Positive	27‡	22.74	614.00	
	Ties	0#			
LF	Negative	14§	19.71	276.00	0.001†
	Positive	34‡	26.47	900.00	
	Ties	0#			
HF	Negative	37§	25.11	929.00	<0.001†
	Positive	11‡	22.45	247.00	
	Ties	0#			
LF/HF ratio	Negative	12§	25.17	302.00	0.003†
	Positive	36‡	24.28	874.00	
	Ties	0#			
SD1	Negative	16§	21.56	345.00	0.013†
	Positive	32‡	25.97	831.00	
	Ties	0#			
SD2	Negative	9§	18.56	167.00	<0.001†
	Positive	39‡	25.87	1009.00	
	Ties	0#			
SD1/SD2 ratio	Negative	48§	24.50	1176.00	<0.001†
	Positive	0‡	0.00	0.00	
	Ties	0#			

† Statistically significant

§ Spontaneous>Paced ‡ Spontaneous<Paced # Spontaneous=Paced

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Table V shows that control group's HRV parameters were significantly higher during spontaneous breathing than paced breathing regarding HF, LF/HF ratio, and SD1/SD2 ratio, while HRV parameters were significantly higher during paced breathing than spontaneous breathing regarding SDRR, RMSSD, LF, SD1, and SD2. On the other hand, HRV parameters did not differ significant regarding average heart rate, PRR50, and VLF

SDRR, RMSSD, LF, SD1, and SD2 were significantly higher during resonant paced breathing in sedentary individuals/control group and similarly even in regular gym-goers SDRR, RMSSD, LF, LF/HF and SD2 were found to be significantly higher than during spontaneous breathing similar to study by Padaguan et al [10] who showed that SD and LF increase during resonant breathing. LF and SD2 indicates sympathetic activation during the conscious attentive controlling of respiratory frequency and duration.

DISCUSSION

During paced breathing compared to spontaneous breathing the SDRR, RMSSD, LF, LF/HF and SD2 in gym-goers and SDRR, RMSSD, LF, SD1, and SD2 in sedentary individuals/control group were significantly higher indicating more vagal modulation. LF includes the frequency range between 0.04 Hz and 0.15 Hz and is combination of sympathetic and parasympathetic effects. LF during slow deep breathing reflects more parasympathetic activity [11]LF/HF ratio shows the sympathovagal balance with higher values indicating lesser vagal domination. RMSSD (root mean square of successive RR intervals) is the square root value of the total squared differences of successive NN intervals with sinus conduction. SDRR and RMSSD are considered as important indicators of parasympathetic activity. This transient activation of sympathetic system reflects the various mechanism of autonomic nervous system interplay. SD1 and SD2 indicate short- and long-term variability respectively. SD1 of Poincaré plot standard deviation perpendicular the line of identity is an index of the instantaneous recording of the variability of beat-to-beat and hence is a marker of parasympathetic activity and SD2 index depicts the long-term HRV and gives insight into the overall variability.

Comparing the two groups during paced breathing, exercised participants had higher median values for their average heart rate, VLF, LF and LF/HF ratio while control group had higher median values for their SDRR, RMSSD, PRR50, HF, SD1, SD2 and SD1/SD2though not statistically significant. This indicates higher sympathetic activity parameters during paced breathing than during spontaneous breathing in regular exercisers and higher para sympathetic activity domains during paced breathing than in those who are not regular exercisers though it has not been found to be statistically significant. But the individual groups do show enhanced parasympathetic domain parameters during slow breathing of 6 /minute frequency. To get the maximum benefit of this effect the resonant frequency should be assessed for each individual. Furthermore, the resonant frequency of an individual may differ from time to time [12].

CONCLUSION

Heart rate variability is an important biofeedback tool as a window to the autonomic functions of the body. The different parameters like the time domain, frequency domain and the linear domains of Poincare plot indicate the activity of parasympathetic, sympathetic, combined sympathetic and parasympathetic activity. The ratio of these

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parameters such as LF/HF and SD1/SD2 reveal the sympathovagal balance. In the physiological function a higher vagal function is associated with more relaxed state and decreased blood pressure, decreased average heart rate, increased tidal volume and mental psychological wellbeing. Regular exercise training has been shown to improve HRV parameters such as RMSSD, HF and decrease LF and LF/HF ratio. HF or high frequency is a function of parasympathetic activity. Low frequency or LF indicates combined parasympathetic and sympathetic activity but during decreased breathing rates of less than 7 breaths per minute LF is a marker of parasympathetic dominance. Analyzing the HRV between the two groups there was no statistical difference as HRV as affected not only by exercise but many other factors such as age, gender, genetics, chronic diseases, sleep, diet, hydration, menstrual cycle etc. so a cross sectional study may not show statistically significant difference though individual longitudinal study can show a significant difference

In our cross-sectional study there was no significant difference between the HRV of the exercising and non-exercising/control group. But it has been established that regular exercise increases serial HRV when measured longitudinal. The HRV parameters can revert back after few weeks of cessation of exercise. Enhanced HRV is closely linked to the increase vagal tone associated with exercise. Resonant breathing is another maneuver by which HRV can be improved. Regular paced breathing is advised for one to two sessions of ten minutes each on a daily basis. Even in exercises such as yoga the paced breathing is used. Yogic sessions like pranayama use slow deep breathing which seems to increase the autonomic function, decrease heart rate, increase VO2, increase blood flow and regularize organ functions including that of endocrine glands. HRV recording during exercise shows increase in LF and decrease in LF/HF ratio influenced by the mass sympathetic activation occurring during this activity. Similar effect can be seen during paced breathing with increased sympathetic activity acutely. But HRV measurements during rest in regular exercisers or regular followers of paced breathing maneuvers shows increased HRV with decrease in LF and LF/HF ratio with tremendous improvement in RMSSD. This clearly indicates improvement in sympatho-vagal balance and enhancement of vagal tone beneficial to the overall wellbeing. In today's stressful and fast paced life HRV can be an important biofeedback technique to keep ourself healthy and safeguard us from the detrimental effects of prolonged heightened sympathetic activity taking its toll on the physiological functions. Heightened sympathetic activation is the root cause of many lifestyle related diseases such as hypertension, Diabetes, Hormonal imbalance, irritable bowel syndrome, insulin resistance, anxiety disorders and Metabolic syndrome. Increasing steps should be taken to spread the knowledge and awareness about the important role of exercise in maintaining a healthy autonomic system and thus the overall fitness. Exercise is shown to decrease the age-related decline in HRV and therefore can be used effectively to delay aging changes in lieu with the present increasing elder population. This will help tremendously in increasing the self-reliance of the elderly decreasing physical suffering and economic cost of age-related diseases on the person as well as the society and the country as a whole. More and more such studies should be encouraged to understand HRV and its mechanism more clearly so

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as to understand and formulate the necessary lifestyle changes needed to keep pace with the current requirement of the society. HRV biofeedback with resonant breathing can be a boon in the quest to maintain the overall wellbeing and improve performance of an individual and the society as a whole.

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