Assessment of Autonomic Function Using Heart Rate Variability in Young Indian Adults: Influence of Sex

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Abstract

Background: Heart rate variability (HRV), the beat-to-beat oscillation in the interval between successive cardiac cycles, has emerged as a non-invasive electrophysiological tool for evaluating autonomic nervous system (ANS) activity. The interplay between sympathetic and parasympathetic outflow to the sinoatrial node generates these oscillations, and altered HRV has been linked with adverse cardiovascular outcomes, metabolic disorders, and impaired stress adaptation. **Aim**: The present cross-sectional study was undertaken to characterize time-domain and frequency-domain HRV parameters in apparently healthy young Indian adults and to evaluate the influence of sex on autonomic balance. **Materials and Methods**: A total of 100 healthy adults (58 males, 42 females; aged 18–30 years) were recruited from the Department of Biochemistry, South India, between September 2008 and February 2009. After a 10-minute supine rest, a five-minute lead II electrocardiogram was acquired using a Powerlab 26T data acquisition system (ADInstruments, Australia). Time-domain (mean RR, SDNN, RMSSD, pNN50, triangular index) and frequency-domain (Total Power, LF, HF, LF n.u., HF n.u., LF/HF ratio) parameters were computed using LabChart Pro v8.1.21 HRV module. Independent samples t-test was used to compare male and female parameters; statistical significance was set at $p<0.05$. **Results**: Males demonstrated higher mean RR interval (814.6 ± 91.2 vs 772.4 ± 82.4 ms, $p=0.018$), SDNN (58.4 ± 14.6 vs 52.2 ± 13.2 ms, $p=0.031$), and LF/HF ratio (1.34 ± 0.42 vs 0.96 ± 0.34, $p<0.001$), suggesting a relative sympathetic predominance. Females exhibited higher HF (n.u.) values, indicating greater parasympathetic modulation. **Conclusion**: Healthy young Indian adults demonstrate clinically meaningful sex-based differences in autonomic balance, with male preponderance of sympathetic activity and female preponderance of parasympathetic tone. These population-specific HRV reference values are clinically relevant for the early detection of

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dysautonomia, cardiovascular risk stratification, and the design of targeted preventive strategies in young adults.

Keywords
Heart rate variability; Autonomic nervous system; Sympathetic activity; Parasympathetic tone; LF/HF ratio; Healthy adults; Cardiovascular physiology.

1. Introduction

The autonomic nervous system (ANS) governs visceral homeostasis through a finely tuned balance of sympathetic and parasympathetic outflow. The heart, by virtue of its rich autonomic innervation, serves as an accessible window into the integrity of central autonomic regulation [1]. Beat-to-beat fluctuations in heart rate, termed heart rate variability (HRV), arise from the dynamic interplay of vagal and sympathetic influences on the sinoatrial node and have become an established surrogate marker of cardiac autonomic function [2,3].

Diminished HRV has been independently associated with elevated all-cause mortality, sudden cardiac death, post-myocardial infarction adverse outcomes, diabetic autonomic neuropathy, congestive heart failure, hypertension, and depressive disorders [4,5,6]. Conversely, higher HRV is regarded as a marker of resilience, cardiovascular fitness, and effective stress adaptation [7]. Quantification of HRV is broadly accomplished through three approaches: (i) time-domain analysis, which evaluates statistical descriptors of the RR-interval series; (ii) frequency-domain analysis, which uses spectral decomposition to partition variance into low-frequency (LF) and high-frequency (HF) bands; and (iii) non-linear methods such as Poincaré plots, sample entropy, and detrended fluctuation analysis [8,9].

The frequency-domain parameters are particularly informative for ANS dissection: the HF band (0.15–0.40 Hz) reflects predominantly parasympathetic, respiratory-coupled cardiac modulation, while the LF band (0.04–0.15 Hz) reflects a mixture of sympathetic and parasympathetic influences modulated by baroreflex activity. The LF/HF ratio is widely used as a proxy of sympatho-vagal balance, although recent literature has emphasised that this interpretation must be made cautiously [10,11].

Despite the wealth of HRV literature, normative data from the Indian subcontinent remain heterogeneous and frequently lack stratification by sex, age, and body composition. Geographic,

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dietary, genetic, and lifestyle factors are known to influence autonomic balance, underscoring the need for population-specific reference data [12,13]. The present study was therefore designed to characterise the time- and frequency-domain HRV parameters in a cohort of healthy young Indian adults and to examine the impact of sex on autonomic function.

2. Materials and Methods

2.1 Study Setting

This cross-sectional observational study was conducted in the Autonomic Function Testing Laboratory, Department of Biochemistry, South India, between September 2008 and February 2009.

2.2 Participants

One hundred apparently healthy adult volunteers (58 males, 42 females; aged 18–30 years) were recruited from among medical and paramedical students of the institute by purposive sampling. Inclusion criteria comprised non-smoker status, body mass index (BMI) between 18.5 and 25.0 kg/m², resting blood pressure below 140/90 mmHg, and absence of any chronic illness. Exclusion criteria comprised diabetes mellitus, hypertension, cardiovascular or pulmonary disease, thyroid dysfunction, regular use of any cardiovascular or psychotropic medication, pregnancy, or any acute infection within the preceding two weeks. All female participants were assessed during the early follicular phase of the menstrual cycle (days 2–7) to minimize hormonal influence on autonomic function.

Table 1. Anthropometric and Baseline Cardiovascular Characteristics of Participants

Variable	Males (n=58)	Females (n=42)	p-value
Age (years)	23.6 ± 2.8	23.2 ± 2.6	0.471
Height (cm)	171.4 ± 6.1	159.8 ± 5.4	<0.001
Weight (kg)	65.8 ± 8.7	54.2 ± 7.1	<0.001
BMI (kg/m²)	22.4 ± 2.5	21.2 ± 2.4	0.018
Resting Heart Rate (bpm)	74.6 ± 8.1	78.2 ± 7.4	0.027
Systolic BP (mmHg)	118.4 ± 8.6	112.6 ± 7.9	0.001
Diastolic BP (mmHg)	76.2 ± 6.8	73.4 ± 6.1	0.034

2.3 Pre-test Preparation

All participants were instructed to abstain from caffeine, tea, alcohol, and strenuous physical activity for at least 12 hours and from heavy meals for 2 hours prior to testing. Recordings were

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obtained between 0900 and 1200 hours to control for diurnal variation in autonomic activity. The laboratory was maintained at 24 ± 1°C with subdued lighting and minimal acoustic distraction. After a brief verbal explanation of the procedure, anthropometric data (height, weight, BMI) and resting blood pressure (Omron HEM 7120, Japan) were recorded after five minutes of supine rest.

2.4 HRV Recording and Analysis

After a further 10-minute supine rest in the cardiac autonomic laboratory, a continuous lead II electrocardiogram was recorded for 5 minutes using a Powerlab 26T data acquisition unit (ADInstruments, Bella Vista, Australia) sampled at 1000 Hz. Participants were instructed to breathe normally without talking, swallowing, or moving. Recordings with ectopic beats exceeding 5% of total beats or with significant artefact were excluded. The R-peak detection and HRV analysis were performed using LabChart Pro v8.1.21 HRV module (ADInstruments) with manual verification of automated detection.

Time-domain parameters analysed included: mean RR interval (ms), standard deviation of all NN intervals (SDNN, ms), root mean square of successive differences (RMSSD, ms), proportion of successive NN intervals >50 ms (pNN50, %), and HRV triangular index. Frequency-domain analysis was performed using a Fast Fourier Transform (FFT) approach with a Welch periodogram. Total Power (0–0.40 Hz), Low Frequency power (LF; 0.04–0.15 Hz), and High Frequency power (HF; 0.15–0.40 Hz) were computed in absolute units (ms^2) and normalised units (n.u.). The LF/HF ratio was calculated as a proxy of sympatho-vagal balance, in accordance with the Task Force guidelines [14].

2.5 Statistical Analysis

Data were analysed using IBM SPSS Statistics v26.0. Continuous variables were tested for normality using the Shapiro–Wilk test and expressed as mean ± SD. Independent samples t-test was used to compare HRV parameters between males and females. Pearson's correlation was used to evaluate the association of BMI with HRV indices. A two-tailed p-value of less than 0.05 was considered statistically significant.

3. Results

All 100 enrolled participants completed the recordings without adverse events. Anthropometric and baseline cardiovascular characteristics are summarized in Table 1. As expected, males were

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significantly taller, heavier, and exhibited higher systolic and diastolic blood pressures, while resting heart rate was modestly higher in females, in keeping with classical sex-related cardiovascular differences.

Time-domain HRV parameters are presented in Table 2. Males demonstrated significantly longer mean RR intervals (814.6 ± 91.2 vs 772.4 ± 82.4 ms, p=0.018) and higher SDNN (58.4 ± 14.6 vs 52.2 ± 13.2 ms, p=0.031). RMSSD and pNN50, which reflect predominantly vagal modulation, were marginally higher in females, although the differences did not reach statistical significance. The triangular index also showed a non-significant tendency towards higher values in males.

Table 2. Time-Domain Heart Rate Variability Parameters

HRV Parameter (Time domain)	**Males (Mean ± SD)**	**Females (Mean ± SD)**	**p-value**
Mean RR Interval (ms)	814.6 ± 91.2	772.4 ± 82.4	0.018
SDNN (ms)	58.4 ± 14.6	52.2 ± 13.2	0.031
RMSSD (ms)	46.7 ± 16.4	48.9 ± 17.1	0.512
pNN50 (%)	22.6 ± 11.4	24.1 ± 12.6	0.534
Triangular Index	18.4 ± 4.6	16.9 ± 4.2	0.094

Frequency-domain HRV findings are summarised in Table 3. Total power was significantly higher in males (3284.6 ± 962.4 vs 2876.4 ± 891.2 ms², p=0.034), as was the absolute LF power (1184.7 ± 412.6 vs 984.2 ± 384.7 ms², p=0.014). Notably, in normalised units, males showed higher LF (n.u.) and lower HF (n.u.) than females, with the LF/HF ratio significantly elevated in males (1.34 ± 0.42 vs 0.96 ± 0.34, p<0.001), reflecting a relative sympathetic predominance. Females, in contrast, demonstrated higher HF (n.u.), indicating greater parasympathetic dominance at rest.

Table 3. Frequency-Domain Heart Rate Variability Parameters

HRV Parameter (Frequency domain)	**Males (Mean ± SD)**	**Females (Mean ± SD)**	**p-value**
Total Power (ms²)	3284.6 ± 962.4	2876.4 ± 891.2	0.034
Low Frequency (LF, ms²)	1184.7 ± 412.6	984.2 ± 384.7	0.014
High Frequency (HF, ms²)	938.4 ± 372.6	1086.4 ± 396.7	0.067
LF (n.u.)	56.8 ± 9.4	48.2 ± 8.6	<0.001
HF (n.u.)	43.2 ± 9.4	51.8 ± 8.6	<0.001
LF/HF ratio	1.34 ± 0.42	0.96 ± 0.34	<0.001

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BMI demonstrated a weak negative correlation with SDNN (r = -0.218, p=0.029) and RMSSD (r = -0.236, p=0.021), and a weak positive correlation with the LF/HF ratio (r = 0.241, p=0.018), indicating that even within the healthy range, increasing BMI is associated with a subtle shift towards sympathetic predominance.

4. Discussion

The principal finding of this study is that healthy young Indian adults exhibit measurable sex-based differences in cardiac autonomic activity, with males showing greater sympathetic predominance and females showing relatively greater parasympathetic modulation. The mean SDNN value of 55.8 ± 14.0 ms in the combined sample is broadly consistent with the international ranges of 50–55 ms reported by the Task Force [14] for short-term recordings in healthy adults, and with prior Indian data published by Pal et al. [15] and Kaur et al. [16].

The higher LF/HF ratio observed in males in the present study mirrors the findings of Ramaekers et al. [17], Yamasaki et al. [18], and Kuo et al. [19], all of whom reported a male preponderance of sympathetic markers and a female preponderance of vagal markers in healthy adults. Several mechanisms have been proposed to account for this dimorphism: oestrogen is known to enhance baroreflex sensitivity and to potentiate parasympathetic tone, while testosterone tends to upregulate sympathetic outflow [20,21]. Sex differences in autonomic ganglion density, central autonomic processing in the insular cortex, and afferent baroreceptor sensitivity have also been implicated [22].

The negative correlations between BMI and time-domain HRV indices observed in our cohort, although modest in magnitude, echo the findings of Karason et al. [23], who reported that increasing adiposity is associated with progressive autonomic dysregulation. The continuum of cardio-autonomic decline appears to begin within the 'healthy' BMI range, suggesting that early lifestyle interventions may have substantial preventive value [24]. The relevance of this observation is amplified by the rapidly rising prevalence of overweight and obesity among Indian young adults [25].

From a clinical perspective, our normative data have several practical applications. First, they provide reference values that can support the early identification of cardiac autonomic neuropathy among Indian patients with diabetes mellitus, hypertension, or chronic kidney disease, in whom HRV-based screening has well-established prognostic value [4,26]. Second, they may aid in the

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interpretation of HRV alterations associated with mental health disorders, post-traumatic stress, and burnout, which are increasingly prevalent among Indian young adults [27]. Third, they reinforce the rationale for sex-stratified analysis in autonomic research, given the consistency and magnitude of male–female differences observed.

The strengths of the present study include its strict participant selection, control of menstrual cycle phase, standardised laboratory environment, use of internationally accepted Task Force protocols, and analysis of both time- and frequency-domain parameters. Limitations include its single-centre, cross-sectional design, the relatively narrow age range, and the absence of non-linear HRV metrics such as Poincaré indices and sample entropy. Future studies should incorporate longitudinal follow-up, broader age stratification, and integration of HRV with biomarkers of inflammation, oxidative stress, and psychological well-being [28].

5. Conclusion

Healthy young Indian adults demonstrate clinically meaningful sex-related differences in cardiac autonomic balance, characterised by sympathetic predominance in males and parasympathetic predominance in females. Even within the healthy range, increasing body mass index correlates with a subtle but detectable shift towards sympathetic dominance. The population-specific HRV reference values established in this study can support the clinical assessment of dysautonomia, the screening of cardiometabolic risk in young adults, and the design of physiologically informed health-promotion strategies in Indian settings.

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