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Normal Echocardiographic Values of 368 Iranian Healthy Subjects

Anita Sadeghpour, MD, FASE, FACC [1,*]; Mohammadreza Shahrabi, MD [1]; Hooman Bakhshandeh, MD, PhD [2]; Nasim Naderi, MD [2]

[1]Echocardiography Research Center, Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, IR Iran
[2] Rajaie Cardiovascular Medical and Research Center, Iran University of Medical sciences, Tehran, Iran

*Corresponding author: Anita Sadeghpour, MD, FASE, FACC, Department of Cardiovascular Medicine, Echocardiography Research Center, Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Adjacent to Mellat Park, Tehran, IR Iran. Tel: +98-2123922145, Fax: +98-2122042026, E-mail: anita.sadeghpour@gmail.com; asadeghpour@rhc.ac.ir.

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Background: Echocardiography is widely used to diagnose or exclude cardiac disease. The reports on reference values based on an Asian population are limited.
Objectives: We conducted a study to determine normal values for two-dimensional, M-mode, and Doppler echocardiographic measurements and evaluate the relationship between these parameters and age and gender in a large, healthy Iranian population.
Patients and Methods: Among a total of 400 volunteers in a cross-sectional study, 368 healthy individuals aged between 30 and 70 years [171 males at a mean age of 47.6 (9.9) and 197 females at a mean age of 47.6 (9.5)] were enrolled. Standard comprehensive transthoracic echocardiography (TTE) was performed based on the guidelines of the American Society of Echocardiography. The normal limits are presented as mean (SD) and are also indexed to body surface area (BSA).
Results: There was no significant difference between the men and women regarding left ventricular (LV) ejection fraction (57.97% vs. 57.99%). The mean of LV end-diastolic diameter (LVEDD), LV end-systolic diameter (LVESD), interventricular septum (IVS), posterior wall (PW) thickness, and right ventricular diastolic diameter (RVDd) was significantly greater in the men than in the women. However, there was an inverse relationship when LVEDD, RVDd, and left atrial (LA) diameter and area were indexed to BSA. There was no significant difference in the mean of LA area between the males and females (14.28 vs. 13.6 cm2). The LV diastolic parameters correlated negatively with age. A peakE /A velocity ratio < 1 was found in the subjects over 50 years old. The mean of all the measurements in our study was less than the reference values in the published guidelines.
Conclusions: Our study, the first and largest investigation of its kind, provides reference values for the echocardiographic evaluation of the cardiac size and function of Iranian healthy individuals. The mean of our measurements was significantly less than that reported in the published guidelines.

Keywords: Reference Values; Echocardiography; Anatomical Parameters

1. Back ground

Echocardiography plays a key role in the evaluation of chamber size and function and subsequent decision-making. Echocardiographic normative values in healthy subjects are influenced by several variables. Although the normal values of two-dimensional (2D) and Doppler-derived velocities are influenced by age, the effects of gender, race, and geographic origin are unknown. European and American societies of echocardiography have provided many guidelines for the echocardiographic quantification of cardiac chamber size and function and offered reference values for these echocardiographic measurements (1-3). Unsurprisingly, most of these data have been derived from American and European populations and there is a dearth of information on such reference values based on the Asian population.

2. Objectives

Accordingly, we conducted the present study to determine normal values for echocardiographic measurements and evaluate the relationship between these parameters and age and gender in a large, healthy Iranian population.

3. Patients and Methods

3.1. Study Participants

Among 400 volunteers, 368 healthy individuals aged between 30 and 70 years [171 males at a mean age of 47.6 (9.9)

Implication for health policy/practice/research/medical education:
We conducted the study entitled "Normal Echocardiographic Values of 368 Iranian Healthy Subjects" to determine the normal values for echocardiographic measurements and evaluate the relationship between these parameters and age, gender in a large, healthy Iranian population. The reports for reference values based on an Asian population are limited and to our knowledge it is the first report of echocardiographic values of a large number of normal Iranian people which would be useful for further studies. This study was approved by the ethics committee of Rajaie Cardiovascular Medical and Research center and informed consent was obtained from all the patients.

and 197 females at a mean age of 47.6 (9.5)] were enrolled. The normal subjects were chosen by taking into account their history, physical examination, electrocardiography (ECG), echocardiography, and negative recent noninvasive or invasive tests for cardiovascular diseases in men over 45 and women over 55 years of age. The exclusion criteria were comprised of any history of hypertension, diabetes mellitus, dyslipidemia, renal failure, and cardiovascular diseases or consumption of cardiovascular medications as well as abnormal ECG findings or abnormal echocardiographic findings such as left ventricular (LV) wall motion abnormalities or significant valvular disease. Subjects with poor echocardiographic windows or with high blood pressure (systolic $\geq$135 or diastolic $\geq$85 mm Hg) at the time of echocardiographic examination were also excluded.

The study was approved by the Ethics Committee of Rajaie Cardiovascular, Medical and Research Center, and written informed consent was obtained from all the participants.

3.2. Echocardiography

Standard transthoracic echocardiography (TTE) was performed with a GE Vivid 3 system (Horten, Norway), equipped with an M3S multi-frequency phased array transducer and tissue Doppler imaging facility. Data were acquired with the subjects at rest, lying in the left lateral position. Grey-scale images were obtained using second-harmonic imaging (1.7/3.4 MHz). Gain and depth were adjusted to optimize the images for each subject. All the echocardiographic examinations were performed by expert echocardiographers and supervised by echocardiologists. Standard ECG was superimposed on the images, and end-diastole was considered at the peak R wave of the ECG. In all the subjects, LV end-diastolic diameter (LVEDD), LV end-systolic diameter (LVESD), interventricular septal thickness (IVS), and left ventricular posterior wall thickness (LVPW) were measured at end-diastole. Systolic diameter was measured at the time when the LV posterior wall was closest to the septum (first frame just after the end of T wave), which also corresponded to the minimal internal dimension. The mean value of three consecutive measurements was considered. Cardiac chamber quantification by 2D echocardiography was performed according to the guidelines of the American Society of Echocardiography (1) in each subject. LV ejection fraction (LVEF) was measured using the Simpson biplane method. For M-mode parameters, the variables studied comprised ventricular diameters, IVS, LVPW, and left atrial (LA) diameters.

3.3. Doppler Examination

Mitral inflow velocities were examined using pulse wave Doppler. The peak velocities of early (E) and late (A) diastolic flow, E/A ratio, and early flow deceleration time (DT) were also measured. Tissue Doppler imaging is an echocardiographic technique that evaluates longitudinal myocardial tissue velocities during LV systolic and diastolic function, relatively independently of loading conditions. In this study, the tissue Doppler imaging of mitral annular motion was acquired from apical four-chamber view using a 5-mm sample volume placed at the septal and lateral portions of the mitral annulus, and early (e') and late (a') diastolic annular velocities were measured. The ratio of mitral E to TDI e' was calculated using both septal (E/e' sept) and lateral (E/e' lat) velocities.

3.4. Statistical Analysis

All the analyses were conducted using SPSS® 15 for Windows® (SPSS Corp., Chicago, Illinois). The data are presented as mean [standard deviation (SD)] for the interval and count (percentages) for the categorical variables. The one-sample Kolmogorov-Smirnov test was used to show the fitness of the interval variables with the Gaussian distribution. The continuous variables were compared using the independent samples t-test or analysis of variance (ANOVA), and the post-hoc least significant differences (LSD) test was employed for multiple comparisons. The one-sample t-test was used to compare the mean of the variables with the means mentioned in the American and European guidelines and references. The Pearson correlation coefficient (r) was utilized to show the correlations between several echocardiographic findings and age. A p value < 0.05 was considered statistically significant.

4. Results

4.1. General Characteristics

Among 400 volunteers, 368 healthy individuals were enrolled. Table 1 depicts the demographic and clinical characteristics of the study population. The mean of heart rate was 67 (14) bpm, mean systolic blood pressure was 111 (15) mm Hg, and mean diastolic blood pressure was 74 (14) mm Hg. There were no significant differences in heart rate or body surface area (BSA) between the men and women.

Table 1. Clinical Characteristics Stratified by Age

	Men, mean (SD) (n=171)				Women, mean (SD) (n=197)			
Age group, y	30-39 (n=40)	40-49, (n=51)	50-59, (n=60)	60-70, (n=20)	30-39, (n=40)	40-49, (n=75)	50-59, (n=52)	60-70, (n=30)
Heart Rate	68 (15)	67 (12)	64 (15)	62 (13)	68 (13)	68 (12)	67 (14)	61 (12)
SBP[a]	109 (12)	111 (14)	119 (14)	118 (15)	105 (11)	112 (13)	120 (12)	122 (14)
DBP	70 (6)	72 (9)	76 (10)	75 (12)	68 (7)	69 (11)	74 (14)	77 (12)
BSA	1.9 (0.19)	1.9 (0.16)	1.9 (0.17)	1.8 (0.12)	1.7 (0.17)	1.7 (0.13)	1.7 (0.14)	1.6 (0.23)

[a] Abbreviations: BSA, body surface area; DBP, diastolic blood pressure, SBP, systolic blood pressure

Table 2. Normal Values for Echocardiographic Parameters in Men Compared to Women

	Men (n = 171)		Women (n = 197)		P value
	Mean (SD)	95% CI	Mean (SD)	95% CI	
LVEF[a], %	57.8 (3.5)	50.8-64.8	57.7 (2.7)	52.3-63.1	0.8
LVEDD, cm	4.7 (0.42)	3.4-5.9	4.4 (0.42)	3.1-5.6	< 0.001
LVEDD/BSA, cm/m^2	2.4 (0.23)	1.7-3.1	2.6 (0.25)	1.8-3.3	< 0.001
LVESD, cm	3.2 (0.41)	2-4.4	2.9 (0.39)	1.8-4	< 0.001
LVESD/BSA, cm/m^2	1.7 (0.2)	1.1-2.2	1.7 (0.3)	0.8-2.6	0.04
IVS thickness, cm	0.9 (0.1)	0.6-1.1	0.86 (0.15)	0.5-1.2	0.01
IVS thickness /BSA, cm/m^2	0.5 (0.06)	0.3-0.6	0.5 (0.07)	0.3-0.7	0.04
PW thickness, cm	0.8 (0.12)	0.5-1.1	0.8 (0.12)	0.5-1.1	0.01
PW thickness/BSA, cm/m^2	0.4 (0.07)	0.2-0.6	0.5 (0.09)	0.2-0.7	0.04
RVEDD, cm	2.9 (0.3)	2-3.8	2.6 (0.27)	1.8-3.4	< 0.001
RVEDD/BSA, cm/m^2	1.5 (0.2)	1.1-2	1.6 (0.2)	1-2.2	0.08
LAD, cm	3.3 (0.4)	2.1-4.5	3.2 (0.4)	2-4.4	0.08
LAD/BSA, cm/m^2	1.7 (0.2)	1.1-2.3	1.9 (0.2)	1.3-2.5	0.001
LAA, cm^2	14.3 (2.9)	5.6-23	13.8 (2.6)	6-21	0.06
LAA/BSA, cm/m^2/m^2	7.5 (1.5)	3-12	8.4 (1.5)	4-13	0.001

[a] Abbreviations: BSA, body surface area; CI, confidence interval; IVS, interventricular septum; LAA, left atrium area; LAD, left atrium diameter; LVEF, left ventricular ejection fraction; LVEDD, left ventricular end diastolic diameter; LVESD, left ventricular end systolic diameter; PW, posterior wall; RVEDD, right ventricular end diastolic diameter

Table 3. LVEF , LV and RV Dimentions, LA Area and Dimentions

	Men (n = 171)				Women (n = 197)			
Age group, y	30-39, mean (SD) (n = 40)	40-49, mean (SD) (n = 51)	50-59, mean (SD) (n = 60)	60-70, mean (SD) (n = 20)	30-39, mean (SD) (n = 40)	40-49, mean (SD) (n = 75)	50-59, mean (SD) (n = 52)	60-70, mean (SD) (n = 30)
LVEF[a]	58.6 (2.7)	57.9 (3.1)	57.4 (4.5)	57.5 (2.5)	58.2 (2.6)	58.3 (2.7)	57.4 (2.8)	56.6 (2.7)
LVEDD	4.7 (0.49)	4.7 (0.37)	4.7 (0.42)	4.7 (0.42)	4.4 (0.47)	4.4 (0.41)	4.4 (0.41)	4.5 (0.41)
LVEDDI	2.4 (0.21)	2.4 (0.24)	2.5 (0.23)	2.6 (0.22)	2.5 (0.26)	2.5 (0.25)	2.6 (0.27)	2.8 (0.22)
LVESD	3.1 (0.45)	3.2 (0.35)	3.2 (0.43)	3.1 (0.44)	2.8 (0.49)	2.9 (0.36)	3 (0.32)	3 (0.4)
LVESDI	1.6 (0.17)	1.6 (0.2)	1.68 (0.23)	1.8 (0.23)	1.6 (0.29)	1.7 (0.20)	1.75 (0.19)	1.88 (0.2)
LVPW	0.84 (0.11)	0.84 (0.12)	0.8 (0.13)	0.88 (0.13)	0.8 (0.1)	0.8 (0.12)	0.8 (0.12)	0.87 (0.17)
LVPWI	0.43 (0.06)	0.44 (0.07)	0.42 (0.08)	0.49 (0.07)	0.45 (0.06)	0.47 (0.07)	0.48 (0.07)	0.55 (0.18)
IVS	0.85 (0.1)	0.9 (0.09)	0.9 (0.11)	0.93 (0.11)	0.83 (0.2)	0.85 (0.1)	0.87 0.11)	0.92 (0.11)
IVSI	0.44 (0.05)	0.48 (0.06)	0.47 (0.06)	0.52 (0.06)	0.47 (0.14)	0.5 (0.06)	0.51 (0.07)	0.58 (0.1)
RVEDD	2.9 (0.33)	2.9 (0.24)	2.9 (0.4)	2.8 (0.39)	2.6 (0.44)	2.6 (0.26)	2.7 (0.3)	2.6 (0.26)
RVEDDI	1.6 (0.19)	1.5 (0.15)	1.5 (0.2)	1.6 (0.16)	1.5 (0.16)	1.5 (0.17)	1.6 (0.16)	1.6 (0.16)
LAD	3.2 (0.42)	3.3 (0.37)	3.3 (0.4)	3.4 (0.4)	3 (0.43)	3 (0.4)	3.4 (0.47)	3.3 (0.44)
LADI	1.7 (0.17)	1.7 (0.22)	1.86 (0.16)	1.9 (0.17)	1.7 (0.2)	1.8 (0.2)	1.99 (0.8)	2 (0.17)
LAA	13.6 (2.9)	13.7 (2.7)	15 (2.9)	15.1 (3.3)	13.2 (2.3)	13.8 (2.5)	14.2 (3)	13.9 (2.6)
LAAI	7 (1.3)	7.2 (1.3)	7.8 (1.4)	8.4 (1.7)	7.5 (1.1)	8 (1.2)	8.2 (1.7)	8.6 (2.2)

[a] Abbreviations: I, indexed; IVS, interventricular septum; LAA, left atrium area; LAD, left atrium diameter; LVEDD, left ventricular end diastolic diameter; LVEF, left ventricular ejection fraction; LVESD, left ventricular end systolic diameter; PW, posterior wall; RVEDD, right ventricular end diastolic diameter

4.2. Echocardiographic Parameters

4.2.1. Left Ventricle

Table 2 demonstrates the 2D echocardiographic findings in the men and women. There was no significant difference between the men and women regarding LVEF (57.97% vs. 57.99%). The mean of LVEDD and LVESD was significantly greater in the men than in the women [4.75 vs. 4.42 cm (p value < 0.001) for LVEDD and 3.2 vs. 2.9 cm (p value < 0.001) for LVESD]. The mean of interventricular septum diameter (IVSD) and LV posterior wall diameter (LVPWD) was also significantly greater in the men than in the women (Table 2). Nevertheless, there was an inverse relationship when LVEDD, RVDd, and LA diameter and area were indexed to BSA. Table 3 depicts the LV dimensions in different age and sex groups, and Table 4 shows the relationship between the different variables of left heart dimensions and age. As

is illustrated in Table 4, there was a weak but significant negative correlation between age and LVEF in the women (r = -0.19; P = 0.004) but not in the men. LVEDD and LVESD, when indexed to BSA, showed a weak correlation with age in the women (r = 0.16; P = 0.01 and r = 0.2; P = 0.003 for LVEDD/BSA and LVESD/BSA, respectively). Regarding LV wall thickness, IVS and posterior wall thicknesses were increased with age in both men and women (Table 4).

As is shown in Table 2, the mean of LV and right ventricular (RV) dimension measures was less than that of the same measures mentioned in western references (1-3). These differences were statistically significant (P < 0.0001) for all LV and RV dimensions, which signifies smaller heart dimensions among the Iranian population.

Table 4. Correlation of Echocardiographic Parameters of Left Heart With Age

	Men (n=171)		Women (n=197)	
	r	P value	r	P value
LVEF[a], %	-0.12	0.08	-0.19	0.004
LVEDD, cm	0.04	0.5	0.02	0.7
LVEDD/BSA, cm/m^2	0.12	0.1	0.16	0.01
LVESD, cm	0.002	0.9	0.1	0.1
LVESD/BSA, cm/m^2	0.13	0.06	0.2	0.003
IVS thickness, cm	0.2	0.003	0.17	0.01
IVS thickness /BSA, cm/m^2	0.16	0.01	0.2	0.003
PW thickness, cm	0.2	0.003	0.19	0.004
PW thickness/BSA, cm/m^2	0.16	0.01	0.2	0.003
RVEDD, cm	0.14	0.06	0.04	0.5
RVEDD/BSA, cm/m^2	0.019	0.7	0.16	0.02
LAD, cm	0.14	0.05	0.14	0.02
LAD/BSA, cm/m^2	0.28	<0.001	0.21	0.002
LAA, cm^2	0.2	0.004	0.2	0.003
LAA/BSA, cm^2/m^2	0.3	<0.001	0.2	0.003

[a] Abbreviations: BSA, body surface area; IVS, interventricular septum; LAA, left atrium area; LAD, left atrium diameter; LVEDD, left ventricular end diastolic diameter; LVEF, left ventricular ejection fraction; LVESD, left ventricular end systolic diameter; PW, posterior wall; RVEDD, right ventricular diastolic diameter

4.2.2. Left Atrium

There was no significant differences in LA size and area between the men [3.31 (0.4) cm] and women [3.2 (0.4) cm (P = 0.08)]. There was, however, a significant difference between the men and women when these variables were indexed to BSA [1.74 (0.21) cm in men vs. 1.88 (0.21) cm in women; P = 0.001] (Table 2). As is illustrated in Table 3, LA diameter and area increased with age. The mean of the LA size and area was significantly smaller than that cited in the other references (Table 4).

4.2.3. Right Ventricle

In this study, RV size was measured at its mid part at end-diastole (RVEDD). Table 2 shows that RVEDD was larger in the men [2.9 (0.3) cm] than in the women [2.6 (0.27) cm (P < 0.001)], with there being an inverse relationship when it was indexed to BSA [1.54 (0.18) cm in men vs. 1.58 (0.24) cm in women (P = 0.08)].

4.3. Left Heart Doppler Parameters

Table 5 presents the left heart Doppler parameters in the men and women, and Table 6 shows these parameters in different age and sex groups. There was a significant correlation between all the LV diastolic parameters and age (Table 7). There was a decrease in E/A ratio at the age of 50. In the 50-59-year-old age group, E/A ratio was 0.96 (0.2) and 0.99 (0.2) in the men and women, respectively. This ratio was 0.87 (0.3) and 0.84 (0.17) in the men and women after the age of 60. As regards tissue Doppler imaging parameters, lateral e'was higher than septal e' in both sexes [septal e'= 9 (2.2) and 9.4 (2.3), lateral e' = 12.6 (2.7) and 13 (2.9) in men and women, respectively], but there was a decrease in tissue velocities and an increase in E/ e' ratio with age. E/ e' was 7.3 (1.9) and 8.4 (0.16) in the 50-59-year-old age group and 7.6 (1.9) and 8.9 (1.8) in the 60-70-year-old age group in the men and women, respectively.

4.4. Reproducibility

In 30 subjects, who were randomly selected, the intraobserver and interobserver variabilities for all the studied parameters were demonstrated to be mainly between 5 and 10%.

Table 5. Left Heart Doppler Parameters in Men and Women

	Men, mean (SD) (n=171)	Women, mean (SD) (n=197)
E, m/s	0.68 (0.16)	0.76 (0.15)
A, m/s	0.64 (0.13)	0.71 (0.17)
A duration, ms	120.4 (15.9)	120.7 (16.6)
DT[a], ms	219 (41.1)	209.4 (32.8)
IVRT, ms	83.1 (13.9)	82.9 (13.5)
E/A	1.1 (0.33)	1.1 (0.27)
S wave, m/s	51.7 (11.5)	54.7 (9.9)
D wave, m/s	42.7 (8.8)	42.4 (9)
AR duration, ms	107.7 (14.9)	105.8 (14.9)
A-AR duration, ms	11.9 (14.2)	14.6 (16.7)
e' septal	9 (2.2)	9.4 (2.3)
e' lateral	12.6 (2.7)	13 (2.9)
e'mean	10.3 (2.5)	10.5 (2.6)
E/ e', septal	7.8 (1.9)	8.5 (2.3)
E/ e', mean	6.9 (1.7)	7.6 (2.2)

[a] Abbreviations: AR, atrial reversalT, deceleration time; IVRT, isovolumic relaxation time

Table 6. Left Heart Doppler Parameters in Different Age and Sex Group

	Men, mean (SD)	Women, mean (SD)	P value
E	0.68 (0.16)	0.76 (0.15)	< 0.001
A	0.64 (0.13)	0.71 (0.17)	< 0.001
A duration	120.4 (15.9)	120.7 (16.6)	0.8
EDT[a]	219 (41.1)	209.4 (32.8)	0.01
IVRT	83.1 (13.9)	82.9 (13.5)	0.8
E/A	1.1 (0.33)	1.1 (0.27)	0.6
S wave	51.7 (11.5)	54.7 (9.9)	0.005
D wave	42.7 (8.8)	42.4 (9)	0.7
AR duration	107.7 (14.9)	105.8 (14.9)	0.2
A-AR duration	11.9 (14.2)	14.6 (16.7)	0.9
e' septal	9 (2.2)	9.4 (2.3)	0.08
e' lateral	12.6 (2.7)	13 (2.9)	0.2
e' mean	10.3 (2.5)	10.5 (2.6)	0.3
E/ e' septal	7.8 (1.9)	8.5 (2.3)	0.002
E/ e' mean	6.9 (1.7)	7.6 (2.2)	< 0.001

[a] Abbreviations: AR, atrial reversal; DT, deceleration time; IVRT, isovolumic relaxation time

Table 7. Correlation of Doppler Echocardiographic Parameters of Left Heart With Age

	Men (n=171)				Women (n=197)			
Age group	30-39, mean (SD)	40-49, mean (SD)	50-59, mean (SD)	60-70, mean (SD)	30-39, mean (SD)	40-49, mean (SD)	50-59, mean (SD)	60-70, mean (SD)
E, m/s	0.76 (0.16)	0.7 (0.15)	0.66 (0.15)	0.59 (0.15)	0.78 (.0.11)	0.79 (0.15)	0.75 (0.17)	0.68 (0.10)
A, m/s	0.6 (0.1)	0.6 (0.09)	0.7 (0.15)	0.7 (0.17)	0.62 (0.12)	0.68 (0.15)	0.78 (0.19)	0.81 (0.13)
A duration, ms	116.7 (15)	120 (16)	121 (14)	125.7 (19)	114.8 (14.2)	120 (18)	123.7 (16)	123.2 (13)
EDT[a], ms	203.9 (28)	204 (32)	228 (40)	261.6 (51)	194.3 (21)	199 (25)	221.7 (36.3)	234 (35)
IVRT, ms	75.9 (9.5)	79 (10.6)	88 (12)	94.5 (16)	75.4 (11)	79 (10)	88.5 (13)	90.0 (16)
E/A	1.3 (0.3)	1.1 (0.24)	0.96 (0.2)	0.87 (0.3)	1.3 (0.2)	1.2 (0.2)	0.99 (0.2)	0.84 (0.17)
S wave, m/s	49 (11)	50.9 (12)	53.6 (11.4)	53.9 (10.5)	54.4 (9.2)	55.7 (10.6)	54.7 (10)	52.6 (7.5)
D wave, m/s	45.1 (7.7)	43.5 (9)	41.8 (9.7)	38.2 (5.3)	46.1 (9)	42.9 (9)	40.3 (8.8)	39.6 (8)
AR duration, ms	101.5 (11.4)	106.3 (14)	111 (13)	113.7 (22)	101.2 (1.4)	105.8 (15)	108.7 (14.5)	107.2 (12.6)
A-AR duration, ms	14.1 (14)	14.7 (16)	14.7 (13)	11.8 (12)	12.4 (14.8)	13.3 (14)	14.7 (17)	17.1 (13.3)
e' Septal, cm/s	10.6 (2.1)	9.5 (1.8)	8 (1.6)	7.1 (1.8)	10.9 (1.8)	10 (2)	8.6 (2.2)	7.1 (1)
e' lateral, cm/s	14.4 (2.2)	13 (2.7)	11.5 (1.9)	10.6 (3.1)	15.1(2.2)	13.5(2.5)	11.4(2.7)	10.5(2)
e' mean, cm/s	12.8(2.3)	10.8(2.2)	9.3(1.7)	8.1(2.4)	12.5 (2)	11.3 (2.1)	9.4 (2.4)	7.8 (1.6)
E/ e' septal	7.3 (1.6)	7.4 (1.6)	8.4 (2)	8.6 (1.9)	7.3 (1.5)	8.1 (1.9)	9.3 (2.9)	9.7 (1.8)
E/e' mean	6.4 (1.4)	6.5 (1.6)	7.3 (1.9)	7.6 (1.9)	6.4 (1.4)	7.2 (1.7)	8.4 (2.7)	8.9 (1.8)
Total number	40	51	60	20	40	75	52	30

[a] Abbreviations: AR, atrial reversal; DT, deceleration time; IVRT, isovolumic relaxation time

5. Discussion

This study presents the normal values of echocardiographic measurements and the relationship between these parameters and age and sex in 368 normal healthy Iranian subjects. Despite the prevalent use of echocardiography to diagnose or exclude cardiac disease, the existing literature is limited in terms of echocardiographic reference values based on the Asian population (2-9). Echocardiographic reference values would be extremely useful for routine clinical practice and interpretation of Iranian echocardiograms in different age and sex groups.

Our results revealed that the mean value of the echocardiographic measurements in the Iranian population was significantly less than the mean values in the published guidelines (1). Similarly, Rivera et al. (10) reported low left heart normal echocardiographic values in the Mexico city population in comparison to other countries.

We observed a weak but significant age-related decline in LVEF and an age-related increase in indexed LVEDD and LVESD in our female subjects. Heyward et al. (6) showed greater systolic function and lower diastolic compliance in women. Carroll et al. (7) concluded that sex is an important factor in LV function. In contrast, cardiac size was smaller in our female patients (when not indexed to BSA) than in their male counterparts, and there was no significant gender-specific difference in LVEF and LA diameter. There was, however, a significant correlation between age and LV wall thickness, which was consistent with a similar Japanese study by Daimon et al. (9). It is unclear why there was slightly a fall in LVEF and a rise in LV size with increasing age in our Iranian women. Sedentary lifestyle and cultural issues in Iranian women may be a predisposing factor, but further studies are required to shed sufficient light on this issue.

Our results showed that Iranian hearts were smaller than those in other reports and references values. Even after having been indexed to BSA, the dimensions and thicknesses were smaller than the references values in American and European guidelines (1-3) regardless of the gender. Daimon et al. (9) reported that Japanese hearts are smaller than the references values but that their indexed values are within the references values. Taking into account their results and other reports (8-12) on racial differences in LV geometry, the authors concluded that for diagnostic or therapeutic decision-making, racial differences in cardiac chamber dimensions should be carefully considered. There is a need for further investigations to determine beyond any doubt whether Asian hearts are indeed smaller than American or European ones, or whether there are other factors at play rather than race, such as lifestyles or food habits.

Age-related changes in ventricular and atrial geometry have been reported (9 - 13). With age, LV mass and wall thickness increase gradually, while LV diastolic function decreases (9 - 13). Our results chime in with these reported changes: with age, there was a rise in LV wall thickness and LV diastolic function variables in our study population, which is in favor of impaired LV relax-

ation (mild diastolic dysfunction) in both sexes (Tables 4 and 7).

We found an age-related increase in LA size and area. LA area and indexed LA area were significantly greater in a small percentage of the individuals who had mild impaired relaxation based on Doppler study [15.2 (3.4) cm^2 vs. 13.8 (2.7) cm^2; P = 0.01 and 8.5 (2) cm^2/m^2 vs. 7.7 (1.4) cm^2/m^2; P = 0.04]. Consequently, mild age-related diastolic dysfunction might have an impact on LA area. There are conflicting data regarding LA changes with age in the literature (13-16), however. Whereas Daimon et al. (9) reported no change in LA size with age, Pritchett et al. (14) concluded that age-related mild LV impaired relaxation could contribute to LA remodeling and enlargement.

5.1. Diastolic Parameters

In this study, in concordance with previous reports (17-20), LV diastolic parameters decreased significantly with age. This decline was more prevalent in the individuals over 50 years of age (22% in 50-59-year-old age group and 43% in 60-70-year-old age group).

We determined normal values for left heart dimensions and diastolic parameters based on age and sex. We concluded that the assessment of echocardiographic anatomical values requires the consideration of the origin of study, the race of the studied population, and the sex and age of the individuals.

5.2. Study Limitations

Despite its relatively good sample size and different age groups, the present study was a single-center study. Our results would enjoy better generalizability had they been obtained from a multi-center study. Moreover, since we did not assess all variables in left heart study such as LV volume, LV mass, aortic root, and LA volume, we suggest more comprehensive studies be undertaken in this regard.

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Authors' Contribution

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