



Cardiovascular autonomic adjustment during submaximal exercise in adult males

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Abstract

Background: Heart rate response to 3-minutes step is a very simple and convenient tool for assessing the cardiovascular fitness. However, the exact mechanism of autonomic adjustment during the maximal heart rate and exponential decay of accelerated heart beat during recovery after submaximal exercise is less understood.

Objectives: To study the mechanism of cardiovascular autonomic adjustment during submaximal 3 minutes step test and recovery.

Materials and Methods: The experimental protocol consisted of the HRV recording during rest, exercise and recovery. The differences in HRV measures were analyzed using Friedman test followed by multiple comparisons. A p value <0.05, considered as statistical significant.

Results : All the time domain measures and LF power, HF power and Total power of frequency measures were significantly reduced during the step test compared to rest. SDNN, NN50 and PNN50 of time domain and LF power and HF power of frequency domain measures significantly increased during the post exercise recovery compared to exercising condition. However, the comparison of post exercise recovery with the pre exercise rest shows no significant differences.

Conclusion: There as reduction in parasympathetic activity during sub-maximal 3 min step test whereas sympathetic activity was normal indicating that this test for screening physical fitness is based on parasympathetic modulation.

Keywords: Autonomic adjustment, heart rate variability, submaximal exercise

Introduction

Autonomic Nervous System (ANS) coordinates functions of visceral system in the body. The ANS balance is required to cope up with any type of stress and to be healthy. The sympathetic and parasympathetic divisions of ANS regulate and modulate the cardiovascular function. (1) There are complex interactions between autonomic nervous system and the cardiovascular system during exercise. During exercise heart rate, stroke volume and myocardial contractility are increased to meet the energy demands of the working skeletal muscle but after the cessation of exercise all these parameters starts declining to come back to the resting level. (2) Maximum heart rate and recovery heart rate during and after submaximal exercise are commonly used for the prediction of the aerobic and cardiovascular fitness. 3-minutes step is a very simple and convenient method used for studying cardiovascular response to submaximal exercise. (3) Although the maximum heart rate and recovery heart rate are frequently used for prediction of cardiovascular fitness, the exact mechanism of autonomic adjustment during the maximal heart rate and their role in exponential decay of accelerated heart beat during recovery after 3 minutes step test exercise is less understood.

Heart rate variability (HRV) is beat-to-beat variation in cardiac cycle length. HRV results from the modulation of the supposedly constant intrinsic HR by the vago-sympathetic balance. Heart rate variability (HRV) is an innovative and powerful tool to assess cardiac autonomic modulation. (4)The parameters of HRV in time domain and frequency domain are found to be independent predictors of mortality and in number of epidemiological studies. This perspective approach for the study of physiological control system reactions to different forms of physical exercise has been done mainly before and immediately after the exercise but the exact autonomic adjustment during the exercising condition and post exercise recovery after 3 minutes step testis not clear. Thus, we aimed to dissect the exact mechanism of autonomic adjustment during submaximal exercise and during immediate recovery after the exercise.

Materials and Methods

Subjects

After taking written informed consent 20 healthy untrained male subjects were recruited for the study. The subjects were selected using non-probability purposive sampling technique based on the standard inclusion and exclusion criteria for recording of Heart Rate Variability. (4)All the subjects were asked to avoid smoking and drinking beverage before the experiment and none of them were taking medication affecting the cardiovascular function.

Procedure

The experimental protocol consisted of the HRV recording during rest, exercise and recovery. Anthropometric and cardio respiratory variables including resting heart rate were recorded using standard protocol before starting of HRV recording.

HRV during Rest: After 15 minutes of supine restcardiac cycle (R-R interval) signals at spontaneous respiration were recorded for three minutes for resting HRV. The R-R interval for HRV was sampled using portable POLAR HEART RATE MONITOR (S810i) USA/GBR. Moistened strap with electrode was applied around the chest. The transmitter attached to electrode was firmly and comfortably held in central upright position. The wrist receiver was placed within 3 feet or 1 meter from the transmitter and confirmed that the subject was not near to high voltage power lines, television, mobile phones or other sources of electromagnetic disturbance. Room temperature was maintained at $25 \pm 2^\circ \text{C}$.

HRV during step test: Cardiac cycle length (RR interval)were recorded during the three minutes step test. The submaximal exercise, three minutes step test was performed on bench of 30 cm height for three minutes by stepping in up-up and down-down fashion at the rate 96 steps or 24 cycles per minute. (5)The electrode, transmitter and the wrist receiver were placed in the same position during the step test as it was placed during the rest.

HRV during recovery: Then the subject was asked to rest in supine position and recording of recovering RR intervals were taken for three minutes using portable POLAR HEART RATE MONITOR (S810i) USA/GBR similarly as done during rest and exercise.

Analysis of HRV: The R-R intervals recorded in the Polar device were transmitted to the computer using Polar Precision Performance software. RR interval were analyzed for time domain and frequency domain measures using HRV software Kubios HRV (version 2.1, Kuopio FINLAND).

Time domain measures includes SDNN (standard deviation of normal to normal RR intervals), RMSSD (root mean square of difference of successive RR intervals), NN50 count (number of RR intervals that differ more than 50ms), pNN50 (percentage of consecutive RR intervals that differs from more than 50 ms).

Frequency domain analysis was done using Fast Fourier transformation. Frequency domain measures included Power of low frequency (LF, frequency between 0.04 and 0.15 Hz), High frequency (HF, frequency between 0.15 and 0.4 Hz), LF n.u and HF n.u (the power of low

frequency and high frequency in normalized unit) and LF/HF(ratio of LF and HF power).

Statistical Analysis

HRV results were exported to Microsoft excel and then to SPSS, version 11.5 for further analysis. Normally distributed data were expressed as Mean±S.D and non-normally distributed data as Median (Interquartile range).The differences in HRV measures were analyzed using Friedman test followed by multiple comparisons. The data are expressed as median with inter quartile range. A p value <0.05, considered as statistical significant.

Results

The mean age of the subjects was 30.33± 6.43. All the subjects were looked upon for their anthropometric and other cardiovascular parameters including systolic blood pressure, diastolic blood pressure, resting heart rate, maximum heart rate during the exercise and recovering heart rate in the first minute after the cessation of exercise. The results are expressed as Mean±Standard deviation are presented in table 1.

Table 1: Anthropometric and cardiovascular parameters

| Variables | Mean ±SD |
|-------------------------------|--------------|
| Age in years | 30.33±6.43 |
| Height in (mtrs) | 171±0.08 |
| Weight(kgs) | 72.24±6.56 |
| BMI (kg/m ²) | 24.8±3.59 |
| Systolic BP | 116±9.50 |
| Diastolic BP | 79±6.10 |
| Resting heart rate | 73.8±9.35 |
| Maximum heart during exercise | 127.48±11.20 |
| Recovery heart rate | 108.8±10.57 |

The HRV of the patients were recorded in three states i.e. prior to step test after 15 minutes of supine rest, during three minutes step test and during the recovery period after the 3-minute step test. The recorded HRV measures recorded in three different states were compared with each other using Friedman test and multiple comparisons. All the time domain measures and LF and HF power of frequency measures were significantly reduced during the step test

compared to rest. SDNN, NN50 and PNN50 of time domain and LF power and HF power of frequency domain measures were significantly increased during the post exercise recovery compared to exercising condition. However, the comparison of post exercise recovery with the pre exercise rest shows no significant differences. The results of multiple comparisons are presented in table 2.

Table 2: Multiple comparisons of HRV parameters in rest, during step test and recovery

| S.N | Variable | Rest Median(IQ range) | Step test Median(IQ range) | Recovery median(IQ range) | p value | | |
|----------------------------------|--------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|--------------|--------------|----|
| | | | | | p1 | p2 | p3 |
| Time domain measures | | | | | | | |
| 1 | SDNN (ms) | 53.6 [46.2-70.5] | 37.75 [34.25-52.45] | 66.65 [42.82-76.75] | 0.028 | 0.017 | NS |
| 2 | RMSSD (ms) | 38.3 [28.40-65.05] | 16.75 [5.35-41.72] | 35.6 [22.65-54.18] | 0.014 | NS | NS |
| 3 | NN50 | 43 [28.75-166.25] | 10.5 [0.00-44.5] | 39 [12.50-82] | 0.017 | 0.025 | NS |
| 4 | pNN50 % | 11.4 [7.57-46.17] | 2.45 [0.00-13.53] | 8.8 [2.58-19.92] | 0.022 | 0.028 | NS |
| Frequency domain measures | | | | | | | |
| 5 | LF Power (ms ²) | 976.5 [626-1234.35] | 15 [5.0-74.75] | 779.5 [336.75-1049.5] | 0.005 | 0.005 | NS |
| 6 | HF power(ms ²) | 519 [326.25-1877.5] | 6 [1.0-181.0] | 444 [176.25-1044.50] | 0.005 | 0.005 | NS |
| 7 | LF (n.u) | 58.1 [39.52-75.80] | 72.50 [26.75-82.75] | 56.1 [46.62-73.38] | NS | NS | NS |
| 8 | HF (n.u) | 41.9 [24.2-60.47] | 27.50 [17.25-73.25] | 43.9 [26.63-53.38] | NS | NS | NS |
| 9 | Total Power (ms ²) | 2168(1453-6124) | 575 (380-768) | 1862 (860-3699) | 0.00 | 0.00 | NS |
| 10 | LF/ HF | 1.39 [0.66-3.18] | 2.74 [0.36-4.88] | 1.35 [0.87-2.82] | NS | NS | NS |

p1= level of significance between rest and step test, p2= between step test and recovery, p3= between rest and recovery. The p<0.05 was considered statistically significant, NS=statistically non-significant.

Discussion

Rhythmic fluctuations in efferent sympathetic and vagal activities directed at the sinus node and analysis of these fluctuations as Heart Rate Variability will permit inferences on function of

these autonomic influences on cardiovascular system. (4) Thus this study was conducted to explore the state of cardiovascular autonomic adjustment during submaximal three minutes step test exercise and post exercise recovery using HRV measures.

Our study showed that there was significant increment in the heart rate during the submaximal exercise. Further the average heart rate during the recovery period was significantly decreased compared to the exercising condition but it was not regained back to the resting level. Our observation showed that there was reduction in the parasympathetic influence during the three minutes step test but the parasympathetic activity was almost regained back to the resting level within three minutes after the cessation of exercise although the heart rate did not come back to the resting level. The above mentioned inference was based on the results shown by time domain and frequency domain measures of HRV. Most fluctuations in RR intervals of time domain measures are believed to be driven by vagal cardiac signals.(5) In our study time domain measures SDNN, NN50 and PNN50 were significantly reduced during the 3 minutes step test however, they were regained to the resting level within three minutes of post exercise recovery. Our results of time domain were similar to the results of study done by Javorka et al. (6)

Similar to the time domain measures the frequency domain measures also showed significant decrease in vagal dominance during the submaximal exercise. The marker of overall variability in HRV the total power was significantly reduced during the submaximal exercise along with other makers of variability i.e HF power and LF power. HF power is considered as the valid index of parasympathetic nerve activity as it decreases with intensity of exercise and attenuated by cholinergic receptor inhibition. (7) There are some controversies in interpretation of LF power, which is considered to me a marker of sympathetic modulation by some whereas others consider it as a marker of parasympathetic dominance.(4,5,8) As the LF power result parallels the HF power and time domain measures many authors consider it to be influenced mainly by parasympathetic activity and we are also considering the same as mentioned by Javorka et al. (6) Similar to the time domain measures the variability markers in frequency domain analysis also increased significantly during post exercise recovery and they returned to the resting level within three minutes post exercise recovery.

Our finding of HF component are similar to that of Grasso et al. where they found that HF component was reduced during exercise but it was regained after the exercise to the resting level. (8)The findings of our study are also supported by studies done by Salinger J et al, Kluess HA et al and Oida E et al however, the type of exercise and the post exercise recovery period were different in all the exercise. (9-11)

During exercise, the heart rate and other parameters of cardiovascular system changes to supply the oxygen to the working muscles and there was significant increment in heart rate during submaximal exercise and it remained significantly increased during resting period. However, the markers of sympathetic nerve activity LF n.u and LF/HF ratio were not significantly different in all the three conditions showing the similar type of sympathetic neural activity during the submaximal exercise.

Our results suggest that the change in cardiovascular parameters during the submaximal step tests were mainly mediated by the vagal withdrawal where significant alteration in sympathetic activity was not observed. Our results are in the same line of study done by Cater et al where they found that onset of exercise was mediated by vagal withdrawal but as work intensity approaches 100 beats/min sympathetic activity begins to rise further increasing HR and plasma norepinephrine. (12)With cessation of submaximal exercise, baroreflex reactivation and other mechanism contribute to rise parasympathetic activity causing decreased heart rate.

Conclusion

There was reduction in parasympathetic activity during sub-maximal 3 min step test, however sympathetic activity was similar in all three states; baseline, during step test, and during recovery. This indicates that sub-maximal 3 min step test, which is used as screening tool for physical fitness is based on the cardiac parasympathetic modulation.

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