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GENDER VARIATIONS IN CARDIOVASCULAR AUTONOMIC FUNCTION: A CROSS-SECTIONAL STUDY IN MEDICAL STUDENTS

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ABSTRACT

Background: Gender-related differences in cardiovascular autonomic regulation have been widely studied, yet findings remain inconsistent, particularly in young healthy populations. This study aimed to evaluate variations in cardiovascular autonomic function between male and female medical students.

Materials and Methods: A cross-sectional study was conducted among 162 undergraduate medical students. Resting heart rate and blood pressure were recorded, along with autonomic function tests assessing parasympathetic activity (deep breathing difference, E:I ratio, 30:15 ratio) and sympathetic activity (blood pressure response to standing, sustained handgrip test, and cold pressor test) using standardized protocols. Data was analysed using independent -t test and Mann – Whitney U test. A p-value ≤ 0.05 was considered statistically significant.

Results: Females exhibited a significantly higher resting heart rate compared to males (80.47 ± 14.45 vs 76.17 ± 12.65 bpm; $p = 0.036$). In contrast, males had significantly higher systolic (120.46 ± 7.14 vs 114.35 ± 6.19 mmHg; $p < 0.001$) and diastolic blood pressure (77.19 ± 4.20 vs 74.71 ± 5.97 mmHg; $p = 0.022$). Parasympathetic function parameters, including deep breathing difference, E:I ratio, and 30:15 ratio, were slightly higher in males but did not differ significantly. Similarly, sympathetic function tests, including fall in systolic blood pressure on standing, rise in diastolic blood pressure during handgrip, and rise in systolic blood pressure during cold pressor test, showed no statistically significant gender differences.

Conclusion: While significant gender differences were observed in resting cardiovascular parameters, autonomic function indices were comparable between males and females, suggesting similar autonomic regulation in young healthy individuals.

Keywords: Cardiovascular autonomic function, gender differences, heart rate variability, sympathetic activity, parasympathetic activity, medical students.

INTRODUCTION

The autonomic nervous system (ANS) plays a fundamental role in maintaining cardiovascular homeostasis by regulating heart rate, vascular tone, and blood pressure through the coordinated actions of sympathetic and parasympathetic pathways.[1] Variations in autonomic function can be assessed non-invasively using cardiovascular reflex tests and heart rate variability (HRV), which reflect the dynamic interplay between these two components.[1,2] Alterations in autonomic balance have been implicated in the pathogenesis of several cardiovascular disorders, making its assessment clinically relevant even in apparently healthy individuals.[3]

Gender is an important physiological determinant influencing cardiovascular regulation. Previous studies have demonstrated that males and females exhibit distinct patterns of autonomic modulation, potentially due to differences in hormonal milieu, body composition, and cardiovascular physiology.[3,4] Evidence suggests that females tend to have higher resting heart rates, whereas males often exhibit higher blood pressure levels and greater overall autonomic activity.[5] These variations may contribute to observed differences in cardiovascular risk profiles between the two sexes.[3,5]

Heart rate variability studies have further highlighted sex-related differences in autonomic balance, with some reports indicating relatively higher parasympathetic modulation in females and greater sympathetic dominance in males.[4] Such differences are particularly evident in young adults and may diminish with advancing age.[4] Additionally, recent research has emphasized that gender-specific autonomic responses may influence stress reactivity and cardiovascular adaptability under physiological and psychological challenges.[2]

Despite growing evidence, findings regarding gender differences in cardiovascular autonomic function remain inconsistent, particularly in young, healthy populations such as medical students. Most available data are derived from heterogeneous populations with varying age groups and comorbidities, limiting their applicability to healthy young adults.[3,5] Moreover, lifestyle factors, academic stress, and circadian variations may further influence autonomic responses in this group.

Therefore, the present study was undertaken to evaluate gender-based differences in cardiovascular autonomic function among medical students using standardized non-invasive tests. Understanding these variations may provide insights into early physiological differences that could influence future cardiovascular risk.

MATERIALS AND METHODS

Study Design and Setting: This cross-sectional study was conducted among undergraduate medical students. A total of 162 participants were included in the study.

Sample Size Calculation: The sample size was determined using a standard formula for finite population correction. The following parameters were considered: population size (N) = 840, margin of error (e) = 0.07, and confidence level of 95% (Z = 1.96). Substitution of these values yielded a final sample size of 160 participants.

Sampling Technique and Study Population: Participants were selected using a purposive sampling technique based on predefined eligibility criteria.

Inclusion Criteria:

- Undergraduate medical students who provided written informed consent.

Exclusion Criteria:

- History of cardiovascular disease
- Known hypertension
- Known diabetes mellitus
- History of neurological illness
- Use of medications within the preceding 7 days
- Female participants during menstruation
- Individuals unwilling to participate

Ethical Considerations: The study protocol was reviewed and approved by the Institutional Scientific Committee and Institutional Ethics Committee prior to commencement. Written informed consent was obtained from all participants after explaining the study procedures.

Materials Used: The following instruments and tools were utilized for data collection:

- Mercury sphygmomanometer (Diamond) for blood pressure measurement
- Electrocardiography machine (BPL) for recording heart rate parameters (Lead II ECG)
- Stethoscope
- Hand grip dynamometer
- Weighing scale (pedestal type, capacity 120 kg, accuracy 0.1 kg)
- Stadiometer (accuracy 0.5 cm)
- Thermometer

Data Collection Procedure: After obtaining consent, detailed history taking, general physical examination, and brief systemic examination were conducted. Baseline cardiovascular autonomic parameters were recorded.

Anthropometric Measurements

- **Height:** Measured using a stadiometer and recorded to the nearest 0.01 m.
- **Weight:** Measured using a calibrated weighing scale and recorded to the nearest 0.1 kg.
- **Body Mass Index (BMI):** Calculated using the formula: BMI= Weight (kg) / Height^2 $(m)^2$

Cardiovascular Autonomic Function Tests: All measurements were conducted under standardized conditions after ensuring adequate rest.

- **Resting Blood Pressure:** Measured after 15 minutes of rest. Three readings were taken at 2-minute intervals, and the average was used for analysis.
- **Blood Pressure Response to Standing:** Blood pressure was recorded after 15 minutes in the supine position, followed by measurements immediately upon standing and at 30, 60, and 90 seconds. A fall in systolic blood pressure ≥20 mmHg or diastolic blood pressure ≥10 mmHg within 3 minutes was considered indicative of orthostatic hypotension.
- **Blood Pressure Response to Sustained Handgrip:** Maximum voluntary contraction (Tmax) was determined as the mean of three maximal efforts using a handgrip dynamometer. Participants then maintained 30% of Tmax for up to 5 minutes. Blood pressure was recorded at baseline and at 30-second intervals during the maneuver. The response was expressed as the difference between the highest diastolic blood pressure during handgrip and baseline diastolic pressure.
- **Blood Pressure Response to Cold Pressor Test:** After baseline measurement, participants immersed their left hand in ice-cold water (4–

5°C) for 90 seconds. Blood pressure was recorded from the contralateral arm at 30-second intervals.

- **Heart Rate Response to Standing (30:15 Ratio):** Continuous ECG recording was performed in the supine position and after standing. The ratio was calculated using the longest R–R interval around the 30th beat and the shortest R–R interval around the 15th beat after standing.
- **Heart Rate Response to Deep Breathing:** Participants performed deep breathing at a rate of 6 breaths per minute (5 seconds inspiration and 5 seconds expiration). Lead II ECG was recorded, and the following indices were derived:
  - **Deep Breathing Difference (DBD):** Mean difference between maximum and minimum heart rate across six cycles.
  - **E:I Ratio:** Ratio of the sum of the six longest R–R intervals during expiration to the sum of the six shortest R–R intervals during inspiration.

RESULTS

Resting cardiovascular parameters demonstrated statistically significant gender-based differences. Females exhibited a higher resting heart rate (80.47 ± 14.45 bpm) compared to males (76.17 ± 12.65 bpm), which was statistically significant ($p = 0.036$). In contrast, resting systolic blood pressure (SBP) was significantly higher in males (120.46 ± 7.14 mmHg) than in females (114.35 ± 6.19 mmHg) ($p < 0.001$). Similarly, resting diastolic blood pressure (DBP) was also significantly elevated in males (77.19 ± 4.20 mmHg) compared to females (74.71 ± 5.97 mmHg) ($p = 0.022$) [Table 1].

Assessment of parasympathetic function using the deep breathing difference (DBD) showed slightly higher values in males (32.83 ± 8.76) than females (30.55 ± 8.66); however, this difference did not reach statistical significance ($p = 0.1$) [Table 2]. Likewise, the expiratory-to-inspiratory (E:I) ratio was marginally greater in males (1.51 ± 0.18) compared to females (1.47 ± 0.18), but the difference was not statistically significant ($p = 0.17$) [Table 3]. The 30:15 ratio, another indicator of parasympathetic activity, also showed slightly higher values in males (1.20 ± 0.18) compared to females (1.17 ± 0.22), without statistical significance ($p = 0.15$) [Table 4].

Evaluation of sympathetic function revealed comparable responses between the two groups. The fall in systolic blood pressure upon standing was slightly greater in females (4.40 ± 1.75 mmHg) than in males (4.08 ± 1.89 mmHg), though this difference was not statistically significant ($p = 0.28$) [Table 5]. During the handgrip test (HGT), the rise in diastolic blood pressure was marginally higher in males (16.93 ± 3.28 mmHg) compared to females (16.05 ± 3.85 mmHg), but the difference was not significant ($p = 0.11$) [Table 6]. Similarly, the cold pressor test (CPT) showed a comparable rise in systolic blood pressure in females (18.88 ± 3.29 mmHg) and males (18.54 ± 2.90 mmHg), with no statistically significant difference ($p = 0.48$) [Table 7].

Table 1: Comparison of Resting Heart Rate and Blood Pressure between Males and Females

Parameter	Females (N=70)	Males (N=92)	Significance
Resting HR (bpm)	80.47 ± 14.45	76.17 ± 12.65	0.036
Resting SBP (mmHg)	114.35 ± 6.19	120.46 ± 7.14	<0.001
Resting DBP (mmHg)	74.71 ± 5.97	77.19 ± 4.20	0.022

Table 2: Comparison of Deep Breathing Difference between Males and Females

Parameter	Females (N=70)	Males (N=92)	Significance
DBD (breaths per cycle)	30.55 ± 8.66	32.83 ± 8.76	0.1

Table 3: Comparison of E:I Ratio between Males and Females

Parameter	Females (N=70)	Males (N=92)	Significance
E:I Ratio	1.47 ± 0.18	1.51 ± 0.18	0.17

Table 4: Comparison of 30:15 Ratio between Males and Females

Parameter	Females (N=70)	Males (N=92)	Significance
30:15 Ratio	1.17 ± 0.22	1.20 ± 0.18	0.15

Table 5: Comparison of Supine to Standing Fall in BP between Males and Females

Parameter	Females (N=70)	Males (N=92)	Significance
Fall in SBP – Supine to Standing (mmHg)	4.40 ± 1.75	4.08 ± 1.89	0.28

Table 6: Comparison of Rise in DBP during HGT between Males and Females

Parameter	Females (N=70)	Males (N=92)	Significance
Rise in DBP during HGT (mmHg)	16.05 ± 3.85	16.93 ± 3.28	0.11

Table 7: Comparison of Rise in SBP during CPT between Males and Females

Parameter	Females (N=70)	Males (N=92)	Significance
Rise in SBP during CPT (mmHg)	18.88 ± 3.29	18.54 ± 2.90	0.48

DISCUSSION

The present study evaluated gender-based differences in cardiovascular autonomic function among medical students and demonstrated that while resting cardiovascular parameters differed significantly, most autonomic function indices were comparable between males and females. These findings provide insight into physiological gender variations in a young, healthy population.

In the present study, females exhibited a significantly higher resting heart rate compared to males, whereas males demonstrated significantly higher systolic and diastolic blood pressure. These findings are consistent with existing evidence suggesting sex-related differences in baseline cardiovascular physiology. Hormonal influences, particularly the modulatory effects of estrogen on autonomic tone, have been shown to contribute to higher resting heart rates in females and relatively elevated blood pressure levels in males.[6] Additionally, structural and functional differences in vascular regulation and sympathetic activity may account for the higher blood pressure observed in males.[7]

Despite differences in baseline parameters, the indices of parasympathetic function, including deep breathing difference, E:I ratio, and 30:15 ratio, did not show statistically significant gender variation in the present study. Similar observations have been reported in previous studies conducted in young adult populations, where parasympathetic responses were found to be largely comparable between sexes under resting conditions.[8] Although some literature suggests enhanced vagal modulation in females, such differences may not always reach statistical significance in homogeneous, healthy cohorts.[9]

The sympathetic function tests, including blood pressure response to standing, sustained handgrip, and cold pressor test, also did not demonstrate significant gender differences in this study. These findings are in agreement with earlier research indicating that sympathetic reactivity to standard physiological stressors may be similar in young males and females, particularly in the absence of comorbid conditions.[8,10] However, subtle variations in sympathetic activation patterns influenced by sex hormones and neural control mechanisms have been described, which may not be captured by conventional autonomic function tests alone.[7,11]

The absence of significant differences in autonomic function parameters in this study may be attributed to the relatively young age and healthy status of the study population. It has been suggested that gender-related differences in autonomic regulation become more pronounced with aging or in the presence of cardiovascular risk factors.[12] Furthermore, circadian influences and environmental factors may also modulate autonomic responses differently in males and females, potentially contributing to variability across studies.[11]

Overall, the findings of this study indicate that while gender differences exist in resting cardiovascular parameters, autonomic cardiovascular regulation as assessed by standard non-invasive tests remains largely similar in young medical students. These results highlight the importance of considering baseline physiological differences when interpreting autonomic function while also emphasizing that significant gender divergence in autonomic control may not be evident in healthy young populations.

CONCLUSION

The present study demonstrates that while significant gender differences exist in baseline cardiovascular parameters, with females exhibiting higher resting heart rate and males showing higher systolic and diastolic blood pressure, most indices of cardiovascular autonomic function remain comparable between genders. Measures of parasympathetic activity, including deep breathing difference, E:I ratio, and 30:15 ratio, as well as sympathetic responses assessed by postural blood pressure changes, handgrip test, and cold pressor test, did not show statistically significant variation. These findings suggest that despite observable differences in resting hemodynamic status, overall autonomic cardiovascular regulation is largely similar in young healthy medical students. Further studies with larger and more diverse populations may help to elucidate subtle gender-specific autonomic variations and their clinical implications.

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