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RESEARCH ARTICLE

Gender differences in cardiovascular autonomic milieu and its association with academic performance in young adults

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ABSTRACT

Background: Initiated by biological plausibility and supported by the pilot study, we observed possibility of associations between cardiovascular autonomic milieu and academic performances. As there are established cognitive ability differences among gender in literature, we designed a study to observe the differences in the basal autonomic activity as well as the manner of association between autonomic activity and academic performance between genders. Considerable lacunae in literature on this aspect also warranted for scientific introspection on this lacuna. **Aims and Objective:** The aim of this study is to observe the association between resting short-term heart rate variability (HRV) indices and University marks of anatomy, biochemistry, and physiology in young male and female medical students. **Materials and Methods:** Cross-sectional observational study with 102 healthy young participants in which 34 boys and 68 girls between 18 and 22 years were included by convenient sampling after assessing the inclusion and exclusion criteria. HRV is computed under standard conditions as per the task force recommendations in time and frequency domains. The academic performance is assessed by University examination marks at the end of the 1st year. The comparison of HRV parameters, academic performance, and their associations was analyzed separately by gender. Type 1 error allowance fixed at 5% but considering the high dispersion of HRV data, *P* values between 0.1 and 0.05 were also discussed. **Results:** Mean RR intervals showed a negative correlation with academic performance in males. Time domain and geometric indices of HRV showed a negative correlation in boys but not in girls. In case of frequency domain indices, all indices of sympathetic activity showed a positive correlation with academic performance in boys and not in girls. Furthermore, sympathetic indices are more in males compared to females. All indices of parasympathetic reactivity were negatively correlated with academic performance in males. **Conclusion:** High-sympathetic activity is correlated with better cognitive ability in males but the same association is not seen in females.

KEY WORDS: Heart Rate Variability; Gender; Cognition; Sympathetic; Academic; Performance; Medical; Students

INTRODUCTION

Male and female sex hormones play a significant role in the cardiovascular autonomic reactivity.[1] Higher sympathetic reactivity are seen in male gender for a given standardized stimulus.[2] Diseases related with higher cardiovascular sympathetic activity and resulting morbidity are common in male as compared to females.[3] On the contrary, females suffer from conditions of poor sympathetic reactivity or increased parasympathetic reactivity.[4] The incidence of vasovagal attacks is common in young females. Scientific literature do support the difference in autonomic reactivity among gender but not free from conflicting observations.[5,6]

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Autonomic tone refers to the resting basal discharge or basal activity free from physiological perturbations or challenges.[7] This is in sharp contrast to autonomic reactivity which measures the degree of change or activity of a system in response to a given stimulus.[8] Autonomic tone is usually communicated in scientific literature as autonomic balance or sympathovagal balance, which does not indicate the absolute magnitude of activity of parasympathetic and sympathetic system but only the ratio of two activities. Heterogeneity exists in the manner of difference in autonomic nervous system activity among gender.[9,10] This conflicting finding warrants for the conduction of further studies.

In terms of evolutionary shaping, male and female of any species have differential bodily specialties or abilities. This is to cater to the needs of challenges. Differential cognitive capabilities are expressed among genders and are well established in literature.[11] Autonomic nervous system is intimately related to cognition as it determines the level of arousal, emotional quotient, memory, and ultimately learning.[12] The sympathetic nervous system is pivotal in increasing the cognitive abilities during times of emergency.[13] Decreased sympathetic activation has been reported in diseases affecting cognition.[14] Studies relating basal autonomic activity and cognitive ability are not available in literature. As there are differences in autonomic activity among gender, the authors of this study hypothesize that it must be reflected in the cognitive abilities also, and a certain degree of differential association is expected between the state of the cardiovascular autonomic nervous system and cognitive ability between genders.

Heart rate variability (HRV) has emerged out as a tool to measure the cardiovascular autonomic tone. It provides data about overall HRV as well as the individual contributions of parasympathetic and sympathetic nervous system.[15] HRV is measured by a 5-min lead II electrocardiography (ECG) recording. Unlike procedures such as the muscle sympathetic nerve activity and baroreceptor afferent ramp frequency, electrocardiogram being a very robust signal is very easy to record. The present day software tools quickly and accurately measure the RR interval, plot RR tachogram, and measure the HRV in both time and frequency domains in a short span of time. Therefore, in this study, the cardiovascular autonomic tone is ascertained through short-term HRV through a 5-min ECG recording.

Judgments on academic performance are done by summative assessments. University degree examinations at the end of year are best to assess the overall performance of the student. In the present study, cognitive abilities are measured by academic performance. University marks are used as the measure of cognitive ability.

Therefore, in the present study, the authors were interested in observing if there is a difference in resting cardiovascular autonomic activity among gender, as well as to observe if there is any difference in association between cardiovascular autonomic milieu and autonomic activity among the gender.

Objectives of the Study

1. To compare the time domain indices of HRV in male and female participants
2. To compare the frequency domain indices of HRV in male and female participants
3. To find the association between University marks in anatomy, biochemistry, and physiology marks with time domain parameters of HRV
4. To find the association between University marks in anatomy, biochemistry, and physiology marks with frequency domain parameters of HRV.

MATERIAL AND METHODS

Study Design

Observational study, cross-sectional type.

Study Setting

Electrophysiology Laboratory, Department of Physiology, Aarupadai Veedu Medical College, Puducherry.

Study Period

July 2015-July 2017 (2 years).

Sampling Frame

3rd, 4th, and 5th Semester MBBS students.

Sampling Method

Convenient sampling type.

Sampling Size

A total of 100 samples were planned in the protocol with equal distribution in gender. However, the study is now presented with data from 102 samples with 34 boys and 68 girls.

Inclusion Criteria

1. Volunteer MBBS students belonging to 3rd, 4th, and 5th semesters.
2. Age: 18-22 years.
3. Students who have cleared 1st year partcipants in the first attempt.

Exclusion Criteria

1. Known case of any chronic conditions or on any medications.

2. Physiological abnormalities detected in clinical examinations before including in study.
3. ECG was found abnormal during the study.
4. Sports persons or athletes.
5. Acute infection/illness during the time of recording.
6. 1st-year MBBS student (to avoid autonomy issue in consenting).

Methods of Collection of Data

Sampling and subject inclusion

Through oral announcement, interested volunteers were included in the study after getting their informed consent in writing. They underwent basic clinical examination to rule out any pre-existing abnormality and included in the study based on the inclusion and exclusion criteria.

Basic anthropometry

Height, weight, body fat percentage, and skinfold were measured. Height was measured using a wall mounted stadiometer to the nearest millimeter. Weight was measured by Belita BS-D-1123, digital weighing balance to the nearest 0.1 kg. The body fat percentage was measured by Citizen Body Fat Analyzer BM100, Citizen systems Japan Co., Ltd., by bioimpedance method to the nearest 0.1%. The triceps skinfold was measured by ABS slimguide calipers to the nearest millimeter.

ECG and blood pressure recording

All ECG recordings were done between 4.00 pm and 5.00 pm after class hours. Participants were confirmed for nil neurostimulant foods in the preceding 3 h. The participant was allowed to take supine rest in a dim lighted room with comfortable ventilation for 5 min. This was followed by a 6 min recording of lead two ECG at the rate of 256 samples per second and at 10-bit resolution by four channel digital polygraph PG4, INCO, India, communicating through RS232 port to a windows-based user interface software Niviqure V56 by Niviqure Meditech Pvt., Ltd., Bengaluru, India. At the end of the recording, resting heart rate and brachial blood pressure in the right arm was measured oscillometrically by Rossmax MJ701, Rossmax Swiss GmbH, Switzerland, automated blood pressure monitor in duplicate. All ECG recordings employed limb electrodes, and in case of girl student recordings, lady teaching faculty was present throughout the recording.

Post-recording, the discrete voltage data points of ECG are exported in the American Standard Code for Information Interchange (ASCII) format and converted to pulse-code modulation (PCM) wave file by GoldWave software. PCM wave file is read by Audacity software where beat detector function labels and exports R-wave position in ASCII text file. RR intervals were then computed in Microsoft Excel and saved as text file.

Computation of HRV indices

This text file was opened by the HRV analysis software HRV v1.0, Biosignal Analysis Group, Kuopio, Finland,[16] and the HRV in time and frequency domains were noted from 300 s data following the task force recommendations.[17]

The recordings were done after the University examination. All students of the same semester were recorded within a month time to avoid heterogeneity. Recordings were stopped 1 day prior and after a scheduled class test.

Parameters Recorded

a. Basic details: Name, age, gender, physical activity, and medical history.
b. Anthropometric measurements: Height, weight, body mass index (BMI), body fat percentage, and triceps skin-fold thickness.
c. HRV measurements
    - Time domain parameters: Mean RR interval (MRR), standard deviation of normal-to-normal intervals (SDNN), root mean square of successive SD (RMSSD), and number of instances where consecutive RR intervals differed by more than 50 ms (NN50), percentage of NN50 divided by total number of RR intervals (pNN50).
    - Geometric indices: RR triangular index (RRTi) and triangular interpolation of normal-to-normal intervals (TINN).

Frequency Domain Parameters

Very low frequency (VLF), LF, HF, VLF power percentage (VLFPP), LFPP, high frequency PP (HFPP), LF normalized (LFNU), HF power normalized (HFNU), and LF/HF ratio.

Academic Performance Parameters

Three 1st-year MBBS participants are chosen - anatomy, biochemistry, and physiology. In each participant internal assessment (IA) practical, IA theory, record marks, University Viva voce, University theory marks, University practical marks, and total marks are taken for analysis. Absolute marks in the mark sheet are used and not percentage.

Analysis of Data

Data analysis was done in SPSS version 20. Descriptive details of data are presented as both mean ± SD as well as median, interquartile range. Correlation between autonomic indices and academic parameters are done by Spearman's correlation. The allowed Type 1 error is fixed at <5% to reject the null hypothesis. However, with due consideration to the high variance of HRV parameters, correlation coefficients with P value between 0.05 and 0.1 are also discussed with due mention.

Ethical Clearance

Ethical clearance was obtained from the Institute Ethics Committee, Aarupadai Veedu Medical College, Puducherry.

RESULTS

Findings of the presents study are depicted in Tables 1-9.

DISCUSSION

There is no significant difference in the age and BMI among the genders (Table 1). However, males had significantly lesser body fat and triceps skinfold thickness compared to women. This finding is consistent with study by Nielson et al.[18] Males are found to have significantly lesser heart rates but more systolic blood pressures than their female counterparts. These are consistent with studies by Wiinberg et al. and Khoury et al.[19,20] There is no significant difference in diastolic blood pressures between genders, but we observed a higher mean blood pressures in males, though not statistically significant ($P = 0.067$).

In case of time domains, measures of HRV and MRR were found to be significantly different between genders (Table 2). Males had significantly longer MRR interval than females. That is males had lower heart rates as compared to females. There is no significant differences in the other time domain indices such as SDNN, RMSSD, NN50, and pNN50. These results are also partly consistent with results of Voss et al.[21] The geometric indices such as RRTI and TINN also did not show any statistically significant difference between genders.

Data from frequency domain indices showed a statistical difference in fast Fourier transform (FFT)-LFPP between genders. Males had higher FFT-LFPP compared to females (Table 3). Unpaired *t*-test significance yielded a $P = 0.046$ and median comparisons using Mann–Whitney *U*-statistic rejected null hypothesis at a $P = 0.037$. This revealed that males had significantly higher cardiovascular sympathetic activity compared to women. The other frequency domain

Table 1: Anthropometry and basic cardiovascular details of male and female participants

Parameter	Male (*n*=34)		Female (*n*=68)		Mean comparisons (unpaired *t*-test) *P*	Median comparisons (Mann–Whitney *U*-test) *P*
	Mean±SD	Median, IQ range	Mean±SD	Median, IQ range		
Age (days)	7394.82±372.66	7350.00, 7110.25-7729.25	7364.82±347.00	7404.50, 7109.25-7573.25	0.696	0.683
BMI (kg/m^2)	23.79±4.11	22.89, 20.78-26.54	23.44±4.56	22.60, 20.14-26.46	0.694	0.634
BF percent	21.52±6.40	22.00, 17.30-26.75	28.60±10.96	30.75, 24.60-36.08	0.000	0.000
TSFT (mm)	15.94±6.77	16.00, 11.00-21.25	22.44±7.81	22.00, 16.25-28.50	0.000	0.000
RHR_M (BPM)	73.69±14.12	69.50, 63.25-80.00	81.73±10.67	82.00, 75.50-88.50	0.005	0.001
RSB_M (mmHg)	111.75±14.89	108.50, 101.88-120.13	102.24±9.67	100.25, 96.25-107.50	0.001	0.001
RDB_M (mmHg)	67.13±10.48	65.25, 61.00-73.63	65.75±8.10	65.25, 60.13-70.38	0.503	0.647
RMP (mmHg)	82.00±11.11	80.42, 76.29-88.75	77.91±8.07	76.92, 71.79-81.42	0.062	0.051

IQ: Interquartile, BMI: Body mass index, RHR: Resting heart rate, BF: Body fat, TSFT: Triceps skinfold thickness, RSB_M: Mean resting systolic blood pressure, RDB_M: Mean resting diastolic blood pressure, RMP_M: Mean resting mean blood pressure, BPM: Beats per minute

Table 2: Descriptive data of time domain indices in male and female participants

Parameter	Male (*n*=34)		Female (*n*=68)		Mean comparisons (unpaired *t*-test) *P*	Median comparisons (Mann–Whitney *U*-test) *P*
	Mean±SD	Median, IQ range	Mean±SD	Median, IQ range		
MRR (ms)	0.88±0.14	0.87, 0.74-0.99	0.77±0.14	0.78, 0.70-0.84		0.312
SDNN (ms)	0.0476±0.02	0.0470, 0.04-0.06	0.0479±0.03	0.040, 0.03-0.06	0.952	0.345
RMSSD (ms)	46.98±20.31	44.45, 28.75-62.60	48.22±41.00	39.75, 23.00-62.73	0.839	0.972
NN50 (counts)	79.12±55.16	78.50, 23.75-129.50	84.34±74.64	70.00, 14.25-142.75	0.691	0.412
pNN50 (counts)	24.52±17.82	24.40, 6.43-41.33	23.08±21.58	17.00, 3.33-37.25	0.721	0.433
RRTi (%)	0.10±0.07	0.09, 0.07-0.11	0.11±0.13	0.08, 0.06-0.10	0.711	0.177
TINN (ms)	239.59±74.30	237.50, 180.00-296.25	221.87±106.71	205.00, 145.00-287.50	0.332	0.001

MRR: Mean RR interval, SDNN: Standard deviation of normal-to-normal intervals, RMSSD: Root mean square of successive standard deviation, NN50: Number of instances where consecutive RR intervals differed by more than 50 ms, pNN50: Percentage of NN50 divided by total number of RR intervals, RRTi: RR triangular index, TINN: Triangular interpolation of normal-to-normal intervals, IQ: Interquartile

Table 3: Descriptive data of frequency domain indices in male and female participants

Parameter	Male (*n*=34)		Female (*n*=68)		Mean comparisons (unpaired *t*-test) *P*	Median comparisons (Mann–Whitney *U*-test) *P*
	Mean±SD	Median, IQ range	Mean±SD	Median, IQ range		
FFT_VLFP (ms^2)	124.12±88.06	116.50, 54.00-174.50	116.74±117.52	116.50, 57.00-138.50	0.723	0.392
FFT_LFP (ms^2)	345.18±274.64	249.50, 136.00-558.75	274.25±250.44	249.50, 109.50-393.75	0.210	0.096
FFT_HFP (ms^2)	335.94±332.96	247.50, 106.00-425.00	420.25±682.03	247.50, 84.25-545.25	0.404	0.804
FFT_VLFPP (%)	18.14±9.07	18.35, 9.78-22.58	20.35±11.72	18.35, 11.20-28.45	0.297	0.528
FFT_LFPP (%)	43.78±13.16	42.85, 33.48-53.20	38.25±12.52	42.85, 31.05-45.53	0.046*	0.037
FFT_HFPP (%)	38.19±13.86	35.20, 29.43-47.73	41.76±18.24	35.20, 27.63-56.25	0.274	0.297
FFT_LFNU	53.50±15.22	56.30, 41.93-64.35	54.45±42.92	56.30, 37.25-63.05	0.871	0.281
FFT_HFNU	46.43±15.21	43.70, 35.65-58.08	49.66±18.17	43.70, 36.95-62.75	0.347	0.277
FFT_LF_HF_Ratio	1.42±0.91	1.29, 0.72-1.81	1.52±2.03	1.29, 0.58-1.70	0.723	0.198

SD: Standard deviation, FFT: Fast Fourier transform, IQ: Interquartile, VLF: Very low-frequency, VLFP: Very low-frequency power, VLFPP: Very low-frequency power percentage, LF: Low frequency, LFP: Low-frequency power, LFPP: Low-frequency power percentage, LFNU: Low-frequency normalized, HF: High frequency, HFP: High-frequency power, HFPP: High-frequency power percentage, HFNU: High-frequency normalized

indices did not show any statistically significant differences. These findings are partly consistent with findings of Ryan et al.[22]

Correlation between anatomy marks and time domain indices (Table 4) revealed a significant positive correlation between MRR and IA practical's. Higher MRR reflects higher parasympathetic activity. Therefore, higher parasympathetic activity in females is correlated with better academic performance. NN50, which is a measure of overall HRV, showed a significant negative correlation with IA practical's. Therefore, higher HRV is found to have negative association with academic performance in males. The geometric index RRTi showed again a significant negative correlation with IA practical marks. In case of IA theory SDNN, RMSSD, NN50, pNN50, RRTi, and TINN showed statistically significant negative correlation with academic performance. Such correlations were not observed in case of females.

Record marks in anatomy again revealed a significant negative correlation with NN50 only in males (Table 4). Viva marks in anatomy though showed a negative correlation with time domain indices in males did not show statistical significance. Such trends were not observed in females. Practical marks in anatomy did not show any such correlations in males and females. Theory marks in the anatomy through a rough negative correlation with many time domain indices did not reveal statistical significance. In case of total marks in anatomy, MRR, and RRTi were found to have statistically significant negative correlation with academic performance only in males.

In the subject of biochemistry, the practical IA did not show any significant correlations with time domain indices (Table 5). Again in males, RRTi was negatively correlated with practical IA but not statistically significant ($r = -0.330$, $P = 0.057$). MRR, pNN50, and RRTi are negatively correlated with theory IA in a significant manner only in males. Record marks did not correlate with any time domain indices in a significant manner. Although viva marks in anatomy did correlate negatively with RRTi in males, it did not show statistical significance ($P = 0.079$). Practical marks in biochemistry negatively and significantly correlated with RRTi in males but with MRR not significantly ($P = 0.064$). Theory marks in biochemistry negatively and significantly correlated with MRR, RMSSD, NN50, pNN50, RRTi, and TINN in males. In case of males, the negative correlation between SDNN and theory marks is short of statistical significance. ($P = 0.05$). Total marks in anatomy negatively and significantly correlated with MRR, pNN50, and RRTi in males. In case of RMSSD and NN50, the negative correlation had $P = 0.085$ and 0.079, respectively. Thus, in biochemistry, all marks are negatively correlated with time domain indices in males alone. Such correlations are not seen in females.

In the subject of physiology, no statistical significance is observed between practical IAs and time domain indices in both the genders (Table 6). However, in case of theory IA, significant negative correlations are observed with MRR, SDNN, RMSSD, NN50, pNN50, RRTi, and TINN in males. Such correlations are not observed in females. Record marks did not show statistically significant correlations with any of the time domain indices in both the genders. Viva marks are positively and significantly correlated with MRR in females. Significant negative correlations were observed with RRTi in males. Practical marks negatively correlated with pNN50 and RRTi in males. Theory marks did not correlate with

Table 4: Correlation between anatomy marks and time domain indices of HRV

Parameter	MRR		SDNN		RMSSD		NN50		pNN50		RRTI		TINN	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
IA_Pr_Anat	−0.092, 0.603	0.301, 0.013*	−0.148, 0.403	0.012, 0.922	−0.310, 0.075	0.083, 0.499	−0.403, 0.018*	0.028, 0.821	−0.311, 0.073	0.068, 0.584	−0.392, 0.022*	0.064, 0.606	−0.158, 0.374	0.021, 0.863
IA_Th_Anat	−0.313, 0.072	−0.024, 0.846	−0.441, 0.009*	−0.022, 0.860	−0.544, 0.001**	−0.021, 0.863	−0.537, 0.001**	0.009, 0.942	−0.510, 0.002**	−0.031, 0.802	−0.603, 0.000**	0.022, 0.859	−0.463, 0.006**	−0.170, 0.166
Rec_Anat	−0.175, 0.321	−0.184, 0.133	−0.126, 0.478	−0.056, 0.651	−0.308, 0.077	−0.089, 0.471	−0.363, 0.035*	−0.059, 0.634	−0.331, 0.056	−0.089, 0.471	−0.232, 0.186	0.037, 0.765	−0.129, 0.468	−0.072, 0.558
Viva_Anat	−0.323, 0.062	−0.210, 0.085	−0.239, 0.174	−0.072, 0.561	−0.256, 0.143	−0.099, 0.422	−0.242, 0.168	−0.050, 0.685	−0.291, 0.096	−0.077, 0.530	−0.330, 0.057	0.043, 0.728	−0.271, 0.122	−0.070, 0.570
Pr_Anat	−0.289, 0.097	0.048, 0.696	−0.091, 0.609	0.062, 0.613	−0.110, 0.534	0.024, 0.848	−0.198, 0.262	0.038, 0.760	−0.222, 0.208	0.022, 0.860	−0.301, 0.083	0.142, 0.247	−0.071, 0.691	−0.035, 0.778
Th_Anat	−0.337, 0.051	0.027, 0.830	0.032, 0.858	0.103, 0.405	−0.185, 0.295	0.042, 0.732	−0.185, 0.294	0.015, 0.904	−0.230, 0.191	0.008, 0.950	−0.335, 0.053	0.094, 0.447	−0.068, 0.701	−0.046, 0.710
Tot_Anat	−0.362, 0.035	0.014, 0.912	−0.064, 0.719	0.064, 0.605	−0.245, 0.162	0.007, 0.952	−0.275, 0.116	−0.007, 0.954	−0.296, 0.089	0.025, 0.842	−0.387, 0.024*	0.089, 0.469	−0.130, 0.462	−0.080, 0.515

*P<0.05, **P<0.01, values are represented as [r, p] format. MRR: Mean RR interval, SDNN: Standard deviation of normal-to-normal intervals, RMSSD: Root mean square of successive standard deviation, NN50: Number of instances where consecutive RR intervals differed by more than 50 ms, pNN50: Percentage of NN50 divided by total number of RR intervals, M: Male, F: Female, IA: Internal assessment, Pr: Practical, Th: Theory, Anat: Anatomy, Rec: Record, Tot: Total, r: Spearman's rho

Table 5: Correlation between biochemistry marks and time domain indices of HRV

Parameter	MRR		SDNN		RMSSD		NN50		pNN50		RRTi		TINN	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
IA_Pr_Bio	−0.162, 0.361	0.299, 0.013	0.061, 0.732	0.146, 0.233	−0.111, 0.532	0.106, 0.390	−0.159, 0.368	0.094, 0.448	−0.151, 0.394	0.147, 0.232	−0.330, 0.057	0.122, 0.324	0.008, 0.963	0.112, 0.362
IA_Th_Bio	−0.534, 0.001**	−0.030, 0.811	−0.116, 0.514	0.020, 0.871	−0.303, 0.082	−0.045, 0.715	−0.266, 0.129	−0.040, 0.744	−0.371, 0.031*	−0.059, 0.631	−0.381, 0.026*	0.037, 0.764	−0.265, 0.130	−0.163, 0.183
Rec_Bio	0.075, 0.672	0.194, 0.113	0.165, 0.352	−0.060, 0.628	0.018, 0.958	−0.046, 0.711	−0.096, 0.589	−0.119, 0.335	−0.029, 0.871	−0.088, 0.477	−0.119, 0.501	−0.059, 0.632	0.189, 0.285	−0.066, 0.595
Viva_Bio	−0.255, 0.146	0.130, 0.292	−0.020, 0.911	−0.051, 0.681	−0.195, 0.269	−0.014, 0.908	−0.238, 0.174	−0.085, 0.491	−0.258, 0.141	−0.059, 0.633	−0.305, 0.079	−0.061, 0.622	−0.067, 0.706	−0.107, 0.387
Pr_Bio	−0.321, 0.064	0.004, 0.976	0.001, 0.995	0.051, 0.677	−0.188, 0.288	−0.052, 0.671	−0.16, 0.899	−0.242, 0.167	−0.031, 0.805	−0.031, 0.805	−0.401, 0.019*	0.049, 0.689	−0.079, 0.657	−0.065, 0.596
Th_Bio	−0.547, 0.001**	−0.078, 0.529	−0.338, 0.050	−0.031, 0.802	−0.502, 0.002**	−0.072, 0.558	−0.477, 0.004**	−0.093, 0.448	−0.551, 0.001**	−0.123, 0.320	−0.485, 0.004**	0.033, 0.787	−0.409, 0.016*	−0.165, 0.180
Tot_Bio	−0.439, 0.009**	0.044, 0.724	−0.114, 0.521	0.052, 0.676	−0.300, 0.085	−0.011, 0.930	−0.306, 0.079	−0.027, 0.827	−0.368, 0.032*	−0.039, 0.753	−0.456, 0.007**	0.105, 0.395	−0.185, 0.295	−0.104, 0.399

*P<0.05, **P<0.01, values are represented as [r, p] format. MRR: Mean RR interval, SDNN: Standard deviation of normal to normal intervals, RMSSD: Root mean square of successive standard deviation, NN50: Number of instances where consecutive RR intervals differed by more than 50 ms, pNN50: Percentage of NN50 divided by total number of RR intervals, RRTi: RR triangular index, TINN: Triangular interpolation of normal-to-normal intervals, M: Male, F: Female, IA: Internal assessment, Pr: Practical, Th: Theory, Bio: Biochemistry, Rec: Record, Tot: Total, r: Spearman's rho

Table 6: Correlation between physiology marks and time domain indices of HRV

Parameter	MRR		SDNN		RMSSD		NN50		pNN50		RRTi		TINN	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
IA_Pr_Phy	−0.244, 0.165	0.069, 0.574	−0.116, 0.513	−0.052, 0.671	−0.220, 0.211	−0.106, 0.391	−0.206, 0.241	−0.173, 0.158	−0.217, 0.218	−0.144, 0.240	−0.280, 0.109	0.012, 0.924	−0.111, 0.534	−0.110, 0.373
IA_Th_Phy	−0.457, 0.007**	−0.014, 0.912	−0.362, 0.035*	−0.046, 0.711	−0.515, 0.002**	−0.115, 0.315	−0.495, 0.003**	−0.150, 0.221	−0.540, 0.001**	−0.149, 0.225	−0.491, 0.003**	−0.029, 0.812	−0.418, 0.014*	−0.161, 0.189
Rec_Phy	−0.146, 0.411	−0.013, 0.918	−0.189, 0.284	−0.168, 0.171	−0.232, 0.187	−0.132, 0.283	−0.253, 0.189	0.154, 0.210	−0.257, 0.143	−0.150, 0.222	−0.357, 0.038*	−0.186, 0.128	0.198, 0.261	−0.229, 0.069
Viva_Phy	−0.199, 0.260	0.256, 0.035*	−0.074, 0.676	−0.014, 0.911	−0.210, 0.234	−0.020, 0.873	−0.265, 0.130	−0.102, 0.410	−0.285, 0.102	−0.066, 0.592	−0.381, 0.026*	−0.095, 0.442	0.152, 0.390	−0.176, 0.151
Pr_Phy	−0.282, 0.107	0.145, 0.238	−0.176, 0.320	−0.149, 0.227	−0.335, 0.053	0.080, 0.514	−0.313, 0.072	−0.114, 0.355	−0.340, 0.049*	−0.080, 0.514	−0.448, 0.008*	−0.044, 0.721	−0.239, 0.173	−0.152, 0.217
Th_Phy	−0.146, 0.412	−0.028, 0.819	−0.045, 0.801	−0.074, 0.550	−0.098, 0.551	−0.090, 0.465	−0.102, 0.565	−0.102, 0.409	−0.137, 0.440	−0.118, 0.339	−0.248, 0.157	−0.051, 0.677	0.068, 0.703	−0.183, 0.135
Tot_Phy	−0.253, 0.150	−0.056, 0.651	−0.134, 0.449	−0.058, 0.637	−0.289, 0.098	−0.094, 0.448	−0.297, 0.088	−0.138, 0.261	−0.326, 0.060	−0.138, 0.263	−0.413, 0.015*	−0.044, 0.723	−0.145, 0.414	−0.196, 0.109

*$P<0.05$, **$P<0.01$, values are represented as [r, p] format. MRR: Mean RR interval, SDNN: Standard deviation of normal-to-normal intervals, RMSSD: Root mean square of successive standard deviation, NN50: Number of instances where consecutive RR intervals differed by more than 50 ms, pNN50: Percentage of NN50 divided by total number of RR intervals, RRTi: RR triangular index, TINN: Triangular interpolation of normal-to-normal intervals, IA: Internal assessment, Pr: Practical, Th: Theory, Phy: Physiology, Rec: Record, Tot: Total, r: Spearman's rho, M: Male, F: Female

any of the time domain indices. Total marks in physiology had significant negative correlations with RRTi in males. However, in RMSSD, NN50, and pNN50, the negative correlation in males had P = 0.098, 0.088, and 0.060, respectively.

In case of frequency domain indices the following is observed.

In case of anatomy, practical IA did not correlate with any of the frequency domain indices (Table 7). However, in case of females negative correlation between VLF power (VLFP) and practical IA marks were observed though not statistically significant with a P = 0.069. Significant negative correlations were observed between IA theory and VLFP, LFP, HFP, and HFPP in males and VLFP in females. Record marks had significant negative correlations with HFP, HFPP, and HF NU as well as significant positive correlations with VLFPP, LF NU, and LF HF ratio in males alone. Viva and practical marks did not significantly correlate with any of the frequency domain indices in both the genders. In case of theory marks, a similar finding corresponding to record marks was observed but without statistical significance. In case of total marks in anatomy, positive correlation with LF PP and negative correlation with HF PP were observed with P = 0.093 and 0.085, respectively, in males only.

In biochemistry, practical IA marks had significant negative correlation with VLFPP and LF NU in females alone (Table 8). In males, a positive correlation is observed between aforementioned parameters, though not significant. In case of theory IA, significant negative correlations were observed between VLFP in females alone. In males, a negative correlations were observed in case of VLFP and HFP with P = 0.072 and 0.058, respectively. Record marks were positively and significantly correlated with LFPP in males. In case of LFNU, it is positively correlated and HF NU it is negatively correlated with P = 0.080 and 0.080, respectively, in males. Record marks in anatomy were positively correlated with LF HF ratio in males with a P = 0.078. Viva marks in biochemistry did not correlate significantly with any of the frequency domain parameters. Practical marks in biochemistry also did not correlate significantly with any frequency domain parameters, however, in case of HFPP it is negatively correlated with a P = 0.055. Theory marks in biochemistry were significantly correlated in a negative manner with VLFP, LFP, HFP, and HFPP in males alone. Total marks in biochemistry did not correlate significantly with any of the frequency domain indices in both the genders. In males, HFPP negative correlated with total biochemistry marks with P = 0.064.

In physiology, practical IA marks did not correlate with any of the frequency domain indices in both the genders (Table 9). In case of theory IA marks, significant negative correlations were observed between VLFP, LFP, HFP, and HFPP in males and VLFP in females. Record marks in

Table 7: Correlation between anatomy marks and frequency domain indices of HRV

Parameter	FFT_VLFP		FFT_LFP		FFT_HFP		FFT_VLFPP		FFT_LFPP		FFT_HFPP		FFT_LFNU		FFT_HFNU		FFT_LF_HF_RATIO	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
IA_Pr_Anat	−0.174, 0.324	−0.103, 0.403	−0.059, 0.739	0.106, 0.390	−0.230, 0.191	0.115, 0.351	−0.019, 0.917	−0.222, 0.069	0.225, 0.200	−0.028, 0.822	−0.278, 0.112	0.137, 0.265	0.238, 0.174	−0.143, 0.245	−0.238, 0.174	0.039, 0.750	0.239, 0.173	−0.104, 0.398
IA_Th_Anat	−0.359, 0.037*	−0.256, 0.035*	−0.370, 0.031*	−0.053, 0.665	−0.585, 0.000**	0.056, 0.649	0.179, 0.312	−0.178, 0.147	0.270, 0.112	0.093, 0.499	−0.415, 0.015*	0.003, 0.982	0.331, 0.056	0.072, 0.558	−0.331, 0.056	0.000, 0.999	0.332, 0.055	0.020, 0.873
Rec_Anat	0.097, 0.586	−0.121, 0.324	−0.067, 0.706	−0.082, 0.508	−0.360, 0.037*	−0.023, 0.854	0.349, 0.043*	−0.064, 0.607	0.242, 0.168	−0.024, 0.843	−0.572, 0.000**	0.037, 0.762	0.402, 0.018*	0.008, 0.948	−0.402, 0.018*	−0.008, 0.948	0.402, 0.018*	−0.011, 0.931
Viva_Anat	−0.116, 0.513	−0.059, 0.634	−0.252, 0.155	−0.094, 0.445	−0.263, 0.132	−0.042, 0.734	0.175, 0.321	0.057, 0.643	0.018, 0.920	−0.101, 0.412	−0.091, 0.608	−0.015, 0.906	0.034, 0.848	−0.080, 0.518	−0.034, 0.848	0.080, 0.515	0.036, 0.840	0.042, 0.735
Pr_Anat	−0.040, 0.823	−0.121, 0.326	−0.031, 0.864	0.014, 0.912	−0.090, 0.613	0.068, 0.580	−0.057, 0.749	−0.141, 0.250	0.062, 0.729	−0.086, 0.485	−0.073, 0.680	0.086, 0.485	0.084, 0.636	−0.123, 0.317	−0.084, 0.636	0.037, 0.766	0.086, 0.629	−0.069, 0.578
Th_Anat	−0.122, 0.490	−0.129, 0.296	0.017, 0.923	0.062, 0.617	−0.157, 0.376	0.076, 0.540	−0.112, 0.529	−0.122, 0.323	0.320, 0.065	−0.047, 0.705	−0.298, 0.087	0.075, 0.546	0.292, 0.094	−0.039, 0.752	−0.292, 0.094	0.081, 0.513	0.294, 0.092	−0.058, 0.636
Tot_Anat	−0.164, 0.354	−0.159, 0.196	−0.051, 0.774	0.019, 0.877	−0.216, 0.220	0.041, 0.742	−0.084, 0.636	−0.124, 0.313	0.292, 0.093	−0.043, 0.727	−0.300, 0.085	0.057, 0.644	0.283, 0.105	−0.061, 0.623	−0.283, 0.105	0.055, 0.667	0.285, 0.103	−0.046, 0.710

*$P < 0.05$, **$P < 0.01$, values are represented as [r, p] format. FFT: Fast Fourier transform, IA: Internal assessment, Pr: Practical, Th: Theory, Anat: Anatomy, Rec: Record, Tot: Total, r: Spearman's rho, M: Male, F: Female, VLFP: Very low-frequency power, VLFPP: Very low-frequency power percentage, LF: Low frequency, LFP: Low-frequency power, LFPP: Low-frequency power percentage, LFNU: Low-frequency normalized, HF: High frequency, HFP: High-frequency power, HFPP: High-frequency power percentage, HF NU: High-frequency normalized

Table 8: Correlation between biochemistry marks and frequency domain indices of HRV

Parameter	FFT_VLFP		FFT_LFP		FFT_HFP		FFT_VLFPP		FFT_LFPP		FFT_HFPP		FFT_LFNU		FFT_HFNU		FFT_LF_ HF_RATIO	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
IA_Pr_Bio	−0.094, 0.596	−0.219, 0.072	0.052, 0.770	0.122, 0.321	−0.089, 0.616	0.158, 0.199	−0.150, 0.399	−0.321, 0.008**	0.288, 0.099	−0.072, 0.562	−0.246, 0.161	0.208, 0.090	0.255, 0.146	−0.246, 0.043*	−0.255, 0.146	0.150, 0.221	0.256, 0.145	−0.201, 0.101
IA_Th_Bio	−0.313, 0.072	−0.259, 0.033*	−0.229, 0.192	−0.039, 0.749	−0.328, 0.058	−0.053, 0.669	−0.033, 0.851	−0.172, 0.160	0.193, 0.275	0.038, 0.756	−0.242, 0.167	0.006, 0.963	0.184, 0.298	0.021, 0.865	−0.184, 0.298	−0.009, 0.939	0.185, 0.296	0.11, 0.931
Rec_Bio	−0.022, 0.902	−0.208, 0.089	0.240, 0.172	−0.038, 0.761	0.038, 0.832	−0.020, 0.872	−0.221, 0.209	−0.108, 0.381	0.360, 0.036*	0.056, 0.649	−0.253, 0.148	0.046, 0.710	0.304, 0.080	−0.046, 0.707	−0.304, 0.080	−0.021, 0.867	0.307, 0.078	−0.026, 0.836
Viva_Bio	−0.271, 0.121	−0.196, 0.109	−0.023, 0.897	−0.043, 0.729	−0.164, 0.355	0.005, 0.967	−0.228, 0.194	−0.094, 0.446	0.283, 0.105	−0.049, 0.639	−0.194, 0.271	0.056, 0.651	0.208, 0.238	−0.142, 0.247	−0.208, 0.238	0.105, 0.395	0.209, 0.236	−0.099, 0.422
Pr_Bio	−0.003, 0.821	−0.060, 0.629	−0.035, 0.842	−0.044, 0.724	−0.252, 0.151	0.025, 0.840	0.108, 0.542	−0.082, 0.504	0.200, 0.258	−0.074, 0.547	−0.332, 0.055	0.036, 0.770	0.236, 0.180	−0.112, 0.364	−0.236, 0.180	0.104, 0.399	0.236, 0.180	−0.050, 0.686
Th_Bio	−0.376, 0.028*	−0.123, 0.318	−0.355, 0.039*	−0.068, 0.580	−0.503, 0.002**	−0.118, 0.337	0.127, 0.475	0.000, 0.997	0.227, 0.197	0.020, 0.872	−0.356, 0.039*	−0.104, 0.401	0.251, 0.152	0.060, 0.625	−0.251, 0.152	−0.043, 0.725	0.253, 0.149	0.080, 0.514
Tot_Bio	−0.222, 0.206	−0.181, 0.140	−0.143, 0.420	0.001, 0.995	−0.317, 0.068	0.001, 0.992	0.012, 0.947	−0.155, 0.206	0.253, 0.148	−0.035, 0.779	−0.322, 0.064	0.029, 0.817	0.247, 0.158	−0.077, 0.530	−0.247, 0.158	0.068, 0.581	0.248, 0.156	0.042, 0.733

**P*<0.05, ***P*<0.01, values are represented as [r, p] format. FFT: Fast Fourier transform, IA: Internal assessment, Pr: Practical, Th: Theory, Bio: Biochemistry, Rec: Record, Tot: Total, r: Spearman's rho, M: Male, F: Female, VLF: Very low frequency, VLFP: Very low-frequency power, VLFPP: Very low-frequency power percentage, LF: Low frequency, LFP: Low-frequency power, LFPP: Low-frequency power percentage, LFNU: Low-frequency normalized, HF: High frequency, HFP: High-frequency power, HFPP: High-frequency power percentage, HF NU: High-frequency normalized

Table 9: Correlation between physiology marks and frequency domain indices of HRV

Parameter	FFT_VLFP		FFT_LFP		FFT_HFP		FFT_VLFPP		FFT_LFPP		FFT_HFPP		FFT_LFNU		FFT_HFNU		FFT_LF_HF_RATIO	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	M
IA_Pr_Phy	−0.255, 0.146	0.226, 0.063	−0.096, 0.590	0.003, 0.982	−0.173, 0.328	−0.066, 0.590	−0.164, 0.354	−0.154, 0.217	0.118, 0.508	0.124, 0.312	−0.068, 0.702	−0.049, 0.691	0.053, 0.767	0.010, 0.937	−0.053, 0.767	−0.080, 0.515	0.054, 0.763	0.083, 0.500
IA_Th_Phy	−0.380, 0.027*	−0.269, 0.026*	−0.365, 0.034*	−0.028, 0.821	−0.480, 0.004**	−0.117, 0.343	0.053, 0.766	−0.135, 0.273	0.220, 0.211	0.204, 0.095	−0.347, 0.045*	−0.078, 0.526	0.275, 0.115	0.119, 0.332	−0.275, 0.115	−0.119, 0.333	0.275, 0.115	0.128, 0.300
Rec_Phy	−0.144, 0.416	−0.314, 0.009**	−0.112, 0.528	−0.209, 0.087	−0.266, 0.129	−0.167, 0.174	0.139, 0.432	−0.014, 0.192	0.100, 0.572	0.024, 0.843	−0.187, 0.289	−0.042, 0.733	0.107, 0.546	−0.002, 0.985	0.107, 0.546	−0.057, 0.643	0.107, 0.546	0.011, 0.931
Viva_Phy	−0.181, 0.307	−0.281, 0.020*	−0.033, 0.851	−0.085, 0.492	0.192, 0.276	−0.012, 0.923	−0.171, 0.235	−0.131, 0.286	0.333, 0.054	0.005, 0.970	−0.243, 0.166	0.018, 0.886	0.301, 0.084	−0.73, 0.555	−0.301, 0.084	0.005, 0.965	0.303, 0.081	−0.026, 0.836
Pr_Phy	−0.169, 0.338	−0.196, 0.109	−0.165, 0.350	−0.096, 0.435	−0.287, 0.100	−0.078, 0.530	0.046, 0.798	−0.020, 0.874	0.226, 0.198	0.039, 0.752	−0.276, 0.114	−0.044, 0.721	0.266, 0.129	0.023, 0.851	−0.266, 0.129	−0.037, 0.765	0.267, 0.127	0.015, 0.902
Th_Phy	−0.139, 0.432	0.194, 0.114	0.104, 0.560	−0.142, 0.247	−0.155, 0.381	−0.110, 0.371	−0.207, 0.240	0.067, 0.590	0.450, 0.008**	0.040, 0.748	−0.310, 0.074	−0.061, 0.619	0.376, 0.028*	−0.005, 0.969	−0.376, 0.028*	0.086, 0.485	0.381, 0.026*	0.028, 0.822
Tot_Phy	−0.239, 0.173	−0.259, 0.033*	0.086, 0.630	0.121, 0.327	−0.315, 0.069	−0.099, 0.424	−0.072, 0.688	−0.021, 0.863	0.347, 0.045*	0.008, 0.948	−0.330, 0.056	−0.051, 0.677	0.331, 0.056	−0.006, 0.962	−0.331, 0.056	−0.074, 0.550	0.333, 0.054	0.029, 0.818

*$P<0.05$, **$P<0.01$, values are represented as [r, p] format. FFT: Fast Fourier transform, IA: Internal assessment, Pr: Practical, Th: Theory, Phy: Physiology, Rec: Record, Tot: Total, r: Spearman's rho, VLFP: Very low frequency power, VLFPP: Very low-frequency power percentage, LF: Low frequency, LFP: Low-frequency power, LFPP: Low-frequency power percentage, LFNU: Low-frequency normalized, HF: High frequency, HFP: High-frequency power, HFPP: High frequency power percentage, HF NU: High-frequency power normalized

physiology had negative correlations with VLFP in females alone. Viva marks in physiology were negatively correlated with VLFP significantly in females alone. However, in case of males, positive correlations with LF NU and negative correlations with HF NU were observed with $P = 0.084$ and 0.084, respectively. Practical marks did not correlate with any of the frequency domain indices in both the genders. Theory marks were significantly correlated with LF NU in a positive manner and HF NU in a negative manner in males alone. Total marks in physiology in males were significantly and positively correlated with LFPP. Furthermore, in males, there is a positive correlation with LF NU ($P = 0.056$), negative correlation with HF NU ($P = 0.056$), and negative correlation with HFPP ($P = 0.056$). In case of females, total physiology marks were negatively correlated with VLP alone.

Strength and Limitations of the Study

Strengths

1. Very little studies were conducted in this aspect, and therefore can be a novel and reference study.
2. Confounding factors such as age, timing of recording, time from food intake, intake of neurostimulants, and other stressors have been carefully analyzed and their effects are prevented.
3. 1st-year students were not included so that autonomy for consenting for the study is not jeopardized.
4. Participants witnessed the recording sessions of the previous volunteers and so did not suffer from anxiety during their recording sessions.

Limitations

1. Non-randomized study.
2. Every effort to get a larger sample was attempted. However, due to practical constraints, only the present sample size was accomplished. A larger sample is preferable.
3. Although there are associations that showed statistical significance because of the sample size many lost statistical significance marginally. Again, a better sample size must be attempted in the subsequent studies that follow.

CONCLUSION

Time domain indices reveal a strong negative association between an overall HRV and academic performance in males alone. Frequency domain indices reveal a negative association with absolute powers of VLF, LF, and HF in males and females. However, when considered in power percentage, NU unit, and LF-HF ratio, it is very evident that academic performance is directly proportional with indices of sympathetic activity and indirectly proportional with indices of parasympathetic activity in males alone. Academic performance is better with increased sympathetic activity in males and in case of females a similar correlation is not observed. Therefore, we conclude that cognitive ability is directly proportional with sympathetic activity and negatively proportional with parasympathetic activity in males alone.

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