Association between Heart Rate Recovery following the Six-Minute Walk Test and Resting Short-Term Heart Rate Variability in Apparently Healthy Young Male University Students in North India

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Abstract

Heart rate recovery (HRR) is not only an indirect measure of cardiorespiratory fitness but also a valid marker of autonomic dysfunction, poor prognosis and mortality. Heart rate variability (HRV) is a non-invasive, reliable and valid measure of autonomic nervous system, and also a predictor of morbidity and mortality. There are limited data on the correlation of HRR after six-minute walk test (6MWT) with resting short-term HRV in apparently healthy young male university students in North India, and hence the study was planned. 25 young (22.60±1.53 years old) male university students were the volunteers. Following anthropometric variables were measured: height, weight, BMI, waist and hip circumferences, and waist-hip and waist-height ratios. Resting short-term or 5min HRV indices used for analysis were: (a) time domain: RMSSD, LnRMSSD, SDNN and SDSD, (b) frequency domain: LF (ms2), LF (nu), HF (ms2), HF (nu) and LF/HF ratio, and (c) non-linear: SD1, SD2 and SD2/SD1. HRV analysis was done from a lead II ECG recording. Heart rate immediately (RHR0), at 1st min (RHR1) and 2nd min (RHR2) after 6MWT were measured in quiet sitting position, and HRR at 1st min (HRR1) and 2nd min (HRR2) were calculated as HRRi=RHR0-RHRi, i=1 or 2. There were statistically significant positive correlations of HRR1 with RMSSD, LnRMSSD, SDSD, HF (nu), SD1, RHR0 and HRR2. HRR1 correlated significantly and negatively with LF (nu), LF/HF and SD2/SD1. HRR2 showed only statistically significant positive correlation with RHR0 and HRR1. Out of the two HRRs, HRR1 might be a better correlate of resting cardiac vagal modulation, and those who recovered faster at 1st min after 6MWT also had higher vagally mediated markers of HRV.

Keywords: Heart rate recovery; Heart rate variability; Six-minute walk test; Cardiac autonomic modulation; Parasympathetic reactivation; Young adult; Male

1. Introduction

Heart rate recovery (HRR) is the decline in heart rate following maximal or submaximal exercise towards the resting level (1-3). The time duration which the heart rate takes to return to its resting level is an indirect marker of cardiorespiratory fitness (1-3). HRR has also been shown to be a valid marker of autonomic dysfunction, a predictor of poor prognosis and mortality (1, 3-6). The recovery after an exercise is associated with rapid vagal reactivation and progressive sympathetic withdrawal (5, 7).

Although many researchers have measured HRR after submaximal functional exercise tests such as six-minute walk test (6MWT), there is limited published literature evaluating the correlation of HRR after 6MWT with autonomic nervous system function among young North Indian university students. This present paper was an attempt in this direction. The assessment of autonomic nervous system is commonly done using heart rate variability (HRV), which is the variation of time interval between successive heart beats as indicated by R waves in an ECG (electrocardiogram); and which is not only non-invasive, reliable and valid, but also is a valid predictor of morbidity and mortality (8-11). This study was done with an aim to evaluate the correlation between HRR after 6MWT and resting short-term HRV in apparently healthy young male university students in North India.

2. Methodology

This observational, analytical, cross-sectional correlational study was done in the Cardio-Autonomic and Vasculo-Endothelial Medicine section of the Sports-Exercise Medicine & Sciences: Lifestyle & Performance Medicine (Health &

Physiological Medicine: Clinical & Interventional Physiology) Lab., Department of Physiology, Institute of Medical Sciences (IMS), Banaras Hindu University (BHU), Varanasi (U.P.), India. Twenty-five young (22.60±1.53 years old) male university students were the volunteers. They were all apparently healthy, with no history of acute or chronic illness, injury, disability or deformity and addiction of any kind. They took no medication or supplement, including those which might affect autonomic nervous system, heart rate, blood pressure, sleep, exercise capacity and post exercise recovery. Informed consent was taken from all the volunteers and the study was approved by the ethical committee of the institute.

All the volunteers came to the lab. for data recording after having an adequate restful and sound night sleep of about 7-8hours. They did no strenuous exercise or physical activity for at least 24 hours before and drank no caffeinated drinks for at least 12 hours before. They came after having a light breakfast or meal at least 2-3 hours before and emptying their bladder. Demographic and relevant information was recorded along with brief medical history and examination by a resident medical doctor. Height (HT) was measured using a stadiometer and body weight (WT) using a digital weighing machine respectively. BMI was calculated. Waist (WC) and hip (HC) circumferences were measured using a non-stretchable and flexible measuring tape. Waist-to-hip (WHR) and waist-to-height (WHtR) ratios were calculated. BMI, WC, WHR and WHtR were used as markers of adiposity (8).

Subjects were then asked to rest in supine position for about 15-20min, and then lead II electrocardiogram (ECG) was recorded for 10min. Short term HRV was analyzed from the last 5min of this 10min ECG as reported in an earlier study using PowerLab 15T with LabChart software (ADInstruments) (8). During the entire recording, respiration was kept spontaneous. Following indices of HRV were measured as per standard protocol and used for analysis (8-11): (i) time domain measures: root mean square of successive NN interval differences (RMSSD), natural logarithm of RMSSD (LnRMSSD), standard deviation of NN intervals (SDNN) and standard deviation of successive NN interval differences (SDSD), (ii) frequency domain measures: absolute power of the low-frequency band (LF in ms2), relative power of the low-frequency band in normal units (LF in nu), absolute power of the high-frequency band (HF in ms2), relative power of the high-frequency band in normal units (HF in nu) and ratio of LF-to-HF power (LF/HF), and (iii) non-linear measures: Poincaré plot standard deviation perpendicular to the line of identity (SD1), Poincaré plot standard deviation along the line of identity (SD2) and ratio of SD2-to-SD1 (SD2/SD1).

The subjects were then asked to do 6MWT as per standardized protocol and as reported earlier in a walking course of 30m conducted indoor, in a straight, flat and hard corridor, with an instruction that they should aim to walk as far distance as possible during the six-minute duration of the test (12, 13). The total distance walked (6MWD) in the 6MWT was recorded. Heart rate was recorded in quiet sitting position immediately after 6MWT (RHR0), 1^{st} min (RHR1) and 2^{nd} min (RHR2) after the test. Heart rate recovery at 1^{st} min (HRR1) and 2^{nd} min (HRR2) were calculated as RHR0-RHR1 and RHR0-RHR2 respectively (1, 14). Polar H10 heart rate sensor chest strap device was used to record heart rate after the exercise.

Statistical Analysis

Data analysis was done using version 20 of SPSS (Statistical Package for the Social Sciences). Descriptive statistics were presented in the form of mean and standard deviation, and median and quartile deviation. Correlations of the HRR1 and HRR2 with studied variables were evaluated using Pearson's correlation. Spearman correlation was used for those variables which were not normally distributed. Normality testing was done using Shapiro-Wilk test and Kolmogorov-Smirnov test. Statistical significance was set at p-value<.05.

3. Results

Descriptive statistics are given in Table 1. Both mean and standard deviation, and median and quartile deviation are given. The correlation of HRR1 and HRR2 with the studied variables are given in Table 2. Statistically significant positive correlation of HRR1 was found with RMSSD, LnRMSSD, SDSD, HF (nu), SD1, RHR0 and HRR2. Also, HRR1 correlated significantly and negatively with LF (nu), LF/HF and SD2/SD1. On the other hand, significant positive correlation of HRR2 was found with only RHR0 apart from HRR1.

Table 1. Descriptive statistics of the studied subjects (n=25)

Statistics	Mean	SD	Median	QD
Age (years)	22.60	1.53	22.00	0.50
Weight (kg)	60.96	7.27	60.50	6.60
Height (cm)	169.46	5.67	170.00	2.75
BMI (kg/m2)	21.19	1.84	20.90	1.43
WC (cm)	77.18	6.16	76.00	5.13
HC (cm)	92.80	4.54	93.00	3.25
WHR	.83	.06	0.82	0.03
WHtR	.46	.04	0.45	0.03
RMSSD (ms)	58.63	35.29	52.19	14.66
LnRMSSD (ms)	3.93	.55	3.95	0.28
SDNN (ms)	57.78	24.29	52.64	12.75
SDSD (ms)	58.67	35.31	52.23	14.68
LF (ms2)	763.53	667.14	689.70	296.75
LF (nu)	42.09	13.98	39.63	8.93
HF (ms2)	1141.64	1001.71	1022.00	492.97
HF (nu)	56.01	13.23	59.79	7.71
LF/HF	.89	.65	0.66	0.27
SD1 (ms)	41.48	24.96	36.93	10.38
SD2 (ms)	69.67	25.73	66.64	12.06
SD2/SD1	1.91	.57	1.88	0.37
RHR0 (bpm)	139.64	20.45	138.00	15.75
RHR1 (bpm)	98.44	18.76	96.00	12.25
RHR2 (bpm)	84.04	17.42	83.00	13.50
HRR1 (bpm)	41.20	12.19	45.00	8.00
HRR2 (bpm)	55.60	18.12	58.00	13.50
6MWD (m)	716.88	61.93	711.18	36.48

SD=standard deviation, QD=quartile deviation

4. Discussion

The study evaluated the correlation between heart rate recovery in the form of HRR1 and HRR2 with resting short-term heart rate variability in apparently healthy young male students. In our study, there were no significant correlation of the markers of heart rate recovery with indices of adiposity and also with six-minute walk distance. This might be because all the studied subjects were not only apparently healthy, but also had average adiposity indices and heart rate recoveries well within the low health risk range (1, 14, 15). Also, the sample size of this present study was relatively small. The average 6MWD of the studied subjects was 716.88±61.93m which lay between 25th to 50th percentile of 6MWD as per earlier published Indian data (13). Among the studied markers of adiposity, negative correlations of HRR1 & HRR2 were found with WC, WHR and WHtR, although statistically non-significant (Table 2). Earlier studies reported statistically significant lower HRR1 and HRR2 in those having higher BMI, percentage body fat, WC and WHR, both in healthy males (14) and type II diabetic males (1).

Among the time domain variables, RMSSD, LnRMSSD and SDSD correlated positively and significantly with HRR1 (Table 2). RMSSD or LnRMSSD is one of the best markers of parasympathetic tone, and is least affected by respiration (8). Heart rate recovery during the first 0.5 or 1min post exercise has been reported to be mediated mainly by parasympathetic nervous system activation (1, 6, 7). The significant positive correlation between HRR1 and RMSSD or LnRMSSD is therefore understandable. We also got statistically significant positive correlation between SDSD and HRR1 (Table 2). The definitions of SDSD and RMSSD indicate that they are mathematically and physiologically similar (9), and there is good correlation of SDSD, which indicates short term variability, with RMSSD (8, 16).

Among the frequency domain markers of HRV, HRR1 correlated significantly and positively with HF (nu) (Table 2). Similar pattern was also seen with non-linear measurements of HRV, among which SD1 correlated significantly and positively with HRR1 (Table 2). SD1 measures short-term HRV and correlates well with baroreflex sensitivity (BRS) (10). The positive correlation of HF with RMSSD and SDSD has been reported (9). Earlier report suggested good correlation between SD1 and SDSD (8, 16), and also SD1 and RMSSD have been reported to indicate identical HRV metrics (10, 17). The time domain measurements of HRV including RMSSD or LnRMSSD, SDSD, along with SD1, HF (nu) have been used to indicate parasympathetic part of the autonomic nervous system assessment (11, 18).

There was statistically significant negative correlation of HRR1 with LF (nu) and LF/HF among frequency domain variables, and with SD2/SD1 among non-linear measurements of HRV (Table 2). Since, LF or LF (nu) is affected both by parasympathetic and sympathetic activity (11), the use of LF/HF ratio as an indicator of only sympatho-vagal balance may not be appropriate (10, 19). Similarly, this is true for SD2/SD1, specially for short monitoring period, and SD2/SD1 correlates well with LF/HF ratio (10). SD2 indicates short- and long-term HRV and correlates well with LF power and BRS (10). With the exception of SD2 which correlated weakly, non-significantly and positively with HRR1; the negative correlation of HRR1 with LF/HF and SD2/SD1 might be due to the significant positive correlation of HRR1 with HF and SD1, and negative correlation with LF (Table 2).

No statistically significant correlation of HRR2 was found with any of the HRV variables (Table 2). Heart rate recovery during the first two min or beyond has been reported to be mediated by both parasympathetic reactivation and sympathetic withdrawal (1, 7). Perhaps relatively less sample size of the present study was the reason behind the non-statistically significant correlation coefficient. However, the directions of the correlation coefficients of HRR2 with the studied markers of adiposity and markers of HRV were same as those of HRR1 (Table 2). There was significant positive correlation between HRR1 and HRR2 (r-value=.760, p-value<.001, Table 2). So as per our study, HRR1 which had both significant correlation with HRR2 and markers of HRV, might be a choice if only one of the markers of heart rate recovery has to be used among HRR1 and HRR2. HRR1 has been used as a predictor of all-cause mortality in an early study (4). We found statistically significant positive correlation between RHR0 and both the markers of heart rate recovery. Both HRRs after the 6MWT were calculated as RHR0 minus RHRi, where i=1 or 2 (1). This finding in our study might indicate that those who achieved higher heart rate immediately after 6MWD also recovered faster. Although earlier study reported that HRR retained prognostic importance of mortality prediction even after adjustment for heart rate change during exercise, workload achieved apart from age, gender, use or non-use of medication, resting heart rate and standard cardiac risk factors etc (4). With the exception of RHR1, both the markers of heart rate recovery had same direction of correlation with RHR0 and RHR2 (Table 2).

Table 2. Correlation of recovery heart rate 1 and 2 with selected variables (n=25)

Variables	HRR1		HRR2	
	r-value	p-value	r-value	p-value

Age (years)	.044#	.835	-.059	.778
Weight (kg)	.162	.438	.226	.278
Height (cm)	.006	.979	.147	.484
BMI (kg/m2)	.223	.284	.209	.317
WC (cm)	-.195	.351	-.115	.585
HC (cm)	.033	.874	.218	.295
WHR	-.341#	.095	-.363#	.074
WHtR	-.182	.385	-.162	.438
RMSSD (ms)	.462*#	.020	.340#	.096
LnRMSSD (ms)	.400*	.048	.292	.157
SDNN (ms)	.271#	.191	.196#	.348
SDSD (ms)	.462*#	.020	.340#	.096
LF (ms2)	.061#	.774	.023#	.911
LF (nu)	-.531**#	.006	-.362#	.075
HF (ms2)	.335#	.101	.244#	.240
HF (nu)	.502*#	.011	.369#	.070
LF/HF	-.536**#	.006	-.385#	.058
SD1 (ms)	.462*#	.020	.340#	.096
SD2 (ms)	.103#	.626	.100#	.634
SD2/SD1	-.601**	.001	-.330	.108
RHR0 (bpm)	.431*	.032	.598**	.002
RHR1 (bpm)	-.180	.388	.158	.452
RHR2 (bpm)	-.285	.167	-.338	.098
HRR1 (bpm)	-	-	.760**	<.001
HRR2 (bpm)	.760**	<.001	-	-
6MWD (m)	.098	.642	.072	.732

Pearson Correlation, #Spearman's Correlation;
r-value=correlation coefficient; *p-value<.05, **p-value<.01

We found no statistically significant correlation of either HRR1 or HRR2 with 6MWD, however the directions of correlation coefficients were positive (Table 2). Relatively less sample size could be the reason. Earlier study showed significant positive correlation of HRR1 and HRR2 with 6MWD among healthy males of average age 36.95±3.84 years (14). Another study reported positive correlation between HRR1 and 6MWD in not only elderly patients with heart failure who underwent beta blockers but also in healthy elderly individuals without any heart failure (20). Our studied subjects were young healthy males (mean age: 22.60±1.53 years) (Table 1). Also, 6MWD depends on integrated functional exercise capacity and various anthropometric measures rather than autonomic or chronotropic recovery only (14, 21).

5. Conclusion

In the present study, statistically significant positive correlation of HRR1 was found with RMSSD, LnRMSSD, SDSD, HF (nu), SD1, RHR0 and HRR2; whereas it correlated significantly and negatively with LF (nu), LF/HF and SD2/SD1. HRR2 showed statistically significant correlation with only RHR0, apart from HRR1, and both were positive in direction. Hence out of the two measures of post exercise heart rate recovery, HRR1 might be better as far as correlation to resting HRV was concerned. Within the limit of this cross-sectional study, the current result might suggest that those who recovered faster at 1st min after 6MWT also had higher vagally mediated markers of HRV.

6. Limitations

Small sample size was the greatest limitation of this study. Since, the study only included males, no gender difference in the association between heart rate recovery and HRV could be evaluated. 6MWT is a self-paced submaximal exercise test. In future studies, heart rate recoveries after maximal and exhaustive exercise could be done. HRRs after other type of exercise like cycling could also be used. In the present study, heart rate recovery was taken while the subjects rested passively in sitting position. Studies involving active recovery post exercise could also be done in future. In spite of these limitations, our result did provide a firm platform for future well designed and larger sampled study.

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