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Original Article

A study on normal reference values of echocardiographic chamber dimensions in young eastern Indian adults

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ABSTRACT

Objective: Various studies have shown racial differences in adult cardiac chamber measurements by echocardiography. There is lack of any large scale data from India regarding the echocardiographic chamber measurements in cardiologically healthy individuals. In this study we present the normal reference values of echocardiographic chamber dimensions in young eastern Indian adults and compare it with the data in present guidelines and recent studies involving Indian subjects.

Methods: This study was performed on 1377 healthy adults aged 18–35 years. Standard transthoracic echocardiographies were performed to obtain basic measurements. All measurements were indexed to body surface area.

Results: The mean maximal aortic valve cusp separation (ACS) and indexed ACS were significantly more in females ($p = 0.002$, $p = 0.03$). Mean left ventricular (LV) ejection fraction (LVEF) and LV fractional shortening were marginally higher in females. Upper normal reference limit of LV end diastolic dimension (LVEdD) is slightly more for males. Comparing to ASE data, LVEdD, LV end systolic dimension, LV end diastolic volume, indexed LV end systolic volume, left atrial anteroposterior dimension, aortic root dimension and right ventricle outflow diameter were significantly lower in study population while LVEF was significantly higher ($p < 0.0001$).

Conclusion: The study reconfirms that Indian subjects have smaller cardiac chamber measurements compared to western population where as LVEF is higher in the Indian population and also demonstrates the wide variation of normal echocardiographic measurements within Indian subcontinent. No previous data from eastern India makes this research a singular experience.

1. Introduction

Echocardiography is the basic, most important and most commonly used instrument for assessing cardiac structure and function.[1] Management decisions of many cardiac as well as non-cardiac patients depend on echocardiography results. The normal ranges of echocardiographic parameters vary according to age, body surface area (BSA), gender and race.[2,3] Various studies have shown racial differences in adult cardiac chamber measurements by echocardiography.[2,4] Normal ranges for echocardiographic parameters have been published in many guidelines. The European Association of Cardiovascular Imaging (EACVI) and the American Society of Echocardiography (ASE) published the latest recommendations for echocardiographic chamber measurements in 2015 which was endorsed by several echocardiography societies around the globe.[1] A pilot study of 100 healthy volunteers from India was conducted by Bansal et al which showed Indian subjects have some differences in cardiac chamber quantifications as compared to the western populations.[5] Till date no study has been done from eastern India regarding normal echocardiographic chamber quantifications of subjects from this part of the country. In fact there is lack of any nationally representative sizeable database data from Indian sub-continent which gives an idea regarding the echocardiographic chamber measurements in cardiologically healthy individuals from this part of the world. Therefore it is of scientific

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importance to establish echocardiographic chamber dimensions in Indian subjects free of cardiovascular diseases and to find whether there is any difference from the existing guidelines. In this study we present the normal reference values of echocardiographic chamber dimensions in young eastern Indian adults and compare it with the data in present guidelines and recent studies involving Indian subjects.

2. Methods

2.1. Subject recruitment

This cross sectional, observational, single hospital based study was conducted on cardiologically healthy adult subjects aged 18–35 years who were relatives, caregivers or accompanying persons of patients either admitted or attending the outdoor clinic of any department of a tertiary care hospital in eastern India. Subject recruitment process has been depicted in Fig. 1. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and later revisions. Informed consent was obtained from all patients for being included in the study. The study was approved by the institutional review board.

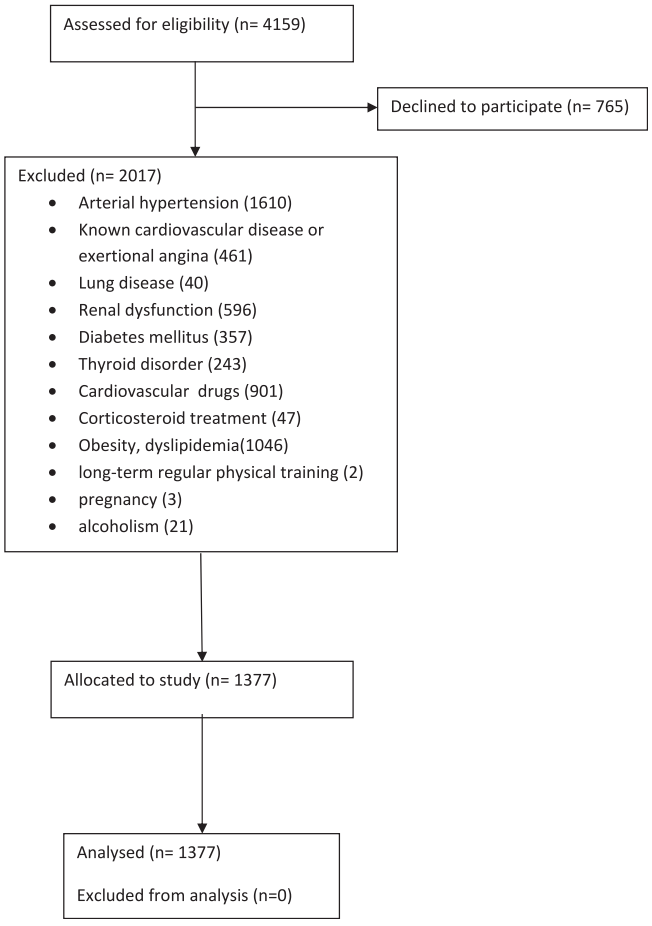

Fig. 1. Flow chart showing subject recruitment pattern.

2.2. Echocardiography

Trans-thoracic echocardiographic studies were done using Vivid S5 machines with an M3S matrix array probe with a frequency range from 1.7 to 3.2 MHz (GE Vingmed, Horten, Norway) by a single experienced cardiologist. Each echocardiography study was associated with machine integrated ECG recording. All subjects were studied in the left lateral decubitus position with normal respiration. Left atrial anteroposterior diameters (LAd) were measured using M-mode on parasternal long axis view at end systole. Aortic root diameters (at maximal diameter of sinus of Valsalva) (Ao) were measured from the same view. 2D guided M-mode acquisition was used to measure left ventricular (LV) dimensions from leading edge of the septal endocardium to the leading edge of posterior wall endocardium as per the recent guidelines.[1] Similar leading edge to leading edge convention was used for LA and right ventricular outflow dimension in end-diastole (RVEdD) measurement. Modified Devereux formula was used to measure LV mass (LVm) from M-mode recordings.[6] LA end systolic volume (LAv), LV end systolic volume (LVESV), LV end diastolic volume (LVEDV) and LV ejection fraction (LVEF) were measured using the biplane Simpson rule. Largest end-diastolic diameter in the outflow tract of the right ventricle was taken as the RVEdD. Average of three measurements was taken for each parameter. Mosteller formula was used to calculate body surface area (BSA).[7] Indexed measurements were derived by dividing all measurements by BSA.

2.3. Statistical analysis

The mean ± 2 standard deviation (SD) rule was used to propose normal echocardiographic reference values from the results acquired in this study. This is based on the assumption that this range contains 95% of values of a reference group, and the sample value can be greater than upper limit or lesser than lower limit in 2.5% of the time respectively, whatever might be the distribution of these values.[8]

For statistical analysis data were analyzed by SPSS (version 24.0; SPSS Inc., Chicago, IL, USA) and GraphPad Prism version 5. Summarization of data was done as mean and standard deviation for numerical variables and count and percentages for categorical variables. Two-sample t-test for a difference in mean was used for independent samples or unpaired samples. Paired t-tests were a form of blocking and had greater power than unpaired tests. A chi-squared test ($\chi 2$ test) was a statistical hypothesis test wherein the sampling distribution of the test statistic is a chi-squared distribution when the null hypothesis is true. Chi-square test or Fischer's exact test, was used to compare unpaired proportions as appropriate. Wilcoxon-Mann-Whitney test was used to compare the normal mean echocardiographic measurements of the results of this study with ASE/ASCVI guideline.p-value ≤ 0.05 was considered for statistically significant.

3. Results

3.1. Demography

In this study number of men (56.1%) was more than women (43.9%). Mean age of the total study population was 26.55 ± 5.55 years and the mean body surface area (BSA) was 1.38 ± 0.17 m^2. The mean age of the men was 26.71 ± 5.54 years while it was 26.34 ± 5.55 years in women. Mean BSA was 1.38 ± 0.18 m^2 in men and 1.37 ± 0.15 m^2 in the women counterparts. Difference of age and BSA between genders was not statistically significant.

Table 1
Comparing mean values of echocardiographic chamber dimensions of subjects according to gender.

Parameters (mean ± SD)	Men (n = 773)	Women (n = 604)	Total (n = 1377)	p-value	
	Absolute measurements				Absolute measurements
LVEdD	43.6 ± 2.0	43.6 ± 1.9	43.6 ± 1.9	0.95	
LVEsD	27.7 ± 3.1	27.7 ± 3.1	27.7 ± 3.1	0.79	
IVSd	9.0 ± 0.7	9.0 ± 0.7	9.0 ± 0.7	0.49	
LVPWd	8.3 ± 1.0	8.2 ± 1.0	8.2 ± 1.0	0.25	
LVEF	68.7 ± 4.8	69.1 ± 5.5	68.9 ± 5.1	0.09	
LVFS	34.3 ± 2.4	34.6 ± 2.8	34.4 ± 2.6	0.09	
LVm	133.3 ± 18.8	133.4 ± 19.1	133.3 ± 18.9	0.93	
LVEDV	74.6 ± 5.4	74.5 ± 4.9	74.6 ± 5.2	0.72	
LVESV	31.1 ± 2.9	28.0 ± 2.5	29.6 ± 2.7	<0.0001	
LAd	24.5 ± 3.6	24.5 ± 3.7	24.5 ± 3.7	0.76	
LAv	26.9 ± 7.9	26.9 ± 8.1	26.9 ± 8.0	1.00	
ACS	17.0 ± 1.7	17.3 ± 1.3	17.2 ± 1.6	0.002	
Ao	27.9 ± 2.5	28.1 ± 2.5	28.0 ± 2.5	0.37	
RVEdD	17.4 ± 3.0	17.4 ± 2.7	17.4 ± 2.9	0.76	
	Indexed measurements				Indexed measurements
ILVEdD	32.1 ± 4.3	32.1 ± 3.9	32.1 ± 4.2	0.78	
ILVEsD	20.4 ± 3.5	20.4 ± 3.1	20.4 ± 3.3	0.82	
IIVSd	6.64 ± 1.0	6.67 ± 0.9	6.7 ± 0.9	0.66	
ILVPWd	6.1 ± 1.1	6.1 ± 1.1	6.1 ± 1.1	0.56	
ILVm	98.1 ± 19.3	98.3 ± 18.3	98.2 ± 18.8	0.85	
ILVEDV	54.9 ± 6.0	54.8 ± 5.6	54.9 ± 5.8	0.75	
ILVESV	22.9 ± 3.4	20.6 ± 3.1	21.8 ± 3.3	<0.0001	
ILAd	18.1 ± 3.7	18.0 ± 3.3	18.0 ± 3.5	0.81	
ILAv	19.9 ± 8.2	19.8 ± 8.5	19.8 ± 8.4	0.83	
IACS	12.5 ± 1.9	12.7 ± 1.6	12.6 ± 1.8	0.03	
IAo	20.6 ± 3.3	20.7 ± 3.0	20.6 ± 3.2	0.51	
IRVEdD	12.8 ± 2.7	12.9 ± 2.5	12.8 ± 2.6	0.62	

ACS- Maximal aortic valve cusp separation, mm; Ao- Aortic root dimension, mm; iACS- Indexed maximal aortic valve cusp separation, mm/m^2; iAo- Indexed aortic root dimension, mm/m^2; iIVSD- Indexed septal thickness at end diastole, mm/m^2; iLAd- Indexed left atrial anteroposterior dimension, mm/m^2; iLAv- Indexed left atrial volume, mL/m^2; iLVEDd- Indexed left ventricular end diastolic dimension, mm/m^2; iLVEDV- Indexed left ventricular end diastolic volume, mL/m^2; iLVEsD- Indexed left ventricular end systolic dimension, mm/m^2; iLVESV- Indexed left ventricular end systolic volume, mL/m2; iLVm- Indexed left ventricular mass, g/m^2; iLVPWd- Indexed posterior wall thickness at end diastole, mm/m^2; iRVEdD- Indexed right ventricle outflow diameter at end diastole, mm/m^2; IVSd- Septal thickness at end diastole, mm; LAd- Left atrial anteroposterior dimension, mm; LAv- Left atrial volume, mL; LVEdD-left ventricular end diastolic dimension, mm; LVEDV- left ventricular end diastolic volume, mL; LVEF- left ventricular ejection fraction, %; LVEsD-left ventricular end systolic dimension, mm; LVESV- left ventricular end systolic volume, mL; LVFS- left ventricular fractional shortening, %; LVm-left ventricular mass, g; LVPWd- Posterior wall thickness at end diastole, mm; RVEdD- Right ventricle outflow diameter at end diastole, mm.

3.2. Means of chamber dimensions and gender wise comparison

Absolute and indexed measurements of means of chamber dimensions are presented in Table 1. Table 1 also shows the comparison of means according to genders. There was no significant difference in absolute echocardiographic parameters except in mean maximal aortic valve cusp separation (ACS) which was significantly more in females ($p = 0.002$) and mean LVESV which was significantly more in male subjects ($p < 0.0001$). Mean LVEF and LV fractional shortening (LVFS) were marginally higher in females. Similarly indexed measurements were not much difference among men and women except mean indexed ACS (iACS) which was more in females ($p = 0.03$) and mean indexed LVESV (iLVESV) which was significantly more in men subjects ($p < 0.0001$).

3.3. Normal reference range

Table 2 presents the absolute and indexed normal reference ranges of echocardiographic chamber dimensions in young eastern Indian adults as per this study. Upper normal reference limit (UNRL) OF LV end diastolic dimension (LVEdD), LVEDV, LVESV, indexed LVEDV (iLVEDV), iLVESV were slightly more for men, while normal reference ranges of LV end systolic dimension (LVEsD), septal thickness at end diastole (IVSd), posterior wall thickness at end diastole (LVPWd), LAd, LAv and Ao were same for both genders. UNRL of LVEF, LVFS, LVm and lower normal reference limit (LNRL) of ACS and RVEdD were slightly higher in women.

3.4. Comparison of normal echocardiographic measurements with present guidelines

Table 3A shows the reference values for echocardiographic measurements in young eastern Indian adults in comparison to ASE and EACVI measurements. The absolute measurements showed LVEdD, LVEsD, LVEDV, LVESV, LAd, Ao were lower in the study population in both genders. IVSd, LVPWd were close to the ASE/AECVI data. RVEdD was also lower in study population compared to the ASE/EACVI data. LVEF was higher in the study population. Strikingly LVm was lower in men but more in women in this study compared to the ASE/EACVI measurements. Indexed measurements were slightly more in the study population which can be attributed to the lower BSA in the study population compared to the population studied by Lang et al.[1)] UNRL of indexed LA volume (iLAv) was also slightly more in the study population.

Fig. 2 and Table 3B shows the difference in the mean of echocardiographic parameters between the study population and the population in the ASE/EACVI data (comparison was done only on those parameters whose mean, SD and sample size were available in the ASE/EACVI guideline documents and supplements).[1] Comparing to ASE data, LVEdD, LVEsD, LVEDV, iLVESV, LAd, Ao and RVEdD were significantly lower in study population while LVEF

Table 2
Normal reference ranges of echocardiographic chamber dimensions in young eastern Indian adults.

Parameters	Whole sample (n = 1377)	Men (n = 773)	Women (n = 604)
Absolute measurements			
LVEdD	40–47	40–48	40–47
LVEsD	22–34	22–34	22–34
IVSd	8–10	8–10	8–10
LVPWd	6–10	6–10	6–10
LVEF	59–79	59–78	58–80
LVFS	29–40	30–39	29–40
LVm	96–171	95–171	95–172
LVEDV	64–85	64–85	65–84
LVESV	24–35	25–37	23–33
LAd	17–32	17–32	17–32
LAv	11–43	11–43	11–43
ACS	14–20	14–20	15–20
Ao	23–33	23–33	23–33
RVEdD	12–23	11–23	13–23
Indexed measurements			
iLVEdD	24–41	24–41	24–40
iLVEsD	14–27	16–27	14–27
iIVSd	5–9	5–9	5–9
iLVPWd	4–8	4–8	4–8
iLVm	61–136	61–137	62–135
iLVEDV	43–67	43–67	43–66
iLVESV	15–28	16–30	14–27
iLAd	11–25	11–26	11–25
iLAv	3–37	4–36	3–37
iACS	9–16	9–16	10–16
iAo	14–27	14–27	15–27
iRVEdD	8–18	7–18	8–18

ACS- Maximal aortic valve cusp separation, mm; Ao- Aortic root dimension, mm; iACS- Indexed maximal aortic valve cusp separation, mm/m^2; iAo- Indexed aortic root dimension, mm/m^2; iIVSD- Indexed septal thickness at end diastole, mm/m^2; iLAd- Indexed left atrial anteroposterior dimension, mm/m^2; iLAv- Indexed left atrial volume, mL/m^2; iLVEDd- Indexed left ventricular end diastolic dimension, mm/m^2; iLVEDV- Indexed left ventricular end diastolic volume, mL/m^2; iLVEsD- Indexed left ventricular end systolic dimension, mm/m^2; iLVESV- Indexed left ventricular end systolic volume, mL/m^2; iLVm- Indexed left ventricular mass, g/m^2; iLVPWd- Indexed posterior wall thickness at end diastole, mm/m^2; iRVEdD- Indexed right ventricle outflow diameter at end diastole, mm/m^2; IVSd- Septal thickness at end diastole, mm; LAd- Left atrial anteroposterior dimension, mm; LAv- left atrial volume, mL; LVEdD-left ventricular end diastolic dimension, mm; LVEDV- left ventricular end diastolic volume, mL; LVEF- left ventricular ejection fraction, %; LVEsD-left ventricular end systolic dimension, mm; LVESV- left ventricular end systolic volume, mL; LVFS- left ventricular fractional shortening, %; LVm-left ventricular mass, g; LVPWd- Posterior wall thickness at end diastole, mm; RVEdD- Right ventricle outflow diameter at end diastole, mm.

was significantly higher ($p < 0.0001$). iLVEDV was comparable among the men ($p = 0.10$) whereas LVESV was comparable among women ($p = 1.00$).

3.5. Comparison of normal echocardiographic measurements with contemporary studies involving Indian subjects

Comparison of reference ranges of echocardiographic measurements with World Alliance Societies of Echocardiography (WASE) study has been presented in Table 4A.[9] LNRL of LVEdD, IVSd, LVm, LVEDV, LVESV and all indexed measurements were higher in the study population. UNRL of LVEF, LVm and all indexed measurements were more in this study while UNRL of LVEdD, LVEsD, IVSd and LVPWd were comparable.

Table 4B demonstrates the comparison of mean echocardiographic measurements in young eastern Indian adults with measurements by Sullere et al.[10] All absolute measurements were significantly lower in this study whereas indexed measurements were significantly higher except indexed left ventricular mass (iLVm) irrespective of gender. LVEF was significantly higher in this study compared to Sullere et al.

4. Discussion

4.1. Demography

In this study, standard basic 2 d and M-mode echocardiographic measurements were performed in a large number of young, cardiologically healthy eastern Indian adults. There was adequate representation from both genders, though number of men was higher.

4.2. Echocardiographic measurements

Generally reference ranges were similar in both genders with a nonsignificant higher LVEdD in men and slightly higher LVEF and LVFS in women. Mean ACS was significantly higher in women which could have been a stray finding or may have some unknown significance and needs further imaging and research. Indexed measurements did not show marked difference among genders except mean iACS.

4.3. Effect of ethnicity on echocardiographic measurements

Ethnicity is an important factor on which cardiac chamber dimensions differ.[1,2,11,12] Several therapeutic decisions depend on proper assessment of cardiac chamber measurements and function and normal reference values are important to avoid putting patients with normal measurements to abnormal category and vice versa.[13–15] Therefore it is strongly recommended that ethnicity specific reference values are used for interpretation of echocardiography results. In this study mean ± 2 standard deviation rule was implemented in producing the reference which ensured inclusion of approximately 95% of the subjects.

4.4. Absolute echocardiographic measurements

Absolute reference values are still widely used despite the well-developed concept of indexing because whether to index with height, weight or BSA still remains controversial.[1,16,17] In the current study LVEdD is slightly more for men, while LVEF, LVFS, LVm are slightly higher in women. The cause for significantly increased mean ACS and iACS in women needs introspection.

4.5. Indexed echocardiographic measurements

Gender, height, weight and age significantly affect the normal heart dimensions and function and hence the need for gender based and indexed measurements.[3] In this study mean BSA was slightly lower in women but no significant difference was noted in indexed measurements among genders except mean iACS.

4.6. Comparison of normal echocardiographic measurements with present guidelines

The comparison between proposed reference values with those outlined in the 2015 recommendations of ASE and EACVI further confirms the need for separate echocardiographic reference ranges for population of this part of the world as depicted in Tables 3 and 4.[1] The significant difference in certain parameters may be

Table 3
A. Comparison of range of echocardiographic measurements in young eastern Indian adults with ASE/EACVI measurements and B. Comparison of mean of echocardiographic measurements in young eastern Indian adults with ASE and EACVI measurements.

A. Parameters (Range)	Young eastern Indian adults		ASE/EACVI[1)]	
	Men (n = 773)	Women (n = 604)	Men	Women
Absolute measurements				
LVEdD	40–48	40–47	42–58	38–52
LVEsD	22–34	22–34	25–39	21–35
IVSd	8–10	8–10	6–10	6–9
LVPWd	6–10	6–10	6–10	6–9
LVEF	59–78	58–80	52–72	54–74
LVm	95–171	95–172	88–224	67–162
LVEDV	64–85	65–84	62–150	46–106
LVESV	25–37	23–33	21–61	14–42
LAd	17–32	17–32	30–40	27–38
Ao	23–33	23–33	28–40	24–36
Indexed measurements				
ILVEdD	24–41	24–40	22–30	23–31
ILVEsD	16–27	14–27	13–21	13–21
ILVm	61–137	62–135	49–115	43–95
ILVEDV	43–67	43–66	34–74	29–61
ILVESV	16–30	14–27	11–31	8–24
ILAd	11–26	11–25	15–23	15–23
ILAv	4–36	3–37	16–34	16–34
IAo	14–27	15–27	13–21	14–22

B. Parameters (mean ± SD)	Gender	Study population	ASE/EACVI	p value
Absolute measurements				
	Men	43.6 ± 2.0 (n = 773)	50.2 ± 4.1 (n = 502)	p < 0.0001
LVEdD	women	43.6 ± 1.9 (n = 604)	45.0 ± 3.6 (n = 769)	p < 0.0001
	men	27.7 ± 3.1 (n = 773)	32.4 ± 3.7 (n = 389)	p < 0.0001
LVEsD	women	27.7 ± 3.1 (n = 604)	28.2 ± 3.3 (n = 630)	p = 0.006
	men	74.6 ± 5.4 (n = 773)	106 ± 22 (n = 201)	p < 0.0001
LVEDV	women	74.5 ± 4.9 (n = 604)	76 ± 15 (n = 319)	p = 0.03
	men	31.1 ± 2.9 (n = 773)	41 ± 10 (n = 201)	p < 0.0001
LVESV	women	28.0 ± 2.5 (n = 604)	28 ± 7 (n = 319)	p = 1.0
	men	68.7 ± 4.8 (n = 773)	62.0 ± 5.0 (n = 201)	p < 0.0001
LVEF	women	69.1 ± 5.5 (n = 604)	64.0 ± 5.0 (n = 319)	p < 0.0001
Indexed measurements				
	men	54.9 ± 6.0 (n = 773)	54 ± 10 (n = 201)	p = 0.1
iLVEDV	women	54.8 ± 5.6 (n = 604)	45 ± 8 (n = 319)	p < 0.0001
	men	22.9 ± 3.4 (n = 773)	21 ± 5 (n = 201)	p < 0.0001
iLVESV	women	20.6 ± 3.1 (n = 604)	16 ± 4 (n = 319)	p < 0.0001
RVEdD	total	17.4 ± 2.9 (n = 1377)	25 ± 2.5 (n = 380)	p < 0.0001

Ao- Aortic root dimension, mm; ASE- American Society of Echocardiography; EACVI- European Association of Cardiovascular Imaging; iACS- Indexed maximal aortic valve cusp separation, mm/m^2; iAo- Indexed aortic root dimension, mm/m^2; iLAd- Indexed left atrial anteroposterior dimension, mm/m^2; iLAv- Indexed left atrial volume, mL/m^2; iLVEDd- Indexed left ventricular end diastolic dimension, mm/m^2; iLVEDV- Indexed left ventricular end diastolic volume, mL/m^2; iLVEsD- Indexed left ventricular end systolic dimension, mm/m^2; iLVESV- Indexed left ventricular end systolic volume, mL/m^2; iLVm- Indexed left ventricular mass, g/m^2; IVSd- Septal thickness at end diastole, mm; LAd- Left atrial anteroposterior dimension, mm; LVEdD-left ventricular end diastolic dimension, mm; LVEDV- left ventricular end diastolic volume, mL; LVEF- left ventricular ejection fraction, %; LVEsD-left ventricular end systolic dimension, mm; LVESV- left ventricular end systolic volume, mL; LVm-left ventricular mass, g; LVPWd- Posterior wall thickness at end diastole, mm; RVEdD- Right ventricle outflow diameter at end diastole, mm.

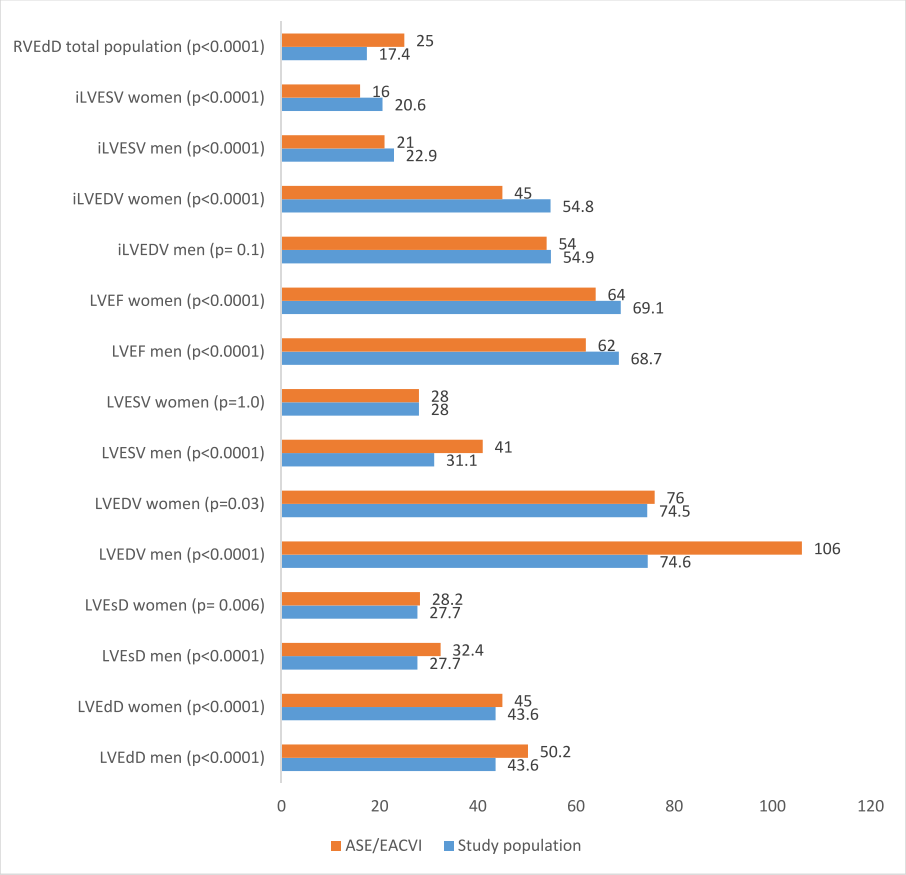

Fig. 2. Comparison of mean of echocardiographic measurements in young eastern Indian adults with ASE and EACVI measurements.

attributable to difference in BSA though further research is needed to identify the reason behind such difference.

4.7. Indian normal echocardiographic reference values

Studies have already shown there is disparity of echocardiographic parameters in Indians and western population. Thus the need of Indian normal reference values is paramount but no such guideline exist because the previous studies were either old with non-contemporary ways of measurements or included only nonresident Indians or had small sample size.[5,18–21] Choi JO et al and Yao GH et al have already presented the normal echocardiographic measurements of Korean and Chinese population respectively in three separate studies.[22–24] Prajapati et al have presented the normal echocardiographic parameters of a small Nepalese population.[25] Variations in LV size and function among race and nationalities were studied in the WASE study but in it Indian population was represented by only 126 subjects from south India and 101 subjects from north India.[9] Moreover only left ventricular parameters were studied in the WASE study. Sullere et al presented the data of 707 subjects from a single center from central India.[10] This is the first study reporting normative echocardiographic values from eastern India and the largest Indian sample studied till date for the same. The wide spectrum of data among these contemporary studies involving Indian subjects re-asserts the influence of race, ethnicity, heredity, lifestyle and BSA on echocardiographic parameters even within a single country. Thus there remains a requirement of a nationally representative sizeable database from which the normal reference values for Indian population can be achieved.

5. Limitations

The limitation of this study firstly was the omission of measurement of detailed RV dimensions and function assessment, doppler parameters since only the basic standard 2D and M-mode measurements were studied which are commonly reported in routine echocardiographies in this centre. M-mode has its limitations because of poor alignment in many casesand hence, there has been a major shift towards using 2D for obtaining various echocardiographic measurements. In most of the echo labs now-a-days, M-mode measurements have largely been given up; so, the data reported using M-mode will not be applicable in those situations. Secondly, though the study was done in a large volume tertiary care centre of Eastern India which caters to a large number of patients from West Bengal and other adjacent states of Eastern India and the study sample was sizeable, still it was a single centre based study. Usually, there are great differences in cardiac dimensions between men and women. This is regardless of ethnicity, region, and how much they are physically trained. In this study, we found no significant gender difference between cardiac dimensions, suggesting that the female population in this study had higher BSA for ordinary women. Further research is needed to verify this part of the data. Subjects from the present study are relatively young, and while comparing with ASE and EACVI reference value, age matching could not be done due to lack of required age related data in the ASE and EACVI guideline documents and supplements. Lastly, the

Table 4
A. Comparison of reference range of echocardiographic measurements in young eastern Indian adults with WASE study measurements and B. Comparison of mean of echocardiographic measurements in young eastern Indian adults with measurements by Sullere et al.

A.Parameters (Range)	Young eastern Indian adults		WASE study		Indian population of WASE study	
	Men (n = 773)	Women (n = 604)	Men	Women	Men	Women
Absolute measurements						
LVEdD	40–48	40–47	36–56	33–51	34–52	32–49
LVEsD	22–34	22–34	22–37	21–34	22–34	20–32
IVSd	8–10	8–10	6–12	5–10	5–11	5–10
LVPWd	6–10	6–10	6–11	5–10	6–11	5–10
LVEF	59–78	58–80	57–68	58–69	58–69	58–68
LVm	95–171	95–172	74–204	55–148	64–169	48–125
LVEDV	64–85	65–84	61–165	47–122	47–113	40–91
LVESV	25–37	23–33	21–65	17–47	18–46	14–35
Indexed measurements						
ILVEdD	24–41	24–40	19–30	20–31	18–31	20–32
ILVEsD	16–27	14–27	12–20	12–21	12–20	12–21
ILVm	61–137	62–135	42–101	36–85	40–88	37–78
ILVEDV	43–67	43–66	34–80	31–70	29–62	26–58
ILVESV	16–30	14–27	12–32	11–28	10–24	9–22

B. Parameters (mean ± SD)	Young eastern Indian adults	Sullere et al		Young eastern Indian adults	Sullere et al	
	Men (n = 773)	Men (n = 444)	p- value	Women (n = 604)	Women (n = 263)	p- value
Absolute measurements						
LVEdD	43.6 ± 2.0	47.2 ± 4.0	<0.0001	43.6 ± 1.9	44.4 ± 4.3	0.0002
IVSd	9.0 ± 0.7	11 ± 1.0	<0.0001	9.0 ± 0.7	10.2 ± 1.2	<0.0001
LVPWd	8.3 ± 1.0	10.8 ± 0.8	<0.0001	8.2 ± 1.0	10.2 ± 1.0	<0.0001
LVEF	68.7 ± 4.8	60.6 ± 4.9	<0.0001	69.1 ± 5.5	62.2 ± 5.1	<0.0001
LVm	133.3 ± 18.8	188.5 ± 33.7	<0.0001	133.4 ± 19.1	157.2 ± 36.0	<0.0001
LVEDV	74.6 ± 5.4	93.4 ± 19.8	<0.0001	74.5 ± 4.9	79.0 ± 19.1	<0.0001
LVESV	31.1 ± 2.9	37.2 ± 10.2	<0.0001	28.0 ± 2.5	30.4 ± 9.6	<0.0001
LAd	24.5 ± 3.6	33.1 ± 3.2	<0.0001	24.5 ± 3.7	30.8 ± 3.6	<0.0001
LAv	26.9 ± 7.9	34.1 ± 7.8	<0.0001	26.9 ± 8.1	31.7 ± 7.8	<0.0001
RVEdD	17.4 ± 3.0	28.1 ± 2.8	<0.0001	17.4 ± 2.7	25.9 ± 3.2	<0.0001
Indexed measurements						
iLVm	98.1 ± 19.3	99.1 ± 20.7	0.39	98.3 ± 18.3	93.3 ± 24.2	<0.0001
iLVEDV	54.9 ± 6.0	49.0 ± 11.5	<0.0001	54.8 ± 5.6	46.8 ± 12.4	<0.0001
iLVESV	22.9 ± 3.4	19.5 ± 5.7	<0.0001	20.6 ± 3.1	18.1 ± 6.0	<0.0001
iLAv	19.9 ± 8.2	17.8 ± 4.4	<0.0001	19.8 ± 8.5	18.7 ± 5.0	0.05

iLAv- Indexed left atrial volume, mL/m^2; iLVEDd- Indexed left ventricular end diastolic dimension, mm/m^2; iLVEDV- Indexed left ventricular end diastolic volume, mL/m^2; iLVEsD- Indexed left ventricular end systolic dimension, mm/m^2; iLVESV- Indexed left ventricular end systolic volume, mL/m^2; iLVm- Indexed left ventricular mass, g/m^2; iLVPWd- Indexed posterior wall thickness at end diastole, mm/m^2; IVSd- Septal thickness at end diastole, mm; LAd- Left atrial anteroposterior dimension, mm; LAv-left atrial volume, mL; LVEdD-left ventricular end diastolic dimension, mm; LVEDV- left ventricular end diastolic volume, mL; LVEF- left ventricular ejection fraction, %; LVEsD-left ventricular end systolic dimension, mm; LVESV- left ventricular end systolic volume, mL; LVm-left ventricular mass, g; LVPWd- Posterior wall thickness at end diastole, mm; RVEdD- Right ventricle outflow diameter at end diastole, mm; WASE- World Alliance Societies of Echocardiography.

intra-observer and inter-observer variability for comparison with the reference values from other populations remains a problem while comparing datasets from different parts of the world.

6. Conclusion

The study which included resident Indians from eastern part of the country reconfirms that Indian subjects have smaller cardiac chamber measurements compared to western population where as LVEF is higher in the Indian populationand also demonstrates the wide variation of normal echocardiographic measurements within Indian subcontinent. This study is one of its kind, since it is the first study reporting normative echocardiographic values from eastern India and the largest Indian sample studied till date for the same.

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ASE- American Society of Echocardiography; EACVI- European Association of Cardiovascular Imaging; iLVEDV- indexed left ventricular end diastolic volume, mm/m^2; iLVESD-indexed left ventricular end systolic volume, mm/m^2; LVEdD-left ventricular end diastolic dimension, mm; LVEDV- left ventricular end diastolic volume, mL; LVEF- LV ejection fraction, %; LVEsD- LV end systolic dimension, mm; LVESV- left ventricular end systolic volume, mL; RVEdD- Right ventricle outflow diameter at end diastole, mm.

Declaration of competing interest

None.

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