Original Article

Heart Rate Variability among Healthy Untrained Adults during Mild Intensity Stationary Cycling Exercise

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Abstract

Background: Stationary cycling is the popular, preferred, and convenient form of exercise. During exercise, autonomic modulation is seen which can be assessed by heart rate variability (HRV). The aim of the study was to evaluate the changes in HRV during mild-intensity cycling exercise.

Materials and Methods: An observational cross-sectional study was done on 20 healthy male volunteers with the age (35.44 ± 4.12), height (71.12 ± 11.98), and weight (161.23 ± 11.65), BMI (27.12 ± 3.49) attending various YOGA sessions in AYUSH OPD. Volunteers underwent an exercise program at the mild intensity of 30% to 50% of maximal heart rate on a stationary cycle for 20 min. HRV was recorded by the HRV mobile unit Dynamika Machine at rest, every 5 min (4×) over 20 min and during the recovery period. Repeated measures of analysis of variance with post-hoc analysis with Bonferroni and Holm's multiple comparisons.

Results: Significant change was observed in mean heart rate and time domain parameters. Frequency domain parameters that showed significant change were total power, High Frequency- HF (ms^2), Very Low Frequency -VLF (ms^2), Low Frequency -LF (ms^2), and Very Low Frequency %-VLF (%).

Conclusions: The HRV parameters conclusively point towards cardiac parasympathetic withdrawal and sympathetic dominance at the initiation of exercise. With the progression of exercise, the sympathetic influence is retained. In the recovery period parasympathetic reactivation gains control over heart rate as well as HRV. The HRV response to exercise challenges may be helpful in designing exercise programs based on variations in the autonomic response.

Keywords: Autonomic nervous system, electrocardiogram, endurance training, exercise, fitness testing

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Introduction

The exercise is a physiological challenge that brings about body system alterations to fruitfully complete the ergogenic task.[1] The exercise alters the balance of the parasympathetic and sympathetic systems in the heart and is reflected in acute alterations in heart rate variability (HRV).[2]

During exercise, various cardiovascular adjustments take place in the body. At rest and at the start of exercise, there is parasympathetic control and as the exercise progresses, balance shifts toward sympathetic control. During the recovery phase, there is parasympathetic reactivation and sympathetic involvement is seen.[3] There are various factors that may influence sympathetic and parasympathetic involvement during the exercise. We had come across various studies where the effect of exercise intensity on HRV has been studied,[4-7] however, the effect on HRV with the intensity of exercise and its duration is limited.[8,9] In the present study, the effect of 20 min stationary cycling

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exercise at mild to moderate intensity in a normal individual was studied.

HRV is a non-invasive, reproducible measure for assessing autonomic nervous system function. The autonomic nervous system function during exercise may be assessed with HRV.

The use of a stationary cycle is the popular, preferred, and convenient form of exercise. The HRV alterations would be reflected as changes in the power of very low frequency, low frequency, and high frequency over the exercise duration These changes enable autonomic modulation of cardiac response during exercise. Knowledge of the pattern of HRV may be useful to design this HRV biofeedback control mechanism.[10] Hence, we endeavored to undertake this study so as to have knowledge of HRV patterns during exercise.

The study aims to evaluate the changes in HRV during mild intensity cycling exercise. Does mild-intensity bicycle cycling bring about changes in HRV among untrained male volunteers? The primary objectives of the study were to compare the resting HRV, HRV during exercise, and HRV during the post-exercise recovery period in response to 20 min of exercise on a stationary cycle.

Materials and Methods

The study protocol was approved by Departmental Review Committee and Institutioanal Human Ethics Committee, Approval no: IM0427 of the institute. An observational cross-sectional study was undertaken on healthy volunteers attending various YOGA sessions in AYUSH OPD. The purpose and the objective of the study were explained. Informed and written consent was obtained before the initiation of the study. The basic anthropometric parameters were collected. The pre-exercise resting, during-exercise, and post-exercise recovery HRV was assessed in the autonomic function test laboratory in Physiology Department.

The sample size for this study was estimated using G-power software. Our objective was to compare differences in HRV parameters at three levels: Pre-exercise, during mild-intensity cycling exercise, and post-exercise recovery period. Based on previous literature we anticipated a medium effect size of 0.252 for sample variance. Therefore sample size was calculated with a type-1 error of 5%, power of 80%, and an effect size of 0.252 (medium effect size). The calculated sample size was 18 and considering non-response and attrition rate of 10%, the final sample size was 20 and accordingly, 20 Healthy volunteers in the age group of 20 to 50 years were enrolled for the study.

Inclusion criteria

Were the Male Volunteers in the age range of 20 to 50 years, No history of medical illness, such as Chronic Obstructive Pulmonary Disease (COPD), Asthama, or heart disease that limit exrcise performance and willing to give consent for the study participation.

Exclusion criteria

The high-performance athletes, the patients with Diabetes mellitus, Hypertension, any serious physical illness, serious chronic diseases or health complications that would prevent the volunteers to complete the exercise challenge, taking prescribed medications that could affect exercise performance, smokers including tobacco chewers and alcoholics were excluded.

Exercise protocol

Initially, study participants were given rest for five minutes, and HRV was recorded in the resting condition for five min. They performed stationary cycling exercises at mild (30 to 50% of maximal heart rate) for 20 min. After 20 min, volunteers slowly stopped the exercise (cool-down period of five min). They were given to rest for around 10 min. The exercise was stopped at the time when volunteers felt an uncomfortable or an abrupt increase in heart rate was seen. HRV recording was done during the pre-exercise resting period, every five min of the interval during a 20 min exercise, and in post-exercise recovery period. Earlier literature reported the protocol of the 12-min Bicycle Test by Cooper in 1982.[11] In line with that, since our exercise was stationary cycling exercise, we modified it to 20 min of stationary exercise as this improves blood flow, lifts the mood, helps kick start metabolism, and revs up the body.

Before HRV recording, volunteers were instructed to abstain from any type of exercise, eating and drinking anything, such as caffeine, at least 2 h before the scheduled time for the test.

HRV recording protocol

HRV recording time schedule and procedure are given as follows:

HRV was assessed at three different moments:

1. at baseline (before exercise challenge)—during a 5-min evaluation with the Dynamik HRV device (Dynamik, Moscow, Russia).
2. During the 20-min exercise challenge on a Power max Fitness stationary cycle
3. After completion of the challenge (during a 5-min evaluation post-exercise during cool-down period of 5 min)

HRV was scientifically assessed by the HRV mobile unit Dynamika (Dynamic Technologies, Moscow, Russia) which measures HRV for subjects before during, and after an exercise sessions. The software and the hardware of Dinamika meet the standard of measurement, physiological interpretation, and clinical use of cardiac intervalometer indices, adopted by the European society of cardiology and and North American Association of electrophysiology.[12,13]

HRV was recorded using standard procedure.

The electrodes were placed on the wrist with jelly. The baseline record of the subject was taken for 5 min. Recording of HRV was done during exercise at 5,10, and 15,20 min. The same record was done for 5 min after the exercise session i.e., post-recovery period.

All frequency domain and time domain parameters of HRV were recorded. The parameters which were studied are as follows-

- Mean heart rate
- SDNN- standard deviation of differences between adjacent RR interval
- RMSSD- The root mean square of the mean sum of the squares of differences between adjacent RR interval
- pNN50- percentage number RR interval differences ≥50 ms
- Total power (ms^2)
- Very low-frequency power (ms^2) and percentage
- Low-frequency power (ms^2) and percentage
- High-frequency power (ms^2) and percentage
- LF/HF ratio
- HF power (nu)- High frequency in normalized unit
- LF power (nu)- Low frequency in normalized unit

Statistical analysis

The study parameters data were checked for completeness and correctness. The assumptions of univariate normality and homogeneity of variance were met, using Fisher's test of skewness and Levene's test, respectively. Analysis was conducted using repeated measures of analysis of variance (RM-ANOVA) with posthoc analysis with Bonferroni and Holm's multiple comparisons using the Statistical Package for the Social Sciences (SPSS) for Windows, Version 28.0 Chicago, SPSS Inc.

Results

The study was conducted on 20 male volunteers in the age group of 20 to 50 years. The basic characteristics of the subjects are shown in Table 1.

The study observations revealed statistically significant changes in both time domains, and frequency domain parameters of HRV with mild-intensity cycling exercise.

The mean heart rate increased significantly during exercise and remained at a plateau for the 20 min of exercise, which then decreased significantly post-exercise but was higher than that resting heart rate [Figure 1].

Time domain parameters SDNN, pNN50, and RMSDD show a statistically significant fall during exercise as compared to resting pre-exercise value and remained at a plateau for the 20 min of exercise which then show a rise in the post-exercise period but was less than that of the resting pre-exercise values. [($P < 0.05$*]. All these changes were significant [Figure 1, Table 2].

Table 1: Characteristics of study participants

Characteristics of study participants	Mean±SD	Range (Minimum-maximum)
Age (Years)	35.44±4.12	21-49
Weight (Kg)	71.12±11.98	51-86
Height (CM)	161.23±11.65	135-182
BMI (Kg/m^2)	27.12±3.49	21.9-33.12

Total power, HF, LF, and VLF were higher at rest and during the recovery period. During 20 min of exercise, it decreased with fluctuations at various time intervals during exercise [Figure 2]. Statistically significant changes were seen in all these parameters. ($P < 0.05$*)

HF power (nu%) at rest and during recovery was lower compared to that of at various intervals during exercise. LF power (nu%) at rest and during recovery was higher compared that of at various intervals during exercise. LF/HF ratio at rest and during recovery was lower compared to that at various intervals during exercise. All these patterns of change were not significant ($P > 0.05$) [Figure 3].

Relative percentage changes of VLF% were significant ($P < .05$*) while LF % and HF % changes in pre, during and post-exercise were not significant ($P > 0.05$) [Figure 4]. Sharp increase was seen in VLF % in the initial 5 min interval then a drop was seen at 5 to 10 min, 11 to 15 min, and 16 to 20 mins. A sharp decrease was seen in LF% in the initial 5 min interval compared to rest. It then increased to 5 to 10 min, 11 to 15 min, and 16 to 20 mins. It then decreased sharply during recovery [Figure 4]. Sharp decrease was seen in HF % in the initial 5 min interval compared to rest, it then increased at 5 to 10 min, 11 to 15 min, 16 to 20 mins, and during recovery [Figure 4].

Discussion

This study aimed to evaluate the changes in HRV during mild-intensity cycling exercise. Autonomic modulation

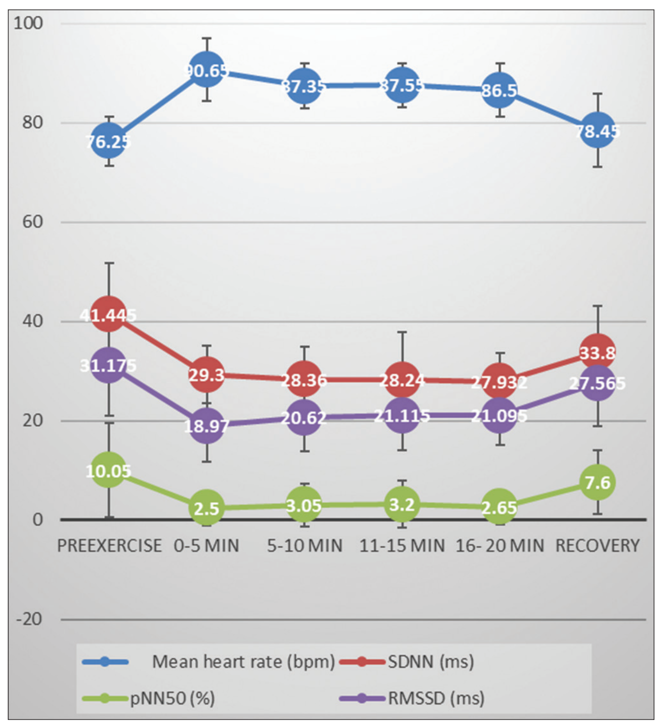

Figure 1: Mean heart rate and time domain parameters before exercise, during exercise (min interval over 20 min) and recovery period. * Significant change $P < 0.05$

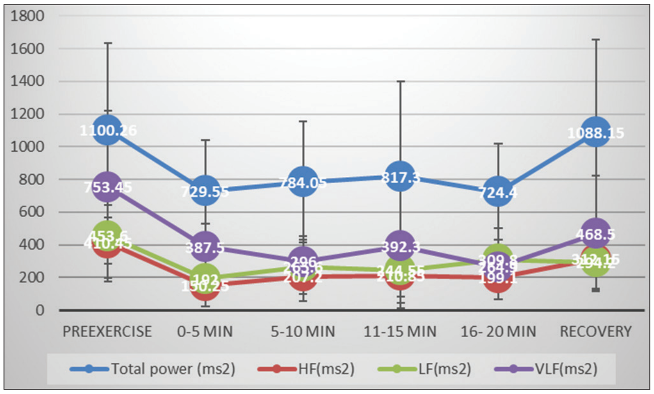

Figure 2: Total power, HF, LF and VLF before exercise, during exercise (5 min interval over 20 min) and recovery period. *-Significant change $P < 0.05$

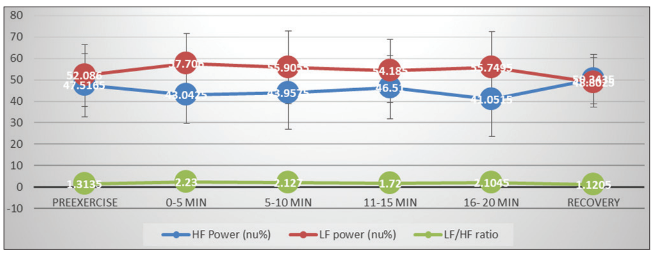

Figure 3: HF (nu %), LF (nu %) and LF/HF ratio before exercise, during exercise (5 min interval over 20 min) and recovery period. No significant change

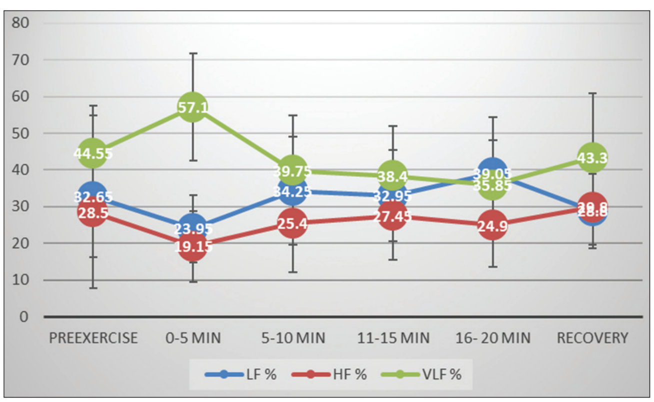

Figure 4: Relative percentages of LF, HF and VLF before exercise, during exercise (5 min interval over 20 min) and recovery period. * Significant change $P < 0.05$ only VLF %

occurring during the mild intensity of exercise i.e., 30% to 50% of maximal heart rate was studied in the present study.

Significant changes were observed in mean heart rate and all-time domain parameters. The frequency domain parameters which showed significant changes were Total power, HF (ms^2), VLF (ms^2), LF (ms^2), and VLF (%).

SDNN depends on relative VLF, LF, and HF power. The VLF, and LF has greater power than the HF band and hence their contribution to SDNN is of a greater extent as per findings evident in the present exercise protocol.[14,15] The

Table 2: Heart rate Variability Parameters Before, during and After Exercise

HRV parameters	Pre Exercise (A)	During Exercise				Post Exercise (C)	Repeated measures ANOVA
		1	2	3	4		*F* (df 2,57) (*P*)
Mean heart rate (bpm)	76.2500±4.8545	90.6500±6.3766	87.3500±4.4754	87.5500±4.4660	86.5000±5.3459	78.4500±7.3375	21.0786 ($P<0.05^*$)
SDNN (ms)	41.4450±10.3766	29.3000±5.7875	28.3600±6.6365	28.2400±9.6946	27.9320±5.8140	33.8000±9.3595	8.5380 ($P<0.05^*$)
pNN50 (%)	10.0500±9.4784	2.5000±3.4717	3.0500±4.2732	3.2000±4.7749	2.6500±3.4378	7.6000±6.3941	6.2470 ($P<0.05^*$)
RMSSD (ms)	31.1750±10.0905	18.9700±7.1207	20.6200±6.7054	21.1150±6.9848	21.0950±5.9450	27.5650±8.5933	7.8106 ($P<0.05^*$)
Total power (ms^2)	1,641.4000±766.7162	729.5500±312.5571	784.0500±369.5322	817.3000±580.8790	724.4000±293.9976	1,088.1500±567.9997	9.8009 ($P<0.05^*$)
HF (ms^2)	410.4500±232.9851	150.2500±125.7629	207.2000±152.8730	210.8500±165.5849	199.1000±132.0004	312.1500±191.0432	6.2462 ($P<0.05^*$)
LF (ms^2)	453.6000±255.5476	192.0000±111.8632	265.6000±164.1775	244.5500±159.3201	309.8000±189.6822	294.2000±161.8110	4.9137 ($P<0.0004^{**}$)
VLF (ms^2)	753.4500±467.5761	387.5000±142.1965	296.0000±154.9560	392.3000±378.7770	264.9000±126.3695	468.5000±352.6038	6.7831 ($<.05^*$)
HF Power (nu%)	47.5165±14.7241	43.0425±13.3073	43.9575±16.9339	46.5100±14.8224	41.0515±17.5561	50.3435±11.4651	1.0155 (0.4119)
LF power (nu%)	52.0860±14.4836	57.7060±13.7798	55.9055±16.9836	54.1850±14.6900	55.7495±16.7511	48.8025±11.4251	0.9327 (0.4626)
LF/HF ratio	1.3135±0.9534	154.1255±682.7956	2.1270±2.5234	1.7200±1.5772	2.1045±2.4290	1.1205±0.5619	0.9970 (0.4229)

Statistically significant $^{**}P<0.01$, $^*P<0.05$

post-exercise SDNN values did not return to the resting values indicating that the HRV recovery is delayed and may be due to the fact that the study participants are not trained athletes and require more time to recover from exercise. Further Para-sympathetically mediated respiratory sinus arrhythmia which is attenuated during exercise would have contributed to the declining trends observed in the HRV parameters.

pNN 50% and RMSSD are mainly measures of parasympathetic activity not influenced by respiration. Predominant decrease in parasympathetic activity during exercise was reflected by a decrease in these time domain parameters.[16,17] Higher-intensity exercise is associated with a curvilinear decay in time domain parameters. A curvilinear decline viz. a rapid and sharp fall in time domain parameters is the function of exercise intensity.[18,19] Earlier researchers have reported a curvilinear decay to a minimum value of 3 to 10 ms in time domain parameter for higher intensity exercise up to a heart rate of 160 bpm.[20,21] As the exercise protocol was of mild intensity in which 30% to 50% of maximal heart rate was achieved, we did not find a similar sharp decline in these parameters. This could be due to the fact that the volunteers were untrained athletes.[4-8]

However, in the present study HF (ms^2), VLF (ms^2), and LF (ms^2) also showed a decrease. While looking at the relative % of respective power, the relative % in VLF shown a marked sudden significant increase in the initial 5 min while HF % and LF % showed a nonsignificant decrease. In the literature, similar results have been seen with total power (ms^2), HF (ms^2), and LF (ms^2).[6,7] However we had not come across any study where a relative % was studied.

With the progression of exercise, respiration increases hence HF declines.[16-19] Similarly HF Power (nu%) is often used an indicator of the cardiac parasympathetic index which has decreased during exercise.[6,7,19] However, in the present study, the decrease in HF Power (nu%) was non-significant.

The findings in the present study point towards a shift of balance among the two systems under quasi-controlled conditions, such as mild exercise and indicates a change appropriate shift of balance towards sympathetic.[3,6,7] Varying result has been found in LF: HF ratio with various intensity and duration of exercise.

The major application of this study is HRV biofeedback. HRV biofeedback is considered to be useful in many disorders and performance enhancement.[10] HRV biofeedback has also been found to be useful to increase exercise endurance.[22] Smartphone-based applications for HRV biofeedback is available in which the subject wears the fitness band and uses it during exercise as a visual feedback cue to time the intensity and duration of exercise such as running, cycling, etc. Hunter JF, *et al*.[23] had done a randomized experimental study to evaluate the effect of brief biofeedback via a smartphone app on stress recovery. It is considered to be useful for better health especially in athletes who have made exercise a habit. HRV data in the present study during exercise in a normal person may be useful in designing similar HRV applications.

A runner who can vary his heartbeat from a low resting value to a high heart rate during exercise shows he is in good health and is fit. By taking steps to improve fitness and health, the average HRV increases over a period of time. On the other hand, if the HRV is less, it can lead to sudden cardiac death, if the athlete exerts himself beyond his limits. Many football players have collapsed on the field while playing. Monitoring of HRV as in our study prevents such sudden fatalities.[24]

Even middle-aged and elderly subjects, who have no habit of exercising, need to monitor their HRV, lest their hearts quit during exercise due to overload.

There lies the innovation of our study, in providing HRV as a tool as biofeedback to monitor endurance, speed, a distance of the exercise, especially in athletes, middle-aged, and elderly subjects.

Our study shows the recovery of the subjects to near baseline, of parasympathetic parameters as depicted by the graphs.

Parasympathetic activity decreases during exercise but comes back to near normal in the untrained athlete in 5 min. Monitoring recovery heart rate is also an index of fitness and health of the exerciser.

Conclusions

The mild intensity of stationary cycling exercise produced predictable changes in HRV in healthy adult untrained subjects. The HRV parameters conclusively point towards cardiac parasympathetic withdrawal and sympathetic dominance at the initiation of exercise. In the recovery period parasympathetic reactivation gains control over heart rate as well as HRV. In untrained healthy participants, the HRV recovery is slower so as to attain the resting pre-exercise values for HRV in a delayed fashion. The HRV response could be helpful in designing an exercise programs based on variations in autonomic response using HRV-based biofeedback applications to facilitate the better exercise performance with respect to duration and intensity.

We will investigate different training intensities of exercise in different groups to understand the effect on HRV with regard to duration and severity. This will help to give biofeedback during endurance training.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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