Evaluation of Cardiac Autonomic Function in Relation to Post-Exercise Heart Rate Recovery Among Medical Students

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ABSTRACT

Introduction: Heart rate variability is the indicator that reflects the cardiovascular autonomic nervous system. Regular exercise stimulates structural and functional changes in the cardiovascular and peripheral system that can be measured by heart rate variability. This study was necessary to evaluate cardiac autonomic tone and its relation with physical fitness level in healthy medical students. So that it could provide important data regarding autonomic status and physical status which will be useful for both clinical and research purposes. **Aims:** To measure cardiac autonomic tone of medical students using heart rate variability and to look for the relationship between recovery heart rate and cardiac autonomic tone. **Methods:** In this cross-sectional study, 57 consenting healthy medical students age 17-30 years, underwent cardiac autonomic tone evaluation through heart rate variability and the cardiac autonomic tone was compared with their physical fitness level which was categorized into four groups that is good, satisfactory, poor and very poor. **Results:** No changes in Heart rate variability among four fitness groups were found. But when Spearman's correlation was done we found out association of heart rate variability measures with recovery heart rate. The recovery heart rate showed significant negative correlation with pNN50, high frequency power and high frequency normalized unit. Whereas, recovery heart rate showed significant positive correlation with low frequency normalized unit and Low frequency/ high Frequency ratio of frequency domain measures of heart rate variability. **Conclusion:** This study reflects that parasympathetic activity was higher in increasing fitness level. But in lower fitness level sympathetic activity was higher.

Keywords: Autonomic Nervous System; Heart Rate Variability; Root mean square of successive normal R-R interval differences; Square of successive normal R-R interval differences

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INTRODUCTION

Physical Fitness Index (PFI) is a good measurement of fitness and a person's ability to recover after a strenuous exercise.[1] Regular exercise stimulates structural and functional changes in the cardiovascular systems and peripheral systems that can be measured by Heart rate variability (HRV).[2, 3] It can be determined by utilizing time and frequency domain indices that can be considered to define autonomic nervous system activity in cardiovascular system.[3] Similarly, the root mean of square of successive normal R-R interval differences (RMSSD) and higher frequency are associated with vagal activity; the standard deviation of normal R-R interval (SDNN) represents global variability.[3] Before and right after physical load, the physiological control system's responses to physical exercise which can be measured by heart rate variability.[3] The rate of decrease in heart rate frequency and the length of time to recovery after moderate to heavy exercise are commonly indicators of cardiovascular fitness.[4] In accordance to the World Health Organization, physical inactivity is now the fourth most significant risk factor for mortality worldwide, accounting for almost 2 million deaths.[5] In medical students, very few studies have evaluated

their physical fitness index (PFI) scores and correlate them to cardiac fitness. Therefore, it was worth to carry out this study to evaluate cardiac autonomic tone and physical fitness in healthy medical students and to determine the relationship between obtained parameters. Therefore, this study will provide important data regarding autonomic and physical status which will be useful for both clinical and research purposes.

i. To measure cardiac autonomic tone of medical students using heart rate variability.

ii. To investigate the relationship between recovery heart rate and cardiac autonomic tone.

METHODS

This cross sectional study was conducted on healthy MBBS male and female medical students in the Department of Physiology, Nepalgunj Medical College, Nepal from November 2025 to March 2026.

Subjects:

1.1 Sample size: 57

Sample size was determined by using the formula

$n=1.96^2\ \sigma^2)/E^2$ where,

σ = estimated standard deviation

E = margin of error

1.2 Sampling technique:

Purposive sampling methods were applied to select the subjects from MBBS students. Fifty-seven medical students fulfilling inclusion & exclusion criteria of the study were enrolled in the study.

1.3 Inclusion criteria

Healthy young adults (MBBS students)

Age from 17 to 30 years

1. 4 Exclusion criteria

Subjects with locomotors and musculoskeletal disorder

Subjects with cardiovascular, respiratory and endocrine disorders and any other disorders affecting autonomic nervous system

Subjects with a history of alcohol abuse, use of neurotoxic drugs or agents

Subjects on regular medication

Details of recording procedure:

Recording Procedure of Heart Rate Variability

To record the HRV, instrument brand named; Polar S810i heart rate monitor was utilized. It was a class 1 laser product manufactured by polar Electro Oy, Professorinite 5 FIN-90440 Kempele. It was designed to measure the degree of physiological strain and intensity during physical activity. The transmitter was secured in place by an elastic strap. The electrodes on either side of the strap detected the heart rate, cardiac cycle length and transmit it to the wrist receiver. The wrist receiver displayed the heart rate, R-R interval and other data. The wrist receiver settings were uploaded to the computer using infrared (IR) communication.

Analysis of R-R intervals for HRV parameters

The R-R intervals saved in wrist unit were transmitted to the laptop for analysis of HRV measures by both time domain and frequency domain methods using HRV software (Kubios HRV version 2.1 released on July 2012, Kuopio FINLAND. But before analysis of HRV the ectopic beats and missing beats were identified and edited manually using Microsoft Notepad, which was found to be less than 3%. The time domain method used statistical method for analysis of HRV measures and frequency domain method calculated HRV using FFT (Fast Fourier Transform).

Heart rate variability parameters calculated to be calculated (Task force, 1996) (2)

Time domain measures

SDNN (ms): Standard deviation of normal to normal RR intervals for the selected heart rate time series

RMSSD (ms): The root mean square of difference of successive RR intervals.

NN50 count: Number of RR intervals more than 50ms

pNN50 (%): The percentage of consecutive RR intervals that differ more than 50ms or equal to 50 ms

Frequency domain measures

Power of very low frequency (VLF), low frequency (LF) and high frequency (HF) bands both in absolute and normalized units.

The sympatho-vagal balance i.e ratio of LF power to HF power (HF/LF).

HF reflects parasympathetic activity [14, 15]

LF reflects sympathetic activity [14,15]

1. 5 Recording Procedure of 3-Minute Step Test

The test were conducted using a bench 13" inches height. Before performing the test subjects were given full instructions about the procedure of the test and were done after 10 minutes rest in resting position. The subjects were given a five to ten second practice session to become comfortable with a stepping cadence to enhance their performance and yield accurate results with a stepping cadence of four-step (up-up-down-down). The subjects performed stepping cycle of four-step cadence (up-up-down-down). For male subjects it was twenty-four complete steps-ups per minute regulated with metronome set at 96 beat

per minute. For women it was twenty-two steps-ups per minute or 88 beats per minute on the metronome. For three minutes, the participants executed the test steps ups and downs.

Calculation of Physical Fitness Score

The participation was given direction to stand after finishing the 3- Minute step test. After completion of the 3-Minute Step Test, the subject was asked to stand. After five seconds, his/ her heart rate (pulse rate) for fifteen seconds was recorded and multiplied by four. This measured HR/ PR was considered as recovery heart rate of the subject. Physical fitness scores were calculated depending upon the recovery heart rate of the subject in 3-Minutes Step Test. Calculation of physical fitness score was done by following the guidelines published by Young Man's Christian Association (YMCA). In our study, the physical fitness level given by YMCA was modified into 4 groups based on the recovery heart rate after the sub-maximal exercise. The modified fitness level assigned was:

Fitness level 1 = Good

Fitness level 2 = Satisfactory

Fitness level 3 = Poor

Fitness level 4 = Very Poor

The detail about the modification is illustrated in the following table I and II.

Fitness level assigned for the present study groups	Fitness category assigned by YMCA	Recovery Heart Rate (BPM) for 18-25 yrs of age (male)
Good fitness level	Excellent	50 – 76
	Good	79 – 84
Satisfactory fitness level	Above Average	88-93
	Average	95 – 100
Poor fitness level	Below average	102 – 107
Very poor fitness level	Poor	111 – 119
	Very poor	124 – 157

Table I: Modification of category of physical fitness level and scores given by YMCA that was used for the present study for male subjects

Fitness level assigned for the present study groups	Fitness category assigned by YMCA	Recovery Heart Rate (BPM) for 18-25 yrs of age (female)
Good fitness level	Excellent	52 – 81
	Good	85 – 93
Satisfactory fitness level	Above Average	96 – 102
	Average	104 – 110
Poor fitness level	Below average	113 – 120
Very poor fitness level	Poor	122 – 131
	Very poor	135 – 169

Table II: Modification of category of fitness level and scores given by YMCA that have been used for the present study for female subjects

Physical Fitness Variables: Recovery heart rate (beat/ min)

Ethical clearance

All participants provided with written informed consent. The Institutional Review Committee (IRC) of Nepalgunj Medical College gave permission to the study.

Statistical Analysis

All data were tested for distribution. The statistical test was applied based on distribution of observations. Statistical analysis was done using statistical software SPSS version 21.0 (SPSS INC, Chicago, ILL, USA).

Intergroup comparison

All the HRV measures were non-normally distributed. Thus, analyzed using Krusakal Wallis followed by multiple comparisons.

Correlation

The Spearman correlation was applied to find the correlation of fitness score with HRV variables. The data are expressed as mean ± SD for normally distributed data and median (interquartile range) for non-normally distributed data. The correlation is expressed in terms of correlation-coefficient rho and level of significance (p). The $p<0.05$ will be considered statistically significant.

RESULTS

A) Physical fitness variables

According to these study students having maximum percentage (33%) had very poor fitness level. followed by 30% of them having satisfactory fitness level. Twenty one percent of them had poor fitness level whereas only 16%, minimum percentage had good fitness level. (Table III) The proportion of male and female in each fitness groups was almost similar. (Table III)

Physical fitness levels	Recovery HR Mean ± SD (n=57)	Calculated VO2 max Mean ± SD (n=57)	Number of medical students (%)	Male	Female
Good	87.33 ± 4.24	60.15 ± 15.52	9 (16)	4	5
Satisfactory	98.00 ± 6.55	58.47 ± 15.84	17 (30)	9	8
Poor	110.92 ± 5.98	53.97 ± 14.06	12 (21)	7	5
Very poor	128.42 ± 10.78	48.26 ± 7.54	19 (33)	9	10
Total			57 (100)	29	28

HR= Heart Rate, VO2 max= maximum oxygen capacity

Table III: Physical fitness levels of medical students on the basis of recovery heart rate

B) Comparison of resting HRV among four fitness groups

Both time domain and frequency domain measures of HRV were comparable among four fitness groups. (Table III)

HRV measures	Groups Median (interquartile range) Good fitness level (n=9)	Satisfactory fitness level (n=17)	Poor fitness level (n=12)	Very poor fitness level (n=19)	Over all p-values
SDNN (ms)	67.84 (49.99-93.99)	73.21 (57.65-90.25)	68.568 (50.855-95.74)	57.44 (43.54-84.80)	0.778
RMSSD (ms)	83.137 (41.56-94.18)	67.438 (54.61-91.24)	67.0305 (49.25-85.96)	57.16 (32.99-91.67)	0.710
pNN50 (%)	52.20 (21.45-55.20)	45.37 (33.99-55.75)	42.1965 (13.55-56.67)	27.5 (8.76-47.95)	0.170
LF power (ms2)	1427.00 (575.7-2335.5)	832.76 (502.73-1386.5)	1459.70 (370.5-1868.6)	831.32 (380.84-1830.9)	0.843
HF power (ms2)	2243.00 (1027.57-4367.9)	1714.00 (735.15-3081.2)	1431.75 (547.05-2514)	899.17 (368.67-1483.9)	0.173
LF(nu)	38.8870 (30.83-40.83)	34.15200 (26.11-43.7)	43.1045 (25.7-55.31)	54.262 (30.49-64.67)	0.200
HF(nu)	61.10 (55.74-67.47)	65.83 (56.13-73.78)	56.1780 (44.59-74.24)	44.4210 (32.20-67.34)	0.206
LF/HF ratio	0.64 (0.489-0.719)	0.52 (0.36-0.78)	0.77 (0.35-1.24)	1.22190 (0.452-1.83)	0.205
Total power (ms2)	2581.30 (2039.37-7547.15)	3190.62 (1718.17-4818.45)	4068.08 (2080.1-8612.9)	2478.27 (1628.9-6271.5)	0.739

SDNN= standard deviation of RR interval, RMSSD= root mean square differences of successive RR intervals, pNN50%= percentage number of RR intervals > 50ms, LF power= Low frequency power, HF power =High frequency power, LF (nu) = Low frequency normalized unit, HF (nu) = High frequency normalized unit, LF/HF ratio= Low frequency/ High frequency ratio, p<0.05 was considered statistically significant.

Table IV: Comparison of resting HRV measures among four fitness groups

3. Association of HRV measures with recovery HR in healthy young medical students

Spearman's correlation was done to find out association HRV variables with HRV measures. The recovery HR showed significant negative correlation with pNN50, HF power and HF nu (table V). Whereas, recovery HR showed significant positive correlation with LF nu and LF/HF ratio of frequency domain measures of HRV (table V).

Variables	Recovery heart rate rho	Percentage p-value
SDNN	-0.073	0.588 (NS)
RMSSD	-0.129	0.338 (NS)
pNN50%	-0.298	0.024
LF power (ms2)	-.015	0.912 (NS)
HF power (ms2)	-.265	0.046
LF nu	0.301	0.023
HF nu	-.284	0.032
LF/HF ratio	0.287	0.030
Total power	-.045	0.739 (NS)

SDNN=Standard deviation of RR interval, RMSSD= root mean square of differences of successive RR intervals, pNN50%= percentage of number of RR intervals > 50ms, LF power= Low frequency power, HF power =High frequency power, LF (nu) = Low frequency normalized unit, HF (nu) = High frequency normalized unit, LF/HF ratio= Low frequency/ High frequency ratio. p<0.05 was considered statistically significant.

Table V: Correlation of HRV variables and recovery HR

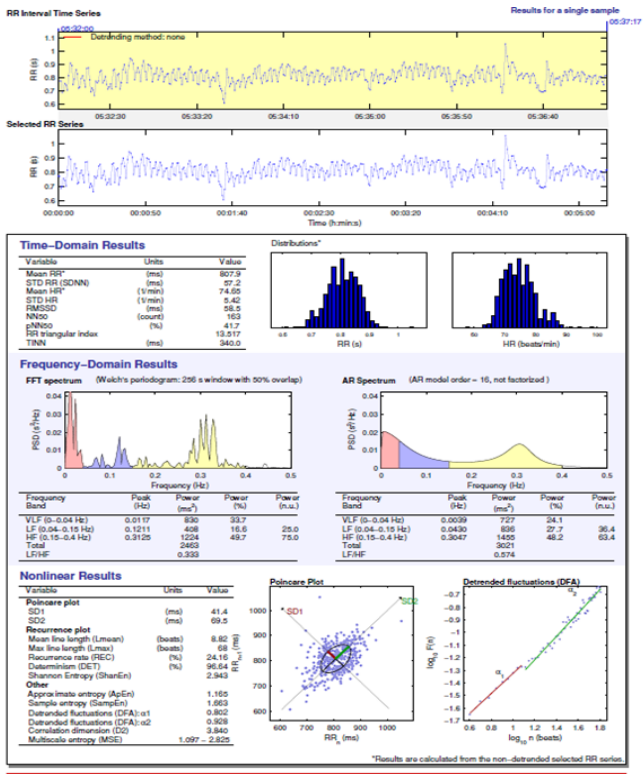

Figure 1: Report of HRV analysis

DISCUSSION

A cross-sectional study was conducted on 57 apparently healthy young medical students. The objectives of the study were 1. To assess cardiac autonomic tone of medical students using heart

rate variability test, 2. To find out correlation among physical fitness scores and HRV parameters values. This study was conducted because very fewer studies had assessed above tests in healthy medical students. In present study medical students were categorized into four fitness groups: Good, satisfactory, poor, very poor based on recovery heart rate obtained after 3-Minute Step Test. For the group division, YMCA guidelines were followed with some modifications. Physical fitness index included recovery heart rate.

We found that results with our study proving that medical students had sedentary life style.[6] They were recommended to do regular physical activity to improve their cardiovascular fitness.

HRV measures among four groups of fitness level

In our study all the time domain measures of HRV (SDNN, RMSSD and pNN50%) at rest were similar among four groups of fitness level. A study conducted by Veira et al, 2012, found that HRV were not indicators of aerobic capacity also showed no correlation between HRV indices with the values of resting heart rate (HR).[7] The above study was conducted on elderly men. Another study conducted by Aubert et al, 2003 found greater vagal control in HRV parameters in high-fit group at rest because of aerobic training.[8] The study conducted by De la Cruz Torres et al, 2008 found that sportsman had high HRV at rest than sedentary people, especially parasympathetic predominance. [9] In our study we did not find any significant changes in HRV among four fitness groups on comparison among the groups. It may be because in our study no students were on aerobic training or sportsman. Our results found that negative correlation with pNN50%, HF power, HF nu markers of parasympathetic and positive correlation with LF nu, LF/HF ratio markers of sympathetic markers showed that physically fit medical students have high HRV and low HRV with less fit medicals students which had similar results above results.

Correlation between recovery heart rate and HRV parameters

In present study the time domain and frequency domain measures of HRV did not show any significant differences among four fitness groups on comparison. However in correlation, pNN50 (time domain HRV measure), HF power, LF nu, HF nu and LF/HF ratio (frequency domain measures) all showed relationship with recovery HR. It may be because result was diluted when it was divided into different groups based on ranges of recovery HR. But when correlation was done with all the subjects linearly, it showed a relationship between recovery HR and HRV measures. In present study pNN50, HF power and HF nu showed negative correlation with recovery HR whereas, LF nu and LF/HF ratio showed positive correlation with recovery HR. The pNN50, HF power and HF nu are indicators of parasympathetic activity, whereas, LF nu and LF/HF ratio are indicators of sympathetic activity.[3] Our results reflected that parasympathetic activity was lower with increasing recovery HR. It means parasympathetic activity was higher with increasing fitness level. Whereas, sympathetic activity was found increasing with increasing recovery HR. It means sympathetic activity was higher with lower fitness level. Very few studies have studied physical fitness and HRV measures. In the study carried out by Kristen et al, Year showed no any significant relationship of SDNN with physical activity in women who were indulged in moderate and vigorous activity.

Strength of study

1. Homogenous group of healthy young medical students were included in the study.

2. The methods were performed properly during the study period. All the obtained data were collected between 8:15 AM and 11 AM of the day and room temperature was maintained at 25 ± 20 C to avoid variation due to circadian rhythm.

3. Recovery heart rate for one minute after 3- Minute Step Test was measured using polar device.

4. Very few studies have been conducted dividing physical fitness into four categories.

LIMITATIONS

We categorized subjects into four groups; some group included less number of subjects. The sample size is relatively small. Thus, could not be included more numbers of students. The hormonal variations, especially in female participants, may alter autonomic responses if cycle phases are not controlled. The findings of this study may not apply to different age groups, diseased populations, athletes, or general communities.

CONCLUSION

All HRV measures were not significantly different among four fitness groups however; there were significantly negative correlation with pNN50, HF power and HF nu with recovery heart rate. The positive correlation with LF nu and LF/HF ratio of frequency domain measures of HRV with recovery heart rate. It shows that parasympathetic activity was lower with increasing recovery HR indicating parasympathetic activity was higher with increasing fitness level. Whereas, sympathetic activity was found increasing with increasing recovery HR indicating sympathetic activity was higher with lower fitness level.

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