Normal echocardiographic measurements in a Turkish population: The Healthy Heart ECHO-TR Trial

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Abstract

Objective: Normal reference values for the cardiac chambers are widely based on cohorts from European or American populations. In this study, we aimed to obtain normal echocardiographic measurements of healthy Turkish volunteers to reveal the age, gender, and geographical region dependent differences between Turkish populations and other populations.

Methods: Among 31 collaborating institutions from all regions of Turkey, 1154 healthy volunteers were enrolled in this study. Predefined protocols were used for all participants during echocardiographic examination. Blood biochemical parameters were also obtained for all patients on admission. The American Society of Echocardiography and European Association of Cardiovascular Imaging recommendations were used to assess the echocardiographic cardiac chamber quantification.

Results: The study included 1154 volunteers (men: 609; women: 545), with a mean age of 33.5±11 years. Compared to men, women had a smaller body surface area, lower blood pressure and heart rate, lower hemoglobin, total cholesterol, lower low-density lipoprotein (LDL) levels, and higher high density lipoprotein (HDL) levels. Cardiac chambers were also smaller in women and their size varied with age. When we compared the regions in Turkey, the lowest values of left cardiac chamber indices were seen in the Marmara region and the highest values were observed in the Mediterranean region. Regarding the right cardiac indices, the Mediterranean region reported the lowest values, while the Black Sea region and the Eastern Anatolia region reported the highest values.

Conclusion: This is the first study that evaluates the normal echocardiographic reference values for a healthy Turkish population. These results may provide important reference values that could be useful in routine clinical practice as well as in further clinical trials. *(Anatol J Cardiol 2019; 22: 262-70)*

Keywords: echocardiography, left ventricle, left atrium, right ventricle, right atrium

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Introduction

Echocardiography is the most widely used noninvasive cardiac imaging technique in the clinical setting for the assessment of heart structure and functions. In addition to its availability and portability, it provides real time imaging. To detect abnormal findings, it is important to be aware of the normal reference values of cardiac chamber size, ventricular mass, and function in the clinical setting according to age, gender, and body surface area (1, 2). Currently, available echocardiographic reference values that define "normality" are mostly based on American and European populations. Physical (3, 4) and racial (5, 6) factors may affect cardiac chamber size and function; therefore, it is important to evaluate the echocardiographic parameters in specific populations.

In the current study, we aimed to evaluate the normal values of echocardiographic measurements and the relationship between these measurements and age, gender, body surface area, and geographical region-dependent differences in a healthy Turkish population (ECHO-TR).

Methods

Study population

Between October 2016 and January 2018, 1295 healthy volunteers from all regions of Turkey were enrolled in this study. The exclusion criteria was; people under 18 years of age, patients who had history of having any cardiovascular disease, hypertension, diabetes mellitus, hyperlipidemia, systemic disease, glomerular filtration rate under 60 mL/min/1.73 m^2, genetic disease with cardiac involvement in first-degree relatives, electrocardiography without sinus rhythm or with left bundle branch block, waist circumference more than 102 cm in men and 88 cm in women, high body mass index, abnormal glycemic values, smoking and/or alcohol abuse. Subjects were also excluded if the presented with any of the following echocardiographic findings; regurgitation of heart valves at a level higher than mild, stenosis of a valve, left ventricular ejection fraction less than 50%, wall motion abnormality, systolic pulmonary artery pressure more than 35 mm Hg, and poor image quality.

After applying the exclusion criteria, a total of 1154 volunteers were included in the study.

Echocardiographic examination

A comprehensive echocardiographic examination was performed for all subjects according to a predetermined protocol recommended by the American Society of Echocardiography and the European Association of Cardiovascular Imaging (Fig. 1-4) (7-10).

Standard transthoracic echocardiographic studies with machine-integrated ECG recording were performed using Vivid S5 machines with an M3S matrix array probe and a frequency range of 1.7–3.2 MHz (GE Vingmed, Horten, Norway). Alternatively, a Philips Ultrasound IE-33 or Sonos 5500/7500 interfaced with a standard 2.5–3.5 MHz phased-array probe was used. All studies were done with patients lying in the left lateral decubitus position and breathing quietly. M-mode, 2D (frame rates: 0.50–70 fps), color Doppler, pulsed-wave Doppler, pulsed-wave tissue Doppler, and tissue Doppler imaging (frame rates ≥110 s-1) data were obtained in all patients. Image acquisition was performed during end-expiration to minimize cardiac respiratory motion. A minimum of at least three cardiac cycles were recorded for analysis. All Doppler-echocardiographic images were recorded in a digital raw-data format (native DICOM format), centralized,

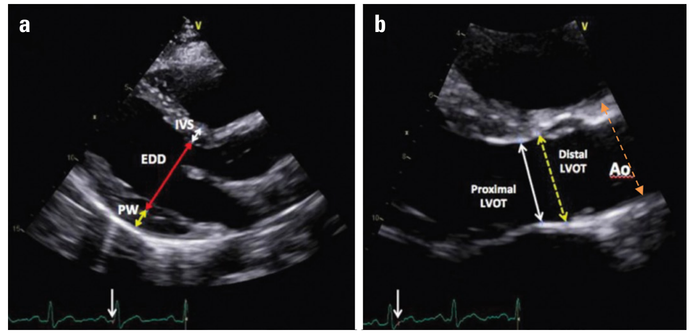

Figure 1. (a) A two-dimensionally guided measurement of LV wall thickness in end-diastole from the left parasternal long-axis view. The interventricular septum thickness (white arrow), LV end-diastolic diameter (red arrow), and the posterior wall (PW; yellow arrow) thickness are measured just distal to the mitral leaflets tips, perpendicular to the long axis of the LV. (b) Proximal LV outflow tract (LVOT) diameter was measured in mid-systole, using the trailing-edge-to leading-edge method, 0.5–1 cm below the aortic cusps in a plane parallel to the aortic annulus (white arrow) from the zoomed parasternal long-axis view. The yellow dashed arrow represents the distal LVOT diameter measured just below the aortic annulus level

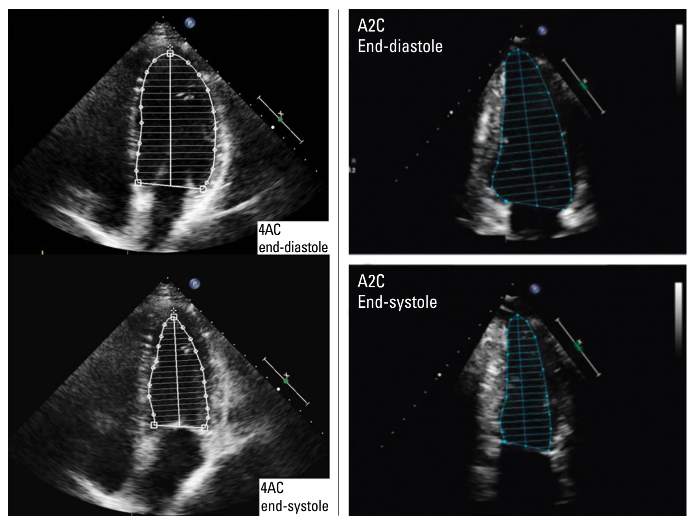

Figure 2. Two-dimensional measurements of left ventricle (LV) volumes using the biplane method of discs (modified Simpson's rule), in the apical four-chamber (A4C) and the apical two-chamber (A2C) views at end-diastole (LVEDV) and at end-systole (LVESV). LV trabeculations and the papillary muscles should be excluded from the cavity in the tracing

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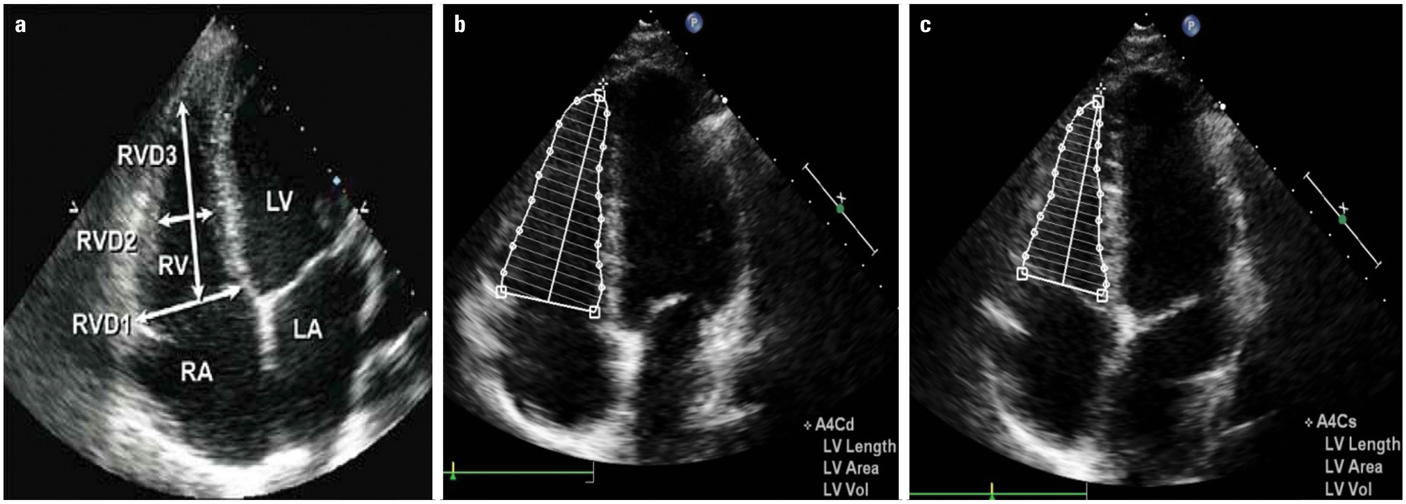

Figure 3. (a) Measurement of right ventricle (RV) linear dimensions from the apical four-chamber view showing the RV basal (RVD1) and mid-cavity (RVD2) dimensions and the RV longitudinal dimension (RVD3). Measurements were obtained at end-diastole. (b) Measurement of the RV end-diastolic area in the apical four-chamber view. The endocardial border is traced in the apical four-chamber views from the tricuspid annulus along the free RV wall to the apex, back to the tricuspid annulus, and along the interventricular septum. Care wastaken to enclose trabeculation, tricuspid leaflets, and chords in this area. (c) Measurement of the RV end-systolic area in the apical four-chamber view. The endocardial border is traced in apical four-chamber views from the tricuspid annulus along the free RV wall to the apex, back to the tricuspid annulus, along the interventricular septum. Care was taken to enclose trabeculation, tricuspid leaflets, and chords in this area

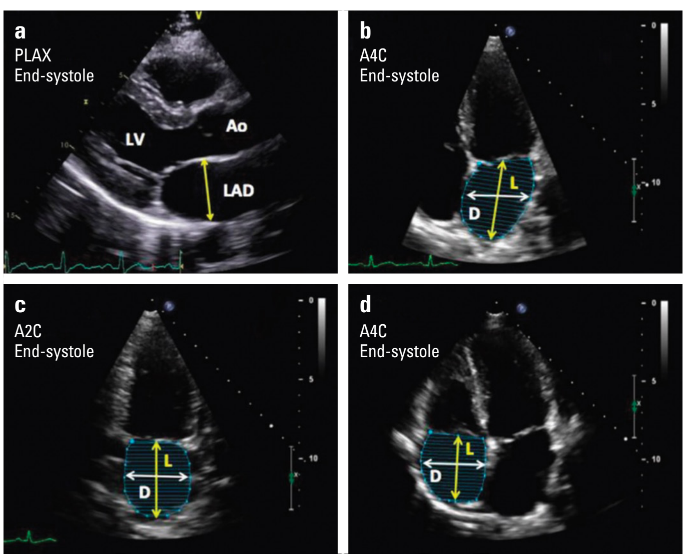

Figure 4. (a) Measurement of the left atrial diameter from the parasternal long-axis view at end-systole. Measurement is done from trailing-edge-to-leading-edge from the posterior aortic wall to the posterior aspect of the left atrial wall in a plane parallel to the mitral annulus. (b and c) Measurement of left atrial volume using Simpson's biplane method from the apical four-chamber (A4C) and apical two-chamber (A2C) views at ventricular end-systole (maximum LA size). The LA length (L) is measured perpendicular from the mid-point of the segment that unifies the hinge points of the mitral leaflets, up to the ceiling of the LA. The LA minor dimension (d) is represented by a white line from the lateral wall to the interatrial septum. Care wastaken to exclude the pulmonary veins while tracing the LA. (d) Measurement of the right atrial (RA) area end-systole from the parasternal four-chamber view. The right atrial major dimension (L) is represented by the yellow line from the tricuspid annulus plane center to the superior RA wall, and the RA minor dimension (d) is represented by the white line from the anterolateral wall to the interatrial septum.

and sent to the core laboratory. The images were evaluated by three experienced echocardiographers who were blinded to any patient data (M.Ö., A.K., Ö.C.). A total of 141 patients with poor image quality and/or inappropriate clinical examinations were excluded according to the predetermined protocol. Ultimately, 1154 healthy volunteers were included in the study.

The left ventricle (LV) mass was calculated from linear measurements that were obtained from parasternal views. LV mass was derived as:

LV mass (g)=0.8{1.04 [([LVEDD+IVS+PW]^3-LVEDD^3)]}+0.6

{LVM: left ventricular mass, 1.04: Specific gravity of muscle (g/mL), LVEDD: left ventricular end-diastolic dimension (cm), IVS: interventricular septal thickness (cm), PW: left ventricular posterior wall thickness (cm), 0.8–0.6: correction factors}

Statistical analysis

Statistical analysis was performed using SPSS (SPSS Inc., Chicago, IL, USA) software version 15. The variables were investigated using histograms, probability plots, and analytical methods (Kolmogorov-Smirnov) to determine whether they were normally distributed or not. Descriptive statistics included mean and standard deviation (SD) and 2 SD range. Categorical variables were reported as percentages. Continuous variables were compared using the Student's t-test and categorical variables were compared using the Chi-square test. The one-way analysis of variance test was used to compare continuous variables between three or more groups. Intra-observer and inter-observer variability was evaluated in 50 randomly selected subjects. Intraclass correlation coefficient with 95% confidence interval and the relative differences (means±SD) were reported overall. The Bland-Altman plot was drawn to obtain better insights into the data quality between two echocardiography operators. A p-value of <0.05 was considered statistically significant.

Ethics Committee

The Healthy Heart ECHO-TR Trial respects the ethical principles of conducting research on human subjects. The study protocol was approved by the Dokuz Eylül University Ethics Committee and written informed consent was given by all subjects.

Results

Demographic data

A total of 609 men (mean age: 34±11 years, from 18–83 years) and 545 women (mean age: 35±11 years, from 18–81 years) were included in the study. The body surface area, height, weight, and blood pressure of women were significantly lower than those of men. The basal demographic features of all the study populations are summarized in Table 1.

Left ventricular parameters

LV mass, dimensions, and volumes were higher in men as compared to women (145.4±33.1 g vs. 118.8±33.8 g for LV mass, 46.9±3.7 mm vs. 43.6±3.8 mm for LVEDD, 102±27.5 mL vs. 83.2±21.5 mL for LVED volume retrospectively, p<0.001 for all). The lower reference values (mean-2 SD) for the ejection fraction were 55.9% in men and 56.9% in women, whereas the values of 77.5 mL and 68.4 mL were observed for LV end-diastolic volume, and 26.2 mL and 22.2 mL for LV end-systolic volumes, respectively. Left ventricular end-diastolic and end-systolic diameters were 43.2/25.8 mm in men and 39.8/23.6 mm in women, respectively. Left ventricular parameters are summarized in Table 2.

The intraclass correlation coefficient was obtained and the Bland-Altman plot test was performed to gain better insights into the data quality between two echocardiography operators. In our study, the intraclass correlation coefficient value is 0.986 (95% CI: 0.975–0.992; p<0.001) (Fig. 5).

Right ventricular parameters

Right ventricular parameters were found to be smaller in women than in men (29.2±3.6 mm vs. 28.3±3.1 mm for RVOT-1, 17.9±3.2 cm^2 vs. 16.2±3.4 cm^2 for the RVED area, respectively, p<0.001 for all), and higher in the Eastern Anatolia and Black Sea regions. Right ventricular parameters are summarized in Table 3 and some regional differences are mentioned in Table 4.

Atrial parameters

Left and right atrial parameters were found to be higher in men than in women (p<0.001).The lower and upper reference values (mean±2 SD) for LA diameters were 23.2 and 40 mm (parasternal long-axis view), and 7.1 and 21.1 cm^2 for LA areas (apical four-chamber view), respectively. The lower and upper reference values for LA volumes (area-length) were 23.6–57.6 mL, right atrial areas were 7.7–18.5 cm^2 and RA volumes (area-

Table 1. Demographic characteristics of the population

Parameters	Total (n=1154)	Male (n=609)	Female (n=545)	*P*-value
Age (years)	34±10	34±11	35±11	0.342
Height (cm)	173±15	178±6.2	168±6.8	0.008
Weight (kg)	71±11	74.4±9.6	67.1±9.5	0.063
Body mass index (kg/m^2)	24±3	25.1±2.6	24.2±3.4	0.078
Body surface area, m^2	1.82±0.2	1.9±0.2	1.72±0.2	0.012
Systolic blood pressure (mm Hg)	115±12	117.4±11	113.3±12.1	0.105
Diastolic blood pressure (mm Hg)	71±8	73±8.4	71±9	0.242
Glycemia (mg/dL)	93±11	94±12	93±11	0.437
Hemoglobin (mg/dL)	14.3±1.5	14.9±1.3	13.3±1.3	0.194
Blood urea nitrogen	19.8±8.9	21,7±10.4	17.8±8.7	0.203
Creatinine (mg/dL)	0.89±0.1	0.87±0.16	0.72±0.15	0.284
MPV (fL)	9±1.3	9.1±1.3	8.87±1.3	0.639
Total cholesterol (mg/dL)	176±31	177±31	176±32	0.739
Triglyceride (mg/dL)	111±39	118±40	103±38	0.751
HDL (mg/dL)	47±11	45±10	51±12	0.001
LDL	108±35	108±28	107±29	0.178
Heart rate (beats/min)	76±31	74±8.5	76±9	0.163

HDL - high density lipoprotein, MPV - mean platelet volume, LDL - low density lipoprotein

Anatol J Cardiol 2019; 22: 262-70
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Table 2. Left ventricular chamber echocardiographic parameters

	Total (n=1154) Mean±SD	Total (n=1154) 2 SD range	Male (n=609) Mean±SD	Female (n=545) Mean±SD	*P*-value
Parasternal long-axis view					
IVS, mm	8.9±1.4	6.1-11.7	9.2±1.4	8.5±1.4	<0.001
PW, mm	8.5±1.4	5.7-11.3	8.8±1.4	8.2±1.4	<0.001
LVEDD, mm	45.4±4.1	37.2-53.6	46.9±3.7	43.6±3.8	<0.001
LVESD, mm	28.6±4	20.6-36.6	29.6±3.8	26.8±3.2	<0.001
Ascending aorta, mm	28.5±4.5	19.5-37.5	29.6±3.4	27±3.1	<0.001
LVOT, mm	20.1±2.2	15.7-24.5	20.9±2.2	19.4±2.2	<0.001
LV mass, g	132.7±36	60.7-204.7	145.4±33.1	118.8±33.8	<0.001
Apical four-chamber view					
LVED volume, mL	93.9±27	49.9-147.9	102±27.5	83.2±21.5	<0.001
LVES volume, mL	34.3±10	15.1-54.7	37.9±11.1	30.4±8.6	<0.001
LVEF, %	63.8±5.6	55.1-74.3	63.6±5.5	64.3±5	0.058
LVFS	39.1±6.8	25.7-51.6	39.1±7.1	39.3±6.6	<0.001
Apical two-chamber view					
LVED volume, mL	95.3±18	59.1-131.3	100±19.5	89.4±14.2	<0.001
LVES volume, mL	32.5±8.6	15.3-50.2	34.6±9	30.2±7.6	<0.001
LVEF, %	62.5±4.3	55.2-72.1	62±4.3	62.9±4.2	0.067
Normalized to BSA					
-Parasternal long-axis view					
LVEDD, mm/m^2	24.9±2.2	20.4-29.5	25.8±2	23.9±2.1	<0.001
LVOT, mm/m^2	11±1.2	8.6-13.5	11.5±1.2	10.6±1.2	<0.001
LV mass, g/m^2	72.9±19.8	33.3-112.5	79.9±18.2	65.3±18.5	<0.001
-Apical four-chamber view					
LVED volume, mL/m^2	51.6±14.8	27.4-81.3	56±15.1	45.7±11.8	<0.001
LVES volume, mL/m^2	18.8±5.5	8.3-30	20.8±6.1	16.7±4.7	<0.001
-Apical two-chamber view					
LVED volume, mL/m^2	52.4±9.9	32.4-72.1	54.9±10.7	49.1±7.8	<0.001
LVES volume, mL/m^2	17.8±4.7	8.4-27.6	19±4.9	16.5±4.2	<0.001

Mean±SD - Mean±standard deviation, 2SD range - 2 standard deviation, BSA - body surface area, LV - left ventricle, LVOT - left ventricle outflow tract, LVED - left ventricular end-diastolic, LVES - left ventricular end-systole, PW - posterior wall

length) were 21.6–48.8 mL. Atrial parameters were summarized in Table 5 and in Table 6.

Discussion

This study is the first to evaluate two-dimensional echocardiographic normal reference ranges for cardiac chamber quantification in Turkey and it aimed to obtain data over a wide range of ages and regions to perform this evaluation.

Echocardiography has become the outstanding cardiac imaging technique for the evaluation of cardiac structure and function. The definition of “abnormal” relies on the definition of “normal” ranges and needs determination of normal physiological variations that may arise from factors such as body size, gender, living at a high altitude, and ethnicity. Reference standards are commonly used in echocardiography to identify abnormal cardiac chamber dimensions, function, and ventricular mass in patients (1, 5, 7). This study adds to the growing discrepancy regarding ethnic-based reference limits and differences arising in patients living at a high altitude. These differences have been highlighted by the Echo Normal study, a meta-analysis of left heart reference ranges that was inclusive of a diverse world population (11). Ethnic variations in cardiac structural measures by echocardiography have a significant

Table 3. Right ventricular chamber echocardiographic parameters

	Total (n=1154) Mean±SD	Total (n=1154) 2 SD range	Male (n=609) Mean±SD	Female (n=545) Mean±SD	*P*-value
Parasternal long-axis view					
RVOT-1, mm	29±3.3	22.6-36.4	29.2±3.6	28.3±3.1	<0.001
Parasternal short-axis view					
RVOT-2, mm	28.2±3.6	21-35.6	29±3.8	27.3±3.2	<0.001
Apical four-chamber view					
RVED area, cm^2	17±3.3	10.4-23.6	17.9±3.2	16.2±3.4	<0.001
RVES area, cm^2	8.5±1.7	5-12.3	8.9±1.7	8.2±1.7	<0.001
FAC, %	49.8±4.7	37.7-60.2	49.9±4.7	49.8±4.7	<0.001
RV basal diameter, mm	34.2±3.4	27-41.4	35±3.6	33.4±3.1	<0.001
RV mid diameter, mm	26.3±4.2	17.9-35.2	27.5±4.1	25.1±3.9	<0.001
RV longitudinal diameter, mm	63.7±7.6	49.2-79.2	65.2±7.6	62.1±7.5	<0.001
Normalized to BSA					
-Parasternal short-axis view					
RVOT-2, mm/m^2	15.5±2	11.5-19.5	15.9±2	15±1.7	<0.001
-Apical four-chamber view					
RVED area, cm^2/m^2	9.5±1.8	5.7-13	9.8±1.7	8.9±1.9	<0.001
RVES area, cm^2/m^2	4.7±0.9	2.7-6.8	4.9±0.9	4.5±0.9	<0.001

Mean±SD - Mean±standard deviation, 2 SD range - 2 standard deviation, BSA - body surface area, RV - right ventricle, RVOT - right ventricle outflow tract, RVED – right ventricular end-diastolic, RVES - right ventricular end-systole, FAC - fractional area change

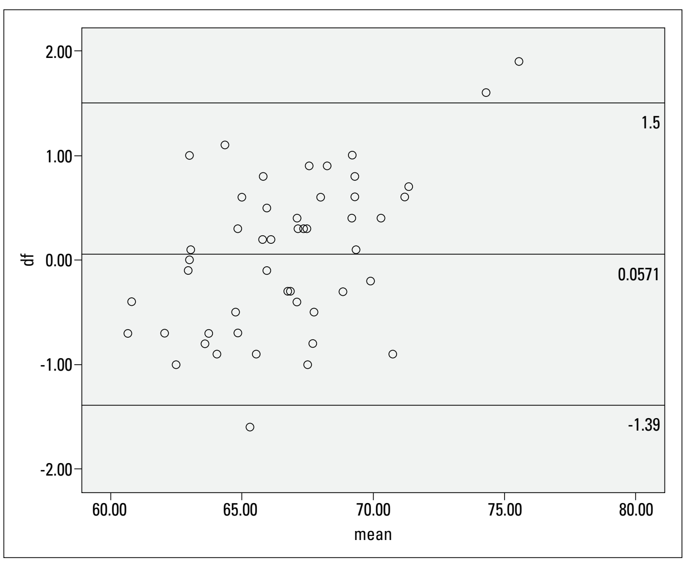

Figure 5. Intraclass correlation coefficient value is 0.986 (95% CI: 0.975–0.992; *P*<0.001)

impact on clinical decision-making. The American College of Cardiology, American Heart Association, and European Society of Cardiology guidelines for the management of valvular heart disease rely heavily on chamber quantification and suggest the use of various cut offs (12, 13). In the current study, the cutoff value for the left ventricular ejection fraction was chosen as 50%, according to the guidelines that mentioned the correct preserved ejection fraction.

The upper and lower reference limits were found to be higher in men as compared to women with age-related changes, highlighting the importance of applying age-gender-specific reference values for reliable identification of cardiac chambers enlargement and dysfunction, as previously shown in the NORRE study (7). Left ventricular ejection fraction was higher in females (64.3±5 vs. 63.6±5.5, p<0.58) and left ventricular volumes were higher in males (102±27.5 vs. 83.2±21.5, p<0.001). The ejection fraction percentages and left ventricular volumes measured in our study were higher than the volumes recorded in European and American populations (7, 13).

In current study, the comparison of the geographical regions demonstrated greater left heart chamber sizes in the western part of Turkey as compared to the East, whereas this was found to be opposite for right heart chamber sizes. However, there was no statistical difference between the left and right chamber sizes. These minor differences can occur due to the high altitude of these regions (above 1500 meters). Similar findings were also reported in a study authored by Yang et al. (14), who found that the diameters and thicknesses of the right ventricle (RV) were larger in Tibetan highlanders than in Han lowlanders [i.e., 30.0 mm (26.0–34.0 mm) vs. 28.6 mm (25.5–31.8 mm) for the basal right ventricular linear dimension]. They concluded that a small

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Table 4. Echocardiographic data of the study population in 7 geographical regions of Turkey

	Mediterranean region (n=163)	Eastern Anatolia region (n=128)	Aegean region (n=178)	Southeast Anatolia region (n=143)	Central Anatolia region (n=199)	Black Sea region (n=123)	Marmara region (n=220)	*P*-value
LVEDD, mm	46±4	46±3	45±4	46±3	45±4	45±3.4	44±4.5	0.543
LVESD, mm	30±4	29±3	28±3	30±4	27±3	27±2.7	27±3	0.138
IVS, mm	8.9±1.3	8.6±1.7	8.7±1.2	8.7±1	9±1.5	10±0.7	8.6±1.2	0.246
PW, mm	8.9±1.1	8.3±2	8.3±1.1	7.9±1	8.9±1.1	9.8±0.8	8±1.2	0.298
Ascending aorta, mm	29±3	28±3	28±3	28±3	28±3	28±2.3	28±3	0.652
LA diameter, mm	33±3	30±3	31±4	31±3.5	32±3	31±3	31±4	0.173
RVED area, cm^2	16±3	18±2.5	17±3	15±3	15±3	19±2	16±3	0.126
RVES area, cm^2	8.7±1.6	9±1.3	8.9±1.2	7.2±1.9	7.9±1.8	9.2±1	8.2±1.5	0.154
RA major diameter, mm	42±3	40±4	44±4	43±4	42±5	43±5	43±4	0.275

LVEDD - left ventricular end-diastolic dimension, LVESD - left ventricular end-systole dimension, RVED - right ventricular end-diastolic, RVES - right ventricular end-systole, PW - posterior wall, LA - left atrial, RA - right atrial

Table 5. Left atrial chamber echocardiographic parameters

	Total (n=1154) Mean±SD	Total (n=1154) 2 SD range	Male (n=609) Mean±SD	Female (n=545) Mean±SD	*P*-value
Parasternal long-axis view					
LA diameter, mm	31.6±4.2	25.4-40.2	32.8±3.8	30.5±3.8	<0.001
Apical four-chamber view					
LA minor diameter, mm	33.9±5.1	27.6-43.4	34.1±5.4	33.9±4.6	<0.001
LA major diameter, mm	43.5±6.4	34-53.2	43.8±6.4	43.3±6.4	<0.001
LA area, cm^2	15.1±4	10.6-20.2	15.4±4.1	14.7±3.9	<0.001
LA volume, mL	40.6±8.5	20.9-62.8	41.8±9	39.4±7.9	<0.001
Apical two-chamber view					
LA minor diameter, mm	32.8±3.7	27.6-40.1	33.5±3.8	32.2±3.6	<0.001
LA major diameter, mm	47.1±4.2	37.9-55.9	47.7±4.5	46.6±3.8	<0.001
LA area, cm^2	15.4±2.3	10.6-19.2	15.7±2.5	15.1±2.2	<0.001
LA volume, mL	48.1±3.7	28.7-68.4	48.6±4	47.6±3.4	<0.001
Normalized to BSA					
-Parasternal long-axis view					
LA diameter, mm/m^2	17.3±2.3	13.9-22.1	18±2.1	16.7±2.1	<0.001
-Apical four-chamber view					
LA minor diameter, mm/m^2	18.6±2.8	15.1-23.8	18.7±2.9	18.6±2.5	<0.001
LA major diameter, mm/m^2	23.9±3.5	18.6-29.2	24±3.5	23.7±3.5	0.009
LA area, cm^2/m^2	8.2±2.2	5.8-11	8,4±2,2	8±2.1	0.01
LA volume, mL/m^2	22.3±4.7	11.5-34.5	22,9±4,9	21.6±4.3	0.549
-Apical two-chamber view					
LA minor diameter, mm/m^2	18±2	15.2-22	18.4±2	17.6±1.9	0.152
LA major diameter, mm/m^2	25.9±2.3	20.8-30.7	26.2±2.5	25.6±2.1	0.092
LA area, cm^2/m^2	8.5±1.3	5.8-10.5	8.6±1.4	8.3±1.2	0.391
LA volume, mL/m^2	26.4±2	15.7-37.5	26.7±2.2	26.1±1.8	0.257

Mean±SD - Mean±standard deviation, 2 SD range - 2 standard deviation, BSA - body surface area, LA - left atrial

Table 6. Right atrial chamber echocardiographic parameters

	Total (n=1154) Mean±SD	Total (n=1154) 2 SD range	Male (n=609) Mean±SD	Female (n=545) Mean±SD	*P*-value
Apical two-chamber view					
RA minor diameter, mm	33.5±4.3	24.8-42.1	34.8±4.4	32.1±3.8	<0.001
RA major diameter, mm	42.7±4.9	33.9-50.3	43.7±5	41.7±4.7	<0.001
RA area, cm^2	13±2.7	7.3-17.9	13.6±2.6	12.1±2.5	<0.001
RA volume, mL	35.2±6.8	17.1-59.3	37.2±8.3	33.1±4	<0.001
Normalized to BSA					
-Apical two-chamber view					
RA minor diameter, mm/m^2	18.4±2.3	13.6-23.1	19.1±2.4	17.6±2	0.178
RA major diameter, mm/m^2	23.5±2.7	18.6-27.6	24±2.7	22.9±2.6	0.029
RA area, cm^2/m^2	7.1±1.5	4-9.8	7.5±1.4	6.6±1.4	0.014
RA volume, mL/m^2	19.3±3.7	9.4-32.5	20.4±4.5	18.1±2.2	0.007

Mean±SD - Mean±standard deviation, 2 SD range - 2 standard deviation, BSA - body surface area, RA - right atrial

LV and a large RV might be related to hypoxia exposure at high altitudes (14).

Study limitations

There are several limitations to this study. Firstly, the study findings pertain only to Turkish individuals. Thus, conclusions concerning other ethnic populations could not be drawn. Furthermore, the possibility of subclinical coronary artery disease that could influence the values of systolic and diastolic parameters could not be excluded in all healthy subjects.

Secondly, the number of participants from the Black Sea and Southeast Anatolia regions were relatively low (3% and 15%, respectively) as compared to other geographical areas, making it difficult to generate reference values for these subpopulations.

Conclusion

In conclusion, we evaluated the distributions of various echocardiographic chamber parameters in a large cohort of Turkish individuals. Most of the parameters were comparable with the European (7), American (9), Japanese (15), Egyptian (16), and Hispanic/Latino populations (17). However, left ventricular dimensions were found to be higher than all other population-based studies, whereas left atrial and right heart dimensions were found to be smaller, although this is statistically insignificant. Consistent with the findings of previous studies, right ventricular parameters were found to be smaller in women than in men in the current study, however, these values were lower than those reported in European and American studies, as opposed to left ventricular diameters that were found to be larger in our study. We feel that these echocardiographic findings of Turkish individuals may provide essential data for cardiologists during clinical evaluation of cardiac chambers and in future research studies.

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Anatol J Cardiol 2019; 22: 262-70
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