Journal of Rare Cardiovascular Diseases
ISSN: 2299-3711 (Print) | e-ISSN: 2300-5505 (Online)
www.jrcd.eu
RESEARCH ARTICLE

Evaluation of Cardiac Hemodynamic Patterns in Adults Using Echocardiographic Imaging: A Cross-Sectional Study

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Article History
Received: 15.03.2025
Revised: 04.04.2025
Accepted: 25.05.2025
Published: 06.06.2025

Abstract: ***Background***: Echocardiography is a widely used, non-invasive imaging modality for assessing cardiac function and hemodynamic status. Evaluating hemodynamic parameters such as stroke volume, cardiac output, ejection fraction, and heart rate provides critical insights into early cardiovascular dysfunction, even before overt clinical symptoms appear. ***Aim***: To evaluate cardiac hemodynamic patterns in adults using echocardiographic imaging and establish variations across age and gender. ***Methods***: A cross-sectional observational study was conducted among 250 adult participants (20–85 years) attending the outpatient department at Meenakshi Medical College Hospital and Research Institute (MMCHRI), Enathur, between February and April 2025. Data were collected using a structured questionnaire, and echocardiographic parameters including stroke volume, ejection fraction, cardiac output, and heart rate were assessed. Participants were stratified by age and gender. Statistical analysis was performed using Jamovi software, with $p < 0.001$ considered significant. ***Results***: Of the 250 participants, 116 were men and 134 were women. Stroke volume was the most frequently altered parameter, with abnormalities observed in 62% of men and 63% of women. Cardiac output abnormalities were found in 35% of men and 39% of women. Heart rate deviations were less frequent, affecting 6% of men and 16% of women. Ejection fraction remained preserved in the majority, with only minor reductions in 5% of men and 2% of women. Age-stratified analysis revealed increasing prevalence of systolic pressure abnormalities in older groups, with 100% of participants aged 70–85 years exhibiting elevated systolic pressure. ***Conclusion***: Echocardiography is an effective tool for assessing cardiac hemodynamics. Stroke volume and cardiac output were the most commonly altered parameters, whereas ejection fraction remained preserved. These findings highlight the importance of echocardiography in detecting early subclinical dysfunction, enabling timely management of cardiovascular disease.

Keywords: Echocardiography, Hemodynamic parameters, Stroke volume, Cardiac output, Ejection fraction; Heart rate; Cardiovascular dysfunction.

INTRODUCTION

Cardiovascular diseases (CVDs) remain the leading cause of morbidity and mortality worldwide, contributing significantly to the global health burden. According to the World Health Organization, an estimated 17.9 million deaths occur annually due to CVDs, accounting for nearly one-third of global mortality. Early detection of subclinical cardiac dysfunction is therefore critical to improve prognosis and prevent complications.

The heart functions as a muscular pump that ensures continuous circulation of oxygenated blood to tissues while facilitating the removal of carbon dioxide and other metabolic by-products. Its performance depends on the coordinated action of chambers, valves, and the specialized conduction system. Hemodynamic parameters such as **stroke volume (SV), cardiac output (CO), ejection fraction (EF), and heart rate (HR)** are essential indicators of cardiac function and efficiency. Alterations in these measures reflect the presence of underlying cardiovascular dysfunction, even before symptoms become clinically evident.

Traditionally, invasive methods such as pulmonary artery catheterization were employed for hemodynamic assessment. However, these techniques are associated with complications and limited utility in routine practice. Echocardiography has emerged as a **non-invasive, reliable, and versatile imaging tool,** capable of providing real-time insights into cardiac structure, function, and hemodynamics. Doppler echocardiography, in particular, enables assessment of both systolic and diastolic function, valve abnormalities, and blood flow dynamics, making it a cornerstone in cardiovascular evaluation.

Previous studies have demonstrated the role of echocardiography in critical care and outpatient settings for monitoring cardiac function. ***Vignon et al. (2005)*** emphasized the superiority of echocardiography over pulmonary artery catheters in critically ill patients, while ***Ferrara et al. (2021)*** highlighted the influence of demographic variables such as age and sex on echocardiographic hemodynamic reference values. However, limited studies from the Indian population provide reference data on echocardiographic hemodynamic parameters across adult age groups.

In this context, the present study was designed to **evaluate cardiac hemodynamic patterns in adults using echocardiographic imaging**, stratified by age and gender. By analyzing parameters such as stroke volume, cardiac output, ejection fraction, and heart rate in a large adult cohort, this study aims to establish baseline

reference trends and identify early indicators of dysfunction that may aid in timely diagnosis and clinical decision-making.

MATERIALS AND METHODS:

This cross-sectional observational study was conducted in the Department of Cardiology at Meenakshi Medical College Hospital and Research Institute (MMCHRI), Ennathur, Tamil Nadu, India, between February and April 2025. A total of 250 adult participants aged between 20 and 85 years were recruited from the outpatient department using consecutive sampling. The study population comprised 116 men and 134 women, all of whom provided written informed consent prior to enrolment. Ethical approval was obtained from the Institutional Ethics Committee of MMCHRI, MAHER University (IEC No. MMCH & RI IEC/UG–AHS/34/MAY/25; approval date: 17 May 2025). The study adhered to the ethical principles outlined in the Declaration of IEC Certificate.

Participants included adults aged 20 years and above, both male and female, with known or suspected cardiac illness attending MMCHRI. Individuals younger than 20 years, pediatric patients with cardiac disease, those with chronic hypertension, autoimmune disorders, renal disease, and pregnant women were excluded from the study. Data were collected using a pre-tested structured questionnaire covering socio-demographic details, dietary habits, and lifestyle factors. Clinical measurements such as blood pressure, height, weight, body mass index (BMI), and body surface area (BSA) were recorded.

Echocardiographic imaging was performed by trained cardiologists using standardized procedures. Hemodynamic parameters assessed included stroke volume (SV), cardiac output (CO), ejection fraction (EF), and heart rate (HR). Stroke volume was measured in millilitres per beat, while cardiac output was calculated as the product of stroke volume and heart rate, expressed in litres per minute. Ejection fraction was measured as the percentage of blood pumped out of the left ventricle during systole, with the normal range considered between 55% and 70%. Heart rate was measured in beats per minute.

Data entry was carried out using Microsoft Excel and analyzed using Jamovi software (version 2.3). Descriptive statistics were expressed as mean ± standard deviation (SD). Comparisons were made using Student's *t*-test or ANOVA, as appropriate. For analysis, participants were stratified into four age groups: 20–40 years, 40–60 years, 60–70 years, and 70–85 years. A p-value of less than 0.001 was considered statistically significant. Results were presented using tables, figures and charts for clarity.

RESULTS:

A total of 250 adult participants were enrolled in the study, including 116 men (46.4%) and 134 women (53.6%). The mean age of the study population was 49.0 ± 13.8 years, with a range of 20 to 85 years. Baseline demographic characteristics are summarized in Table 1.1. Men had significantly higher body surface area (BSA) and body mass index (BMI) compared to women ($p < 0.001$), while women exhibited lower mean BMI and BSA values. The average systolic blood pressure in the overall population was 124.4 ± 12.9 mmHg, while the average diastolic pressure was 79.1 ± 10.6 mmHg. Gender-based comparisons revealed significant differences in both systolic and diastolic pressures across age groups ($p < 0.001$).

With respect to blood pressure abnormalities (Table 1.2), 164 participants (65.6%) exhibited elevated systolic blood pressure, whereas 158 participants (63.2%) demonstrated decreased diastolic pressure. Abnormal systolic blood pressure was most prevalent in the 40–60 years age group (90 out of 132 individuals) and was universal in the 70–85 years group, where all 13 participants showed elevated systolic values. Diastolic abnormalities were also most common in the 40–60 years age group (82 individuals). These findings suggest a clear age-associated trend, with older participants showing a higher prevalence of blood pressure alterations.

Hemodynamic parameters were further evaluated using echocardiographic imaging. Stroke volume emerged as the most frequently altered parameter in the study population. Of the participants, 41 exhibited isolated stroke volume abnormalities, while a larger proportion demonstrated combined changes in stroke volume and cardiac output. Specifically, 57 individuals showed abnormalities in both stroke volume and cardiac output, and 6 participants displayed alterations in stroke volume and heart rate. Only 2 participants showed isolated changes in ejection fraction, whereas 9 demonstrated combined variations in stroke volume and ejection fraction. In total, stroke volume abnormalities accounted for the majority of hemodynamic disturbances, either in isolation or in combination with other parameters (Table 1.3).

Table 1.1 Demographics and General Function of the Study Population

Variable	Overall population	Men (n=116)	Women (n=134)	P Value
Age(Years)	49.0 ± 13.8	50 ± 13.7	48 ± 13.94	**<0.001**
Height(m)	155.0 ± 6.60	154.7 ± 6.9	155.2 ± 6.27	**<0.001**
Weight(Kg)	57.2 ± 6.54	57.3 ± 6.11	57.3 ± 8.27	**<0.001**

Body mass index (kg/m²)	29.4±3.9	24.4±3.2	21.7±3.5	**<0.001**
Body surface area (m²)	1.98 ± 0.9	1.9 ±0.2	1.72±0.8	**<0.001**
Systolic Pressure mmHg	124.4 ± 12.96	128.8 ± 13.7	124.4 ± 12.42	**<0.001**
Diastolic Pressure mmHg	79.1 ± 10.66	80.9 ± 11.5	77.8 ± 9.47	**<0.001**

Data are expressed as mean (standard deviation). *Men vs women

Table 1.2 Statistical Data Analysis on whole population for Normal & Abnormal Blood Pressure

Blood Pressure		AGE							
		20-40 (n=67)		40-60 (n=132)		60-70 (n=38)		70-85 (n=13)	
		Number	Mean	Number	Mean	Number	Mean	Number	Mean
SYSTOLIC BLOOD PRESSURE mmHg	NORMAL (n=86)	24	120±0	42	120±0	20	120±0	-	
	ABNORMAL (n=164)	43	123±17	90	129.5±14	18	126.6±15.	13	119.2±14
DIASTOLIC BLOOD PRESSURE mmHg	NORMAL (n=92)	24	80±62	50	80± 12	14	80±8	4	80±7
	ABNORMAL (n=158)	43	79.5±13.7	82	78.7±13	24	78.6±11	9	73.3±15

Table 1.3 Distribution of Patients Based on Altered Hemodynamic Parameters

Hemodynamic Parameters	**Number of Patients**
EF (%)	2
SV (ml) & (EF %)	9
SV (ml)	41
SV (ml) & HR (bpm)	6
SV (ml) & CO (L/min)	57
SV (ml) , HR (bpm) & CO (L/min)	4
EF %, SV (ml) & CO (L/min)	4

EF -EJECTION FRACTION, SV - STROKE VOLUME, CO - CARDIAC OUTPUT L/min, HR - HEART RATE bpm

Table 1.4: Assessment of Hemodynamic Parameters by Severity Levels in Female Subjects

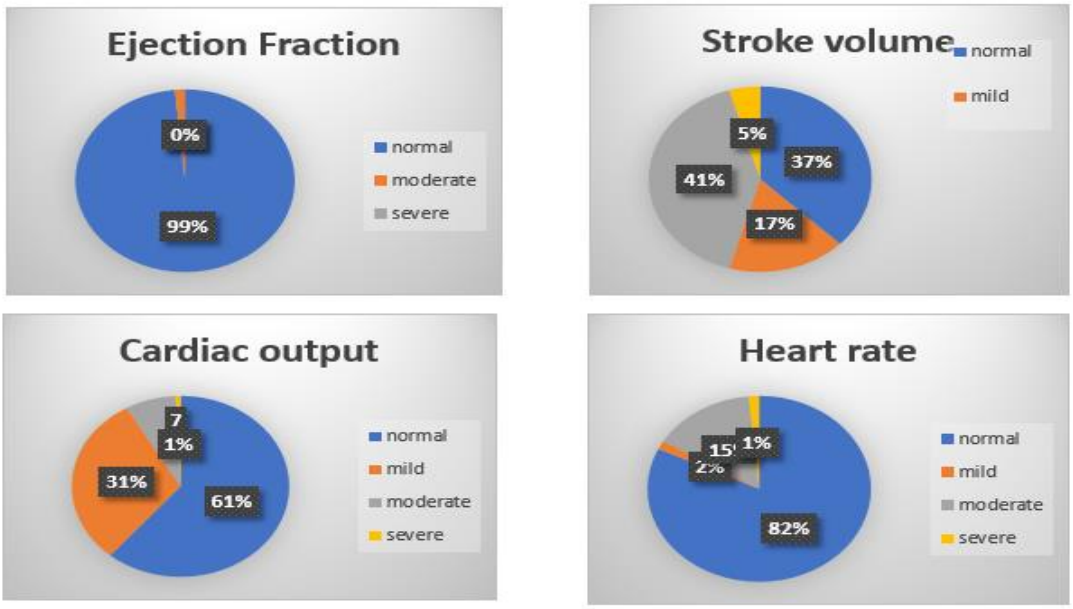


Fig.1.1 pie diagrammatic representation of Hemodynamic parameter of Female group

Hemodynamic parameters	NORMAL	MILD	MODERATE	SEVERE
EJECTION FRACTION%	**111(95%)**	**2(2%)**	**-**	**3(3%)**
STROKE VOLUME ml	**44(38%)**	**25(22%)**	**36(31%)**	**11(9%)**
CARDIAC OUTPUT (L/min)	**75(65%)**	**34(29%)**	**6(5%)**	**1(1%)**
HEART RATE bpm	**109(94%)**	**2(2%)**	**-**	**5(4%)**

Table 1.5: Assessment of Hemodynamic Parameters by Severity Levels in Male Subjects

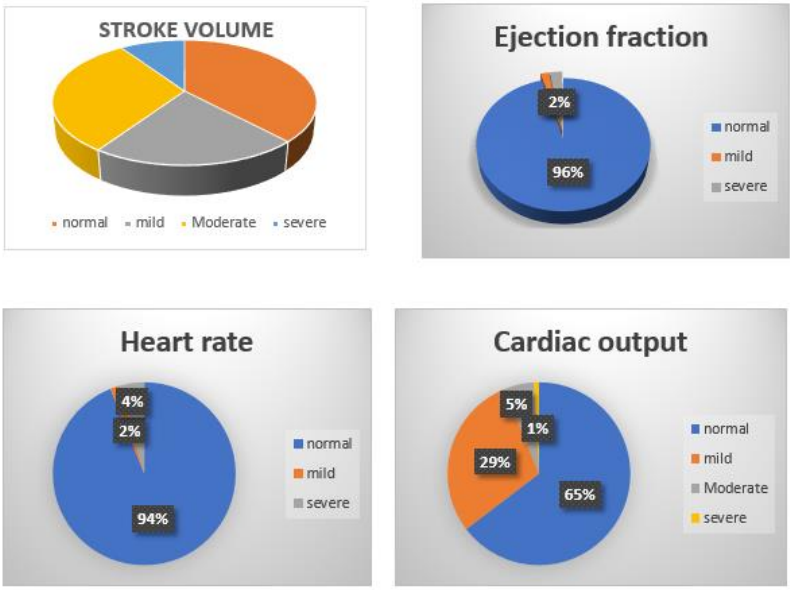
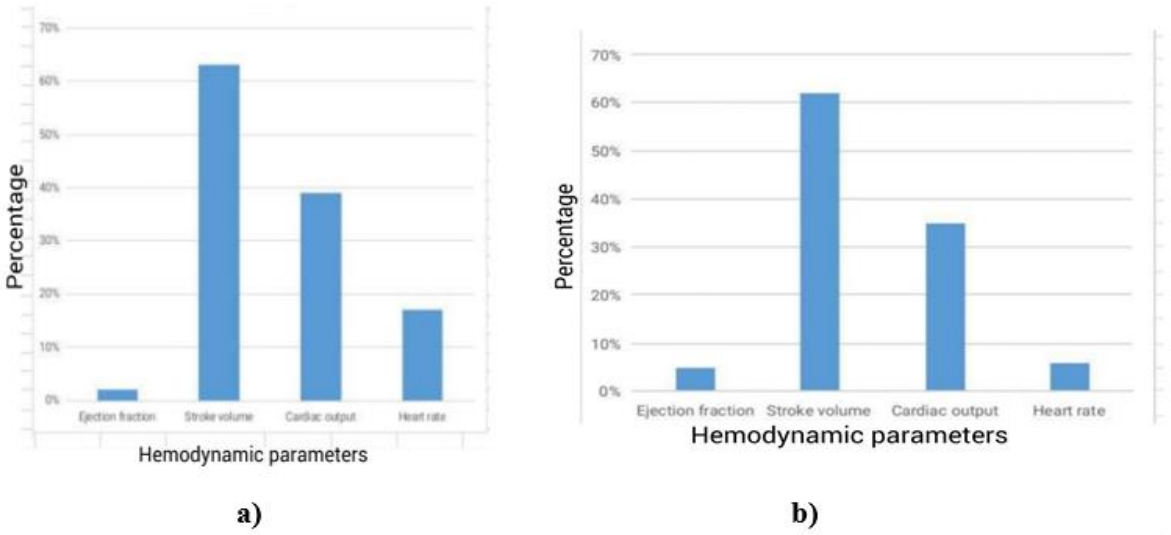


Fig.1.2. pie diagrammatic representation of Hemodynamic parameter of Male group



Graph.1.1. Abnormal hemodynamic parameters in Female and Male

Table 1.4 & 1.5 represents the Gender-specific analysis provided further insights. Among women (n = 134), ejection fraction was preserved in 98% of participants, with only 2% showing moderate impairment. In contrast, stroke volume abnormalities were highly prevalent, with 63% of women exhibiting mild to severe reductions. Cardiac output abnormalities were present in 39% of women, distributed across mild (31%), moderate (7%), and severe (1%) categories. Heart rate was preserved in most participants, with only 17% showing deviations. These findings suggest that in women, stroke volume and cardiac output were more sensitive markers of dysfunction than ejection fraction.

In men (n = 116), similar patterns were observed. Stroke volume was again the most affected parameter, with 62% of male participants demonstrating mild, moderate, or severe abnormalities. Cardiac output was altered in 35% of men, predominantly mild cases (29%). Ejection fraction remained preserved in 95% of male participants, with only 5% showing impairment. Heart rate was largely normal, with deviations seen in only 6% of cases. The comparative analysis between genders revealed no significant difference in the prevalence of stroke volume and cardiac output abnormalities, although women exhibited slightly higher rates of heart rate alterations compared to men (16% vs. 6%).

Age-stratified analysis reinforced these observations. In younger adults (20–40 years), abnormalities in hemodynamic parameters were relatively less common, though 43 individuals showed elevated systolic blood pressure. In the 40–60 years group, hemodynamic disturbances were more pronounced, with combined abnormalities in stroke volume and cardiac output being the most frequent finding. In the 60–70 years group, both systolic and diastolic alterations were observed, with stroke volume abnormalities persisting as the most consistent echocardiographic finding. In the oldest group (70–85 years), universal systolic blood pressure elevation was noted, along with multiple combined abnormalities in stroke volume, cardiac output, and heart rate.

Overall, the analysis revealed that stroke volume and cardiac output were the most commonly altered hemodynamic parameters (Fig 1.1 &1.2) in both genders and across all age groups, while ejection fraction remained preserved in the majority of participants. These findings highlight the clinical significance of stroke volume and cardiac output as early indicators of cardiac dysfunction, even in the absence of overt changes in ejection fraction.

DISCUSSION:

This study evaluated cardiac hemodynamic patterns in 250 adults using echocardiographic imaging and demonstrated that stroke volume and cardiac output were the most frequently altered parameters, whereas ejection fraction remained preserved in the majority of participants. These findings underscore the value of echocardiography as a non-invasive diagnostic tool capable of detecting subclinical cardiovascular dysfunction that may otherwise remain undiagnosed.

Our results are consistent with the findings of ***Ferrara et al. (2021)***, who reported that stroke volume and cardiac output are more sensitive indicators of early cardiac dysfunction compared to ejection fraction, which often remains preserved until later stages of disease. Similarly, Vignon et al. (2005) emphasized the importance of echocardiography in critically ill patients, where stroke volume and cardiac output assessment provide vital information for guiding clinical interventions.

In the present study, stroke volume abnormalities were noted in approximately 62% of men and 63% of women,

indicating that this parameter is consistently altered across genders. This aligns with the findings of ***Ahmed et al. (2007),*** who highlighted that echocardiographic evaluation of stroke volume provides critical insights into ventricular function and filling pressures. Cardiac output abnormalities were also prevalent, affecting around one-third of participants, further supporting its role as a reliable measure of cardiac performance.

Interestingly, ejection fraction remained largely preserved in our study population, with only minor reductions in 5% of men and 2% of women. This observation reflects the phenomenon of "preserved ejection fraction," often described in conditions such as diastolic dysfunction, where patients may exhibit impaired ventricular filling despite normal systolic function. ***Schmidt et al. (2022) and Keller et al. (2023***) have also noted that reliance on ejection fraction alone may underestimate the prevalence of early dysfunction, highlighting the need for comprehensive hemodynamic assessment.

The present study demonstrated that abnormalities in hemodynamic parameters increased with age, particularly in the 40–60 years and 70–85 years' groups. Elevated systolic blood pressure was universal in participants above 70 years, consistent with global epidemiological data indicating higher prevalence of hypertension and cardiovascular dysfunction in elderly populations (***Shanthi et al., 2011).*** Gender-based comparisons revealed similar overall patterns, though women demonstrated slightly higher rates of heart rate abnormalities represented in graph 1.1. This may reflect gender-specific physiological variations, as reported by ***Ferrara et al. (2021),*** who noted differences in stroke volume and cardiac output reference ranges between men and women.

The findings of this study have important clinical implications. First, the observation that stroke volume and cardiac output are commonly altered, even in the presence of preserved ejection fraction, suggests that these parameters may serve as **early markers of dysfunction.** Echocardiography, being non-invasive and widely available, provides a practical means of incorporating such assessments into routine clinical practice. Early identification of patients with abnormal hemodynamic patterns allows for timely interventions, lifestyle modifications, and pharmacological therapy, potentially reducing the risk of progression to overt heart failure or other cardiovascular complications.

Second, the study highlights the importance of age- and gender-specific reference values in interpreting echocardiographic findings. Differences observed between men and women in parameters such as stroke volume and cardiac output indicate that a uniform reference standard may not be applicable across populations. This supports the recommendations of recent literature advocating for population-specific echocardiographic reference values.

Limitations

A major strength of this study is the relatively large sample size (n = 250), encompassing a wide adult age range, which enhances the reliability of findings. The use of echocardiography provided a comprehensive assessment of both systolic and diastolic parameters in a non-invasive manner. Additionally, stratification by age and gender allowed for meaningful subgroup analysis.

However, some limitations must be acknowledged. Being a cross-sectional observational study, causal relationships could not be established. The study population was drawn from a single center, potentially limiting generalizability to broader populations. Furthermore, the exclusion of patients with chronic hypertension and renal disease, while necessary for uniformity, may have restricted the ability to capture hemodynamic alterations in these clinically relevant groups. Future longitudinal studies with diverse populations are needed to validate and extend these findings.

Future Focus:

Future research should focus on incorporating advanced echocardiographic techniques, such as speckle-tracking echocardiography, to provide greater sensitivity in detecting subtle changes in myocardial performance. Additionally, longitudinal follow-up studies would help determine the prognostic value of early alterations in stroke volume and cardiac output in predicting adverse cardiovascular outcomes. Integration of echocardiographic data with biomarkers of cardiac function may further enhance risk stratification and guide personalized management strategies.

CONCLUSION:

This cross-sectional study evaluated cardiac hemodynamic patterns in 250 adults using echocardiographic imaging and demonstrated that stroke volume and cardiac output were the most frequently altered parameters, while ejection fraction remained largely preserved across age and gender groups. These findings suggest that stroke volume and cardiac output are more sensitive indicators of early cardiac dysfunction than ejection fraction, which may remain within normal limits until more advanced stages of disease.

The results highlight the clinical importance of incorporating comprehensive hemodynamic assessment into routine echocardiographic practice. Identifying subtle changes in stroke volume and cardiac output, even in asymptomatic individuals with preserved ejection fraction, may enable earlier diagnosis, timely intervention, and prevention of progression to overt cardiovascular disease. Furthermore, the age- and gender-specific differences observed in this study

underscore the need for population-specific reference values in echocardiographic evaluation.

In conclusion, echocardiography remains a valuable, non-invasive, and versatile tool for assessing cardiac function. By focusing not only on ejection fraction but also on stroke volume and cardiac output, clinicians can improve the early detection and management of cardiovascular dysfunction, thereby reducing disease burden and improving long-term outcomes.

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