Original Article

Normative Data on Heart Rate Variability Time and Frequency Domain Indices in a Healthy Central Indian Population Undergoing Treadmill Exercise

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Abstract

Background: Heart rate variability (HRV) is becoming one of the most valuable tools for assessing a healthy heart's complex and constantly changing oscillations. This study was a pioneering attempt to establish normative data on HRV during treadmill exercise for monitoring the cardiovascular health of the central Indian population.

Methodology: This was a cross-sectional study in the Sports Physiology Laboratory of the Department of Physiology in a Rural Medical College in central India. One hundred and twenty healthy subjects in the age range 17-40 years were recruited. Short-term HRV (5 min) was extracted from ECG recordings obtained using the Power lab system, AD Instruments, Australia.

Results: Time domain indices for males were - Standard deviation of N-N interval (SDNN): 162.61±162.11; Square root of mean squared difference of N-N intervals (RMSSD): 355.79±798.27; the percentage of adjacent NN intervals that differ from each other by more than 50 ms (pNN50): 23.10±27.87. Frequency domain indices in males were- LF power (%)- 535.74±3625.96; HF power(%) - 33.15±24.31, LF nu: 33.12± 16.06 ; HF nu: 57.22±14.89; LF/HF:0.77±0.74. Time-domain indices for females were SDNN as168.49±130.09; RMSSD: 182.41±154.85; pNN50:32.33±26.59. Frequency domain indicesin females were LF power (%)-19.85±6.13; HF power (%) 43.03±16.39, LF nu-30.53±9.88; HF nu - 60.95±8.70; LF/HF:0.54±0.27

Conclusion: Baseline normative values for HRV spectral and time-domain analysis have been established for their clinical use in comparing the HRV of a healthy individual to that of a deceased individual or an athlete.

Keywords: Heart Rate Variability; Spectral Analysis; Time Domain Analysis; Treadmill; Sports Physiology; Baseline Data.

Introduction

The fluctuations of a healthy heart are complex and constantly varying, thus allowing the cardiovascular system to adjust to sudden physical and psychological encounters to homeostasis rapidly. Heart rate variability (HRV) is the cardiac inter-beat variation, that is, variation in the length of the cardiac cycle. It is an affordable, non-invasive, practical and reproducible measure of

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autonomic input to the heart. It is commonly used in research as a "gold-standard" technique for autonomic modulation. Heart Rate Variability was first documented by Stephen Hales in the early 18th century when he first reported fluctuations in beats as well as arterial pressure, which led him to believe that these fluctuations coincided with respiratory cycles. Since this first discovery, both time and frequency analysis techniques must have been used to interpret the sympathetic and parasympathetic inputs. The analysis suggested that the changes in heart rate and the variations beat-to-beat were due to an increased influence of parasympathetic input from the vagus nerve. [1] A heart rate that is variable and responsive to demands is believed to bestow a survival advantage, whereas reduced HRV may be associated with poorer cardiovascular health and outcomes.[2] The parasympathetic nervous system has an instantaneous response and is responsible for beat-to-beat fluctuation in heart rate. Clinical application of HRV is mainly associated with the prediction of sudden cardiac death and assessing cardiovascular and metabolic illness progression; recent observations have suggested its applicability to physical exercise training.[3] HRV is a relevant marker for assessing cardiovascular autonomic parameters that are partially under regulatory control of innervations from sympathetic and parasympathetic system.[4,5] Analysis of HRV permits insight into the interdependent regulatory system which enables us to combat any sudden physical challenge to homeostasis just like a situation which arises when a person undertakes exercise. Since there are various factors which tend to influence heart rate variability, a normative data must be established in this region of the country, considering other major factors that can influence HRV for its clinical use. To the best of our knowledge, there is a paucity of such data, so in this study, we have laid down the baseline values for HRV in the population of the central part of the country.

Aim

To establish normative data of HRV during treadmill exercise for monitoring cardiovascular health of the central Indian population.

Methodology

Study Design

Cross-sectional, observational study.

Study Setting

The study was carried out in the Sports Physiology Lab, Department of Physiology of a rural medical college in India.

Study Participants

One hundred and twenty healthy subjects in the age range 17-40 years who volunteered for the study and gave written informed consent were recruited. They were all active but did not undergo any training exercise.

Subjects screened as high risk for cardiovascular disease, having any history of cardiac, respiratory or psychiatric illness, any significant co-morbidity or those who consumed any drug (like beta-blockers) affecting HRV were excluded.

Equipment

ECG recordings were recorded using a Power lab system, AD instruments, Australia and analysis was done by Lab Chart software. This software's Heart Rate Variability (HRV) Module helped analyze inter-beat interval variation in ECG recordings. (Figure 1).

Short-term HRV (5 min) recording was extracted according to the standards set forth by the Task Force of the European Society of Cardiology and North American Society of Pacing and Electrophysiology in 1996.[6] As per this, two methods of analysis of HRV data are considered: time-domain and frequency-domain analysis. The spectral, as well as time-domain indices of HRV using RR-interval based on ECG are computed and analyzed by the software.

Each subject was given a detailed explanation of protocol and precautions thereof.

After obtaining baseline characteristics and resting BP and Heart rate measurements in the supine posture, the subject was asked to wear the Equivital EQ-02-B3 ECG sensor belt along with a Polar transmitter SPO180 (having chest strap) which is a wireless heart rate kit. Symptom-limited exercise testing was conducted using a motorized treadmill Af101.

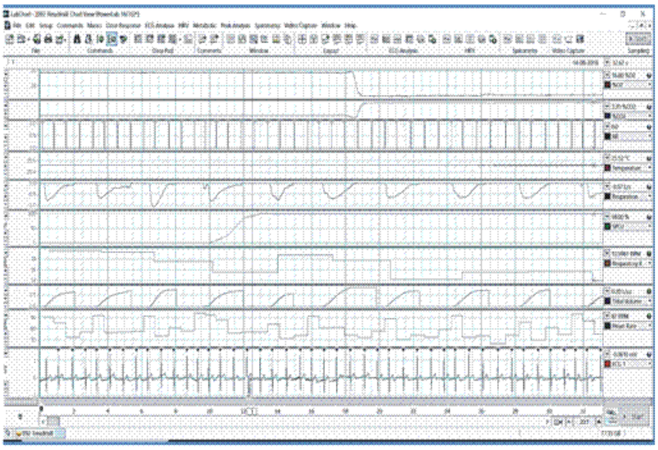

Figure 1: LabChart View of parameters assessed for heart rate variability

Study Parameters

Time-domain indices measured were Mean R-R interval, Standard deviation of N-N interval (SDNN), and Square root of mean squared difference of N-N intervals (RMSSD). The RMSSD is the root mean square of successive differences between normal heartbeats. NN-intervals refer to the intervals between normal R-peaks. The NN50 is the adjacent NN intervals that differ by more than 50 ms, and pNN50 is the percentage of NN50.HRV analysis software analyses the RR interval time-domain components, and the results were given as standard deviation of RR intervals (SDNN), square root of the mean of the sum of the squares of differences between adjacent RR intervals (RMSSD), adjacent RR interval differing more than 50 ms (Nn50).

HRV COMPONENTS	ANALYSIS OF SHORT-TERMRECORDING	FREQUENCY RANGE
Total Power(5 mins)	A variance of N -N intervals over the temporal segment	Approx. ≤0.4Hz
VLF	Power in a very-low-frequency range	0-0.04 Hz
LF	Power in low -frequency range [SYMPATHETIC]	0.04-0.15Hz
LF norm	LF power in normalized units LF/ (total power – VLF) ×100	
HF	Power in the high -frequency range [PARASYMPATHETIC]	0.15-0.4Hz
HF norm	HF power in normalized units HF/ (total power-VLF) ×100	
LF/HF	Ratio LF/HF [SYMPATHO-VAGAL BALANCE]	

After excluding the artefacts and ectopic from the RR interval series given by the Polar transmitter, a five-minute RR interval series was chosen from the recording of exercise and analyzed with LabChart software for HRV, which gives the frequency spectrum components using fast Fourier transformation and the results as spectral power in ms^2 including very low frequency (VLF; 0.003 Hz to 0.04 Hz), low frequency (LF; 0.04 Hz to 0.15 Hz) and high frequency (HF; 0.15 Hz to0.4 Hz). Total spectral power (TP =VLF + LF + HF) and other calculated parameters like low-frequency power in normalized units (LF nu = LF X 100/ (TP–VLF), high-frequency power in normalized units (HF nu = HF X 100/ (TP–VLF) and LF/HF ratio (ratio of LF power to HF power) were obtained.

Statistical Analysis

Statistical analysis was done using an unpaired t-test and Pearson's correlation co-efficient by Statistical Software SPSS Version 20. P-value <0.05 was considered statistically significant.

Results

Males and females of the study population were in the age range of 17-40 years. Out of 120, there were 61 (55%) male subjects and 59(45%) female subjects. The mean age of males was 22.24± 5.48 years. The mean age of females was 22.68± 5.76 years. The mean ± SD values of HRV Indices of all the study subjects are shown in Table 1. It is observed in Table 1 that males show a dominant sympathetic response as compared to females, which is expressed as a higher value of LF/HF (sympathovagal ratio).

Table 1: Mean ± SD values of HRV Indices of study subjects

HRV PARAMETERS	MALES	FEMALES
SDNN	162.61±162.11	168.49± 130.09
RMSSD	355.79±798.27	182.41± 154.85
pNN50	23.10±27.87	32.33± 26.59
LF power (%)	535.74± 325.96	419.85± 266.13
HF power(%)	33.15±24.31	43.03± 16.39
Total power(ms^2)	39514.95 ± 8021.86	33649.21 ± 8461.41
LF nu	33.12± 16.06	30.53± 9.88
HF nu	57.22±14.89	60.95± 8.70
LF/HF	0.77± 0.74	0.54± 0.27

Tables 2 and 3 depict the HRV Indices of male and female subjects, respectively.

Table 2: HRV Indices of male subjects

S.No.	Parameters	Non-athletic males (n=50) Mean ± SD	Athletes males (n=17) Mean ± SD
1	SDNN	139.75±152.65	110.82±137.28
2	RMSSD	246.20±579.35	349.86±981.39
3	PNN50	22.28±27.37	10.44±17.78
4	LF %	17.95±21.72	12.63±7.82
5	HF%	31.62±23.21	22.97±25.43
6	LF NU	34.31±16.35	41.17±21.72
7	HF NU	57.71±14.93	47.34±18.51
8	LF/HF	0.87±1.26	1.30±1.05

Table 3: HRV Indices of Female Subjects

S.No.	Parameters	Non-athletic females (n=70) Mean ± SD	Athletes females (n=13) Mean ± SD
1	SDNN	180.77±178.55	162.74 ± 110.54
2	RMSSD	187.34±195.42	194.20 ± 162.34
3	PNN50	31.24±27.29	32.22±25.71
4	LF %	18.53±6.54	21.43±5.09
5	HF%	40.51±17.32	46.68±16.02
6	LF NU	31.28±13.26	31.26±10.63
7	HF NU	59.26±11.69	62.20±9.55
8	LF/HF	0.71±1.10	0.55±0.26

Discussion

Few studies are available on indices of HRV, and little is known regarding the baseline parameters of HRV during physical exercise. Although several studies have been performed to establish the HRV indices pre and post-exercise but there is a dearth of literature on the HRV of healthy individuals during exercise. A study was conducted on adolescents (age range 12-17 years), which was designed to compare the effects of six months of globally recommended Structured Physical Activity with that of Unstructured Physical Activity in healthy school-going adolescents.[7] On comparing our results with those of in the non-athletic population of the mentioned study, it was seen that the time and frequency domain indices in our study have a higher value as they were calculated during exercise on the treadmill, suggesting that healthy individuals show a higher variability during stress which is expressed as a higher total power(ms^2). The total power median in the mentioned study was 3374.50 ms^2 in girls and 2757 ms^2in boys, and the maximum was 21250 ms^2 in girls and 20350 ms^2 in boys. The same values in our study were found to be the median of total power: 7319 ms^2 in females and 4777 ms^2 in males, and the maximum total power was 518500 ms^2 in females and 360500 ms^2 in males. In both, studies, females show higher variability in heart rate at rest as well as under stress (exercise).

Heart rate and its fluctuations on a beat-to-beat basis (ECG) can be used to monitor autonomic influx and withdrawal. The time-domain parameters are associated mostly with the overall variability of HR over the time of recording, except RMS-SD, which is associated with fast (parasympathetic) variability. RMSSD and pNN50% are used to estimate the parasympathetically mediated changes reflected in HRV. The HF power, LF power and LF/HF ratio are considered to represent parasympathetic activity, sympathetic activity and sympathovagal balance, respectively. Both parasympathetic and sympathetic activity modulates heart rate by influencing the pulse interval (RR interval).[8] Effect of change in parasympathetic outflow to the heart is seen very rapidly as a change in heart rate, usually within 400 ms, and hence it can control heart rate on a beat-to-beat basis.[9]Hence, the beat-to-beat changes determined by time-domain parameters of HRV analysis signify resting parasympathetic activity. The effect of change in sympathetic outflow to the heart usually takes more than 5s to change the heart rate.[10] Hence, the high-frequency component in the RR tachograms considered to be due to resting parasympathetic activity and the low-frequency component is mainly due to resting sympathetic activity. The total power provides the overall heart rate variability observed in the recording. Resting parasympathetic activity is the major contributor to HF power, HFnu, SDNN, RMSSD, and NN50. While LFnu reflects sympathetic activity, the LF component is predominantly due to resting sympathetic activity with some influence from resting parasympathetic activity. The physiological explanation for the VLF component is ill-defined, and it cannot be interpreted based on short-term HRV recordings and there is insufficient evidence to provide any explanations from this study. Linux and HFnu represent controlled, and balanced resting activity of the sympathetic and parasympathetic nervous system and the LF/HF ratio indicates the sympathovagal autonomic balance.

For comparison of HRV of a healthy individual to that of a deceased individual and make use of it clinically, a normative data of the population needed to be established for our area as there is a difference in eating habits, level of physical activities etc. in different regions of the country.

An important aspect concerns moving artefacts which have been taken care of in this study as we used wireless technology. Several factors like body movements cause heart position relative to electrodes to change, and mechanical movements of electrodes produce moving artefacts causing a change in potential due to altered physical dimensions of the electrode-skin half cell (epidermal signals caused by epidermis stretching).[11,12]

Conclusion

Baseline normative values for HRV spectral and time-domain analysis have been established in the Sports Physiology Lab of the rural medical college of central India for its clinical use in comparing the HRV of a healthy individual to that of a deceased individual or an athlete. From a functional standpoint, our study enables us to understand how exercise demands a specific response of frequency spectrum and time domain when fatigue starts to compromise mechanical response.

Conflict of Interest

None declared

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