Original Article

Morphological and Functional Measurements of the Heart Obtained by Magnetic Resonance Imaging in Brazilians

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Abstract

Background: **Still today, measurements used as a reference in the cardiac magnetic resonance imaging have been obtained mainly from studies carried out in North-American and European populations.**

Objective: **To obtain measurements of the diastolic diameter, systolic diameter, end diastolic volume, end systolic volume, ejection fraction, and myocardial mass of the left and right ventricles in Brazilians.**

Methods: **54 men and 53 women, with mean age of 43.4 ± 13.1 years, asymptomatic, with no cardiomyopathies, have been subjected to the cardiac magnetic resonance imaging, using a balanced steady state free precession technique.**

Results: **The averages and the standard deviations of the parameters for the left ventricle have been: diastolic diameter =4.8 ± 0.5 cm; systolic diameter = 3.0 ± 0.6 cm; end diastolic volume = 128.4 ± 29.6 mL; end systolic volume = 45.2 ± 16.6 mL; ejection fraction = 65.5 ± 6.3%; mass = 95.2 ± 30.8 g. For the right ventricle, they have been: diastolic diameter = 3.9 ± 1.3 cm; systolic diameter = 2.5 ± 0.5 cm; end diastolic volume = 126.5 ± 30.7 mL; end systolic volume = 53.6 ± 18.4 mL; ejection fraction = 58.3 ± 8.0%, and mass = 26.1 ± 6.1 g. The masses and the volumes were significantly greater in the men, except for the end systolic volume of the left ventricle. The ejection fraction of the right ventricle has been significantly greater in the women. There has been a significant and inverted correlation of the systolic volume of the right volume with the progression of the age.**

Conclusion: **This study has described, for the first time, cardiac measurements obtained through the cardiac magnetic resonance imaging in Brazilians, asymptomatic, with no cardiomyopathies, showing differences in accordance with gender and age. (Arq Bras Cardiol. 2013;101(1):68-77)**

Keywords: **Magnetic Resonance Imaging / methods; Reference Values; Ventricular Function / physiopathology; Heart Ventricles / anatomy & physiology; Genetics, Population.**

Introduction

The determination of morphological and functional parameters of the heart - such as diameters, volumes, myocardial mass, and systolic function - are essential to the diagnosis, handling, and prognosis of cardiomyopathies[1-4].

The cardiac magnetic resonance imaging (CMRI) has been accepted as a reference method for the obtaining of cardiac measurements, given its high accuracy and reproducibility[5].

The establishment of a database of the CMR with reference values is essential. The majority of the studies which established reference values has acquired their results from North-American and European populations. Those values may not reflect the reality for the definition of the cardiac aggravations in other populations - such as, for example, the Brazilian.

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Populations of a Latin-American origin, such as the Brazilian, have generally been represented to a lesser degree in the most part of the major clinical studies, in spite of their corresponding to a growing portion of the subjects with cardiovascular diseases in the world[6-9].

One of the largest North-American studies ever carried out in the area - the *Multi-Ethnic Study of Atherosclerosis* (MESA) - has obtained cardiovascular measurements in more than 6,000 participants with quite diverse ethnicities[10-13]. In spite of the MESA sub-studies having evaluated Latin-Americans classified as “Hispanics”, the data would be limited to subjects who lived in the United States, thus sharing the same living habits of the North-American population.

That way, it is essential to obtain measurements of the cardiac parameters in CMR which may serve as a reference for Brazilians, for example, not only for the sake of a better clinical evaluation of our patients, but also in order for those reference data to serve as a foundation for other clinical trials or future comparative studies with different populations or ethnicities.

Apart from the importance of obtaining morphological and functional parameters of the heart by means of CMR - which will serve as a reference for the Brazilian population, it is also necessary to evaluate the possible differences between gender and the influences of the age on those measurements.

Then, the purpose of this study has been that of obtaining measurements of morphological and functional parameters of the heart, such as Diastolic diameter (Dd), Systolic diameter (Sd), Diastolic Volume (Dv), Systolic volume (Sv), Ejection Fractions (EF), and Myocardial mass (M) of the left ventricle (LV) and of the Right ventricle (RV) in Brazilian participants of the Latin_American, Multi-Center, reference study of CMR (CMR-LAC Trial), as well as that of evaluating the differences between gender and age groups.

Methods

The Latin-American, Multi-Center, reference study of CMR (CMR-LAC Registry)[14] consists of a transversal study, including asymptomatic subjects, with no cardiomyopathies established, between 20 and 80 years of age, with the participation of CMR centers in three countries (Brazil, Argentina, and Mexico), with the purpose of obtaining measurements of morphological and functional parameters of the LV and RV, such as diameters, volumes, myocardial M, and contractile function, which may be used as a reference in Latin-Americans.

This study composes a sub-study with Brazilian participants of the CMR-LAC Registry, which evaluated data obtained from subjects dwelling in the North-East and the South-East regions of the country. The data has been collected from three different Brazilian centers, one being from the North-East (Universidade Federal do Rio Grande do Norte – UFRN) and two from the South-East (Instituto do Coração do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo – InCor-HC-FMUSP; and Universidade Estadual de Campinas – Unicamp), of the cities of Natal (RN), São Paulo (SP), and Campinas (SP), respectively.

Signs with information on the Brazilian record in CMR have been posted on the social networks, in the ambulatories of the three universities and, also, in private-owned clinics of the cities taking part in this study. Asymptomatic subjects, with ages between 20 and 80 years-old, have been recruited. After a medical interview, the subjects with no factors of risk, no established cardiomyopathy, with normal physical examination and electrocardiograms were invited to take part in the research.

The criteria of exclusion were: current smokers or previous smokers with less than 10 years of interruption, systolic arterial pressure > 120 mmHg or diastolic > 80 mmHg, fasting glycemia > 100 mg/dL, and total cholesterol > 200 mg/dL. Bearers of cardiac pacemaker, implantable cardioverter defibrillator, intraocular foreign bodies or claustrophobia have also been excluded. All of the anthropometric measurements have been standardized in accordance with previously published references[15]. The body mass index (BMI) has been calculated by means of the equation weight / height^2 (kg/m^2) and the body surface area in accordance with the formula published by Mosteller [BSA (m^2) = (*height* (cm) x *weight* (kg) / 3600) ½](15). The measurement of the serum Brain Natriuretic Peptide (BNP) to rule out the cardiac dysfunction has been obtained in the inhabitants of Natal. The clinical and laboratory data were collected before the CMR exam. This study has been approved by the respective local ethics committees and has been conducted in conformity with the ethical standards of the Helsinki declaration of 1964. The participants of the research have read and signed the Informed Consent Form. The study has also been registered at www.clinicaltrials.gov with the identification number: NCT01030549.

Protocol of the CMR

The subjects have undergone examination in devices of 1.5 Tesla (Achieva, Philips Medical Systems, Best, The Netherlands Signa CV/I; GE Medical Systems, Waukesha, WI; and Avanto, Siemens Medical Solutions, Erlangen, Germany). The images synchronized with the electrocardiogram have been acquired upon expiratory apnea (respiratory pause of 15 seconds), using dedicated cardiac coils previously placed on the thorax of the patient. The protocol time of the study has had the duration of approximately 30 minutes. Localizing images in orthogonal planes, vertical and horizontal long axes, and short axis of the heart have been carried out. After those sequences of localizing images, images in cine mode, in the four chamber plane (4ch) of the heart have been obtained to prescribe the short axis, now in cine mode, covering the entire LV and RV from the base (passing the atrioventricular ring) up to the apex, using the balanced steady state free precession technique (SSFP)[16]. The following parameters have been respected in the three centers taking part in the research for the obtaining of the short axis of the heart in cine mode: slice thickness of 8 mm, spacing of 2 mm, temporal resolution < 50 msec, FOV 360-400mm, matrix of 256 x 128, *flip angle* 15 - 30º, TE 3-5msec, TR 8-10msec, 1 NEX.

Analysis of the images

The method of analysis has followed the standards already widely established in the literature, with high indices of reproducibility inter- and intra-observer reproducibility[17].

Locally, the images have been transferred from the magnetos to the local work stations, and analyzed by means of *dedicated software* (View Forum of Philips Medical and Argus of the Siemens Medical Solutions).

Three doctors trained in CMR have analyzed all of the images. The measurements of the diameters of the left and right ventricles have been obtained by plotting a straight line from the inter-ventricular septum to the lateral wall in the plane 4ch (Figure 1). The measurements of the volumes of both the LV and the RV have been obtained by semi-automatically plotting the contours of the endocardial edges of both the LV and the RV in the short axis of the heart, both in diastole and in systole as well, from the base up to the apex. The base cut-off of the LV would be selected if at least 50% of the volume of blood were surrounded by myocardial tissue. The apical slice was defined as the last slice to have intra-cavity blood volume. The papillary muscles have been excluded from the measurements of volume and included for the calculation of the left ventricular mass. For the RV, the volumes below the pulmonary valve were included. The volumes of the RV have been excluded from the entrance pathway should the muscles around be fine instead of trabecular, suggesting that of the right atrium. The Figure 2 shows examples of images in

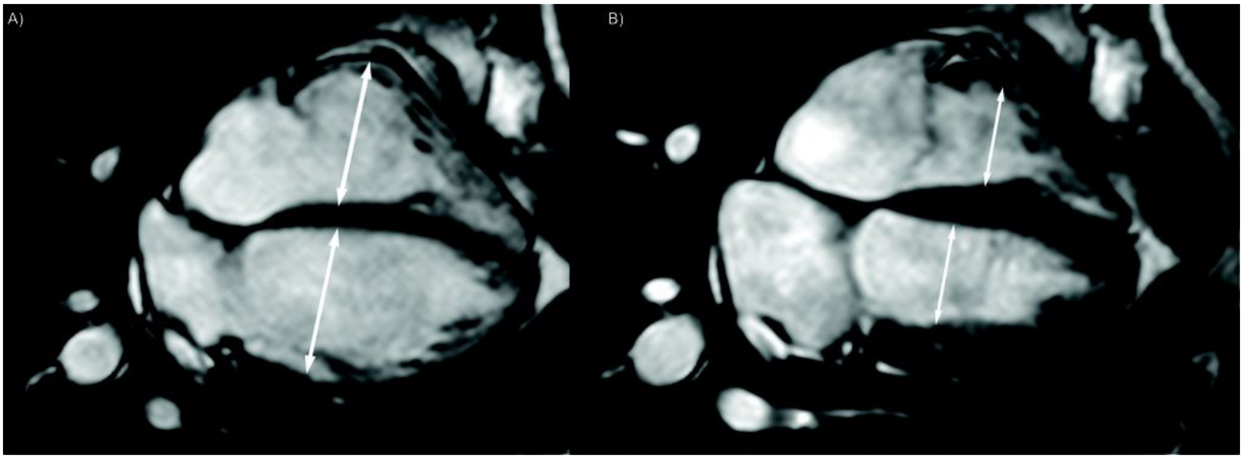

Figure 1 - *Images in the 4-Ch plane of the heart in diastole (A) and systole (B), showing the measurements of the diameters of the left and right ventricles.*

short axis of the heart, in which the endocardial and epicardial outlines of both the LV and the RV, in diastole and in systole, may be observed. The end diastolic and systolic volumes of both the LV and the RV have been determined through the method of the summation of the discs or Simpson's rule (summation of the areas outlined in each slice in the short axes of both the LV and the RV multiplied by the summation of the thickness of those slices with their spacing)[11]. The EF has been calculated as the End Dv (EDv) minus the End Sv (ESv) divided by the EDv. The Myocardial M has been determined by the summation of the myocardial area (difference between the epicardial outlines and those of the of the endocardial outlines) multiplied by the slice thickness plus the spacing of the slice in diastole multiplied by the myocardial density of 1.05 gcm[3 18]. The tissue volume has been obtained from the endocardial and epicardial outlines of both the LV and the RV in diastole (Figure 2).

All of the measurements obtained have been stored in a mainframe server at Unicamp, accessed via the *internet* (www.cmrtrial.com), by means of identification and password provided in the beginning of the study.

Apart from the local analyses, the original images in DICOM have been rendered anonymous and recorded in CD/DVD media, apart from being sent electronically by a *web* server top the central laboratory. As intra- and inter-observer variabilities have been tested with the participation of two observers. For the analysis of the intra-observer variability, the observer 1 has measured the same parameters of both the LV and the RV twice in 30 subjects, after an interval of 30 days. For the inter-observer analysis, the observer 2 has obtained measurements of the same 30 subjects from a random sample previously analyzed by the observer 1.

Statistical analysis

After the collection, the data have been transcribed to the standardized form and typed in computer, for the sake of database management and statistical analysis. The build-up of the database and the statistical analysis have been made in statistics software *Statistical Package for Social Science* (SPSS), version 16.0 for Windows.

In the descriptive analysis, the categorical data are presented in the form of tables, per absolute and relative frequencies, whilst the quantitative data are presented per average and standard deviation (SD). The latter have initially been subjected to the normality test, comparing them to the normal curve by means of the Kolmogorov-Smirnov (K-S) test, all of them being classified as parametric.

Next, to compare the averages of the measurements in relation to the gender, the Student's *t* test has been carried out for independent samples. For the comparison of the measurements as a function of the age, the Variance Analysis (ANOVA) has been carried out, followed by the Tukey's post-test. A simple linear regression has also been carried out so as to evaluate correlations between age and parameters of both the LV and the RV, in accordance with gender.

In the analyses of intra- and inter-observer agreements the Intraclass Correlation coefficient (ICC) has been used.

Throughout the entire statistical analysis, a significant p has been considered with a standard value of 0.05 and a Confidence Interval (CI) of 95%.

Results

One hundred eight subjects (55 men), with mean age of 43.4 ± 13.1 years, have been screened through the criteria of inclusion and exclusion from a total of 300 interviews. The period of interviews took place from May, 2010 until May, 2011. The UFRN has included 52 subjects, the InCor-USP has included 19 subjects, and the Unicamp has included 37 subjects. Only one subject has been excluded for not completing the protocol of the CMR, by virtue of claustrophobia. The clinical characteristics of the participants of this study are demonstrated in the Table 1. Measurements of the Serum BNPs have been obtained from only 40 subjects, inhabitants of Natal.

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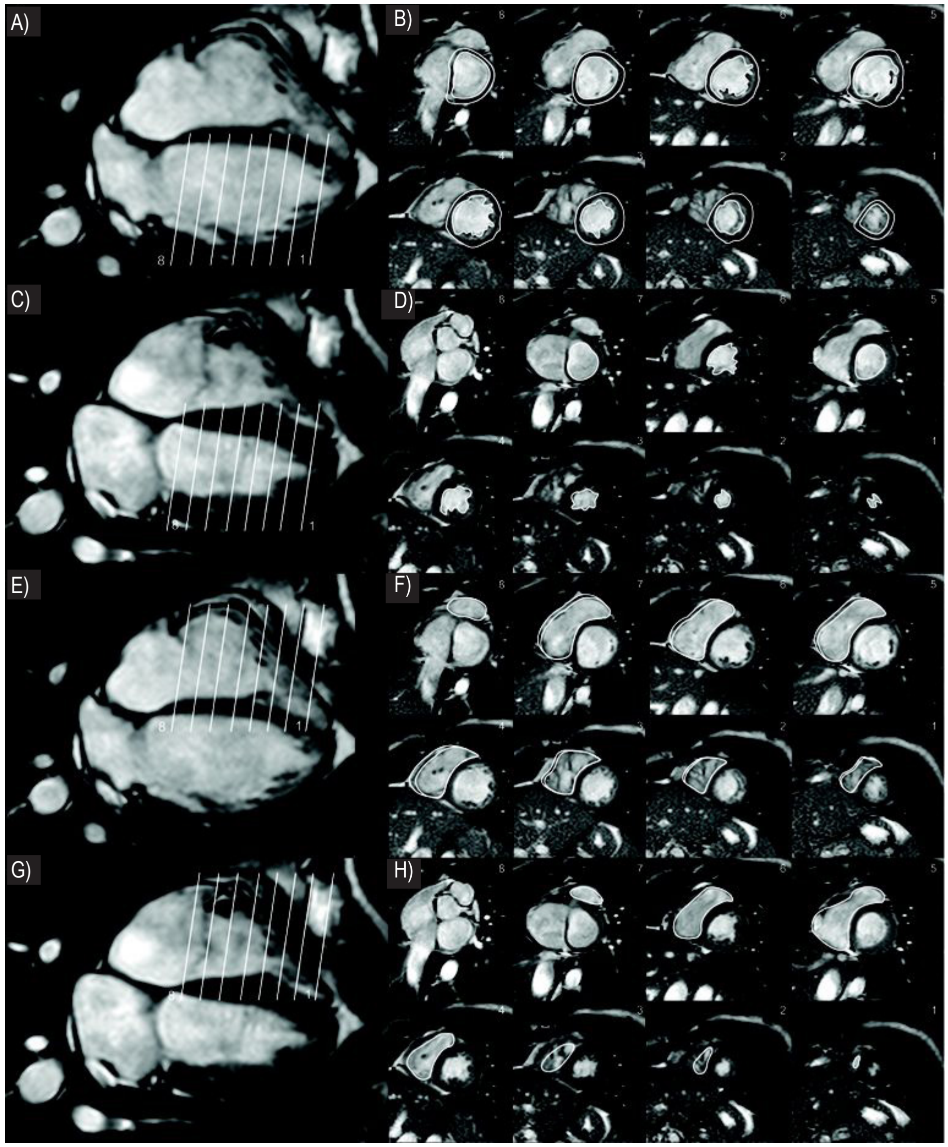

Figure 2 - *(A, C, E and G) Images in 4ch plane of the heart, showing the prescription slice planning to obtain short axis images in diastole and systole. (B, D, F and H) Images obtained in the short axis the heart in diastole and systole, showing the contours of the endocardial and epicardial outlines in the left and right ventricules, respectively.*

The averages and the SD of the measurements of the parameters of both the LV and the RV have been, respectively: Dd LV = 4.8 ± 0.5 cm; Sd LV = 3.0 ± 0.6 cm; EDv LV = 128.4 ± 29.6 mL; ESv LV = 45.2 ± 16.6 mL; EF LV = 65.5 ± 6.3%; Myocardial M of the LV = 95.2 ± 30.8 g; Dd RV = 3.9 ± 1.3 cm; Sd RV = 2.5 ± 0.5 cm; EDv RV = 126.5 ± 30.7 mL; ESv RV = 53.6 ± 18.4 mL; EF RV = 58.3 ± 8.0%; and Myocardial M of the RV = 26.1 ± 6.1 g. Also, the Table 2 shows the averages, SD and the respective CI 95% of all the parameters obtained of both the LV and the RV - both of the women and the men. The volumes and the masses of both the LV and the RV - in absolute numbers, with no adjustments for body surface area - have been significantly greater in men. The diameters of both the LV and the RV have also been significantly greater in men, except for the Dd RV. After adjustments for the body surfaces, the volumes and the masses of both the LV and the RV have remained significantly greater in men, except for the Sv LV. The EF RV has been significantly greater in women.

The Tables 3 and 4 show the averages, SD and CI 95% of all the parameters obtained from the LV and RV, both for women and men, in accordance with the respective age groups. In the age group above 60 years-old, considering only measurements adjusted for the body surface area, the Dd RV has been significantly lower in women. In men, also in the age group above 60 years-old, and considering only measurements

Table 1 - Clinical characteristics of the 107 subjects studied

Variables	Average ± SD	CI 95%
Age (years)	43.4 ± 13.1	40.9 - 46.0
Height (m)	1.67 ± 0.09	1.65 - 1.69
Weight (kg)	70.9 ± 14.2	68.2 - 73.6
Abdominal circumference (cm)	89.9 ± 11.8	87.7 - 92.2
SAP (mmHg)	115 ± 11	112 - 117
DAP (mmHg)	73 ± 7	72 - 75
BMI (kg/m^2)	25.3 ± 3.8	24.5 - 26.0
Body surface area (m^2)	1.80 ± 0.22	1.76 - 1.84
Glucose (mg/dL)	85.8 ± 8.8	81.3 - 89.3
Cholesterol (mg/dL)	174.7 ± 27.6	169.4 - 180.0
BNP (pg/dL)	88.6 ± 47.9	73.2 - 103.9

SD: standard deviation; CI: confidence interval; SAP: systolic arterial pressure; DAP: diastolic arterial pressure; BMI: body mass index; BNP: atrial natriuretic peptide.

adjusted for the body surface area, the diameters and the end diastolic and systolic volumes of the RV have been significantly lower. There has been a significant and inverted correlation of the ESv RV with the progression of the age, being more significant in the men (Figures 3 and 4).

The EF LV of the women and the EF RV in the men have been significantly greater in the higher age groups. The masses of the LV and RV have not been different among the age groups - both in absolute numbers and after adjustments for the body surfaces (Tables 3 and 4).

In the analyses of intra- and inter-observer agreements, there have been found elevated ICC values for all of the measurements of the LV and of the RV, except for the mass of the RV (Tables 5 and 6).

Discussion

This study presents preliminary results of the measurements of morphological and functional parameters of both the LV and the RV obtained by CMR, in Brazilian participants of the CMR-LAC Trial, describing differences between gender and age groups.

Table 2 - Measurements obtained of the left ventricle and right ventricle in accordance with gender, in absolute value numbers and adjusted for the body surface area

Variables	Total (n = 107)		Female (n = 53)		Male (n = 54)		Value of p
iSd (cm/m^2)	Average ± SD	CI 95%	Average ± SD	CI 95%	Average ± SD	CI 95%	
Left ventricle							
EDv (mL)	128.4 ± 29.6	122.7 - 134.1	114.4 ± 26.0	107.9 - 121.9	142.0 ± 2 6.7	134.6 - 150.0	< 0.001
iEDv (mL/m^2)	69.0 ± 15.1	66.1 - 71.8	68.5 ± 16.8	64.3 - 72.2	74.2 ± 13.1	70.1 - 78.4	< 0.05
ESv (mL)	45.2 ± 16.6	41.9 - 48.7	40.1 ± 17.5	36.4 - 43.8	50.1 ± 14.1	45.6 - 54.5	0.002
iESv (mL/m^2)	23.8 ± 10.0	21.4 - 24.9	24.0 ± 11.3	21.4 - 27.6	26.3 ± 7.3	24.5 - 28.7	0.22
Dd (cm)	4.8 ± 0.5	4.7 - 4.9	4.6 ± 0.52	4.2 - 5.0	4.9 ± 0.51	4.5 - 5.3	0.01
iDd (cm/m^2)	2.7 ± 0.4	2.6 - 2.8	2.7 ± 0.4	2.4 - 3.0	2.6 ± 0.4	2.5 - 2.7	0.11
Sd (cm)	3.0 ± 0.6	2.8 - 3.2	2.8 ± 0.6	2.6 - 3.0	3.2 ± 0.3	3.1 - 3.3	< 0.001
iSd (cm/m^2)	1.7 ± 0.4	1.6 - 1.8	1.7 ± 0.4	1.6 - 1.8	1.7 ± 0.2	1.5 - 1.9	0.91
EF (%)	65.5 ± 6.3	64.3-66.7	66.1 ± 6.5	64.9-68.6	64.9 ± 6.1	63.0-66.7	0.31
M (g)	95.2 ± 30.8	89.2-100.7	74.8 ± 20.1	69.7-79.1	115.2 ± 26.0	109.6-120.7	< 0.001
iM (g/m^2)	52.3 ± 14.0	48.5-56.1	44.6 ± 11.7	40.5-48-5	59.8 ± 11.7	55.6-63.2	< 0.001
Right ventricle							
EDv (mL)	126.5 ± 30.7	120.4-131.0	115.0 ± 26.0	109.1-121.3	149.0 ± 33.8	142.4-156.3	< 0.001
iEDv (mL/m^2)	73.2 ± 16.4	69.2-76.6	68.6 ± 15.2	63.4-73.4	77.8 ± 16.4	72.6-82.3	0.004
ESv (mL)	53.6 ± 18.4	49.5-56.4	45.4 ± 14.3	45.1-49.8	64.1 ± 19.3	59.8-69.2	< 0.001
iESv (mL/m^2)	30.3 ± 9.4	28.4-31.2	27.1 ± 8.5	24.5-30.3	33.4 ± 9.0	29.4-37.9	< 0.001
Dd (cm)	3.9 ± 1.3	3.5-4.2	4.0 ± 1.3	3.4-4.6	3.8 0 ± 1.2	3.2-4.4	0.2
iDd (cm/m^2)	2.2 ± 0.6	2.0-2.4	2.2 ± 0.7	2.1-2.3	2.1 ± 0.5	2.0-2.2	0.31
Sd (cm)	2.5 ± 0.5	2.3-2.7	23.0 ± 5.0	24.0-25.0	27.0 ± 5.0	26.0-28.0	< 0.001
iSd (cm/m^2)	1.4 ± 0.3	1.3-1.5	1.4 ± 0.3	1.3-1.5	1.4 ± 0.2	1.3-1.5	0.59
EF (%)	58.3 ± 8.0	56.2-60.1	61.0 ± 7.8	59.7-63.5	57.1 ± 7.1	55.1-58.9	0.008
M (g)	26.1 ± 6.1	24.1-28.4	24.2 ± 7.5	21.9-26.4	29.3 ± 8.1	22.3-26.8	0.03
iM (g/m^2)	15.2 ± 4.5	13.9-17.3	14.5 ± 4.5	12.5-16.5	16.0 ± 4.4	15.0-17.0	0.24

SD: standard deviation; CI: confidence interval; EDv: end diastolic volume; ESv: end systolic volume; Dd: diastolic diameter; Sd: systolic diameter; EF: ejection fraction; M: mass; i: value adjusted (indexed) for the body surface area.

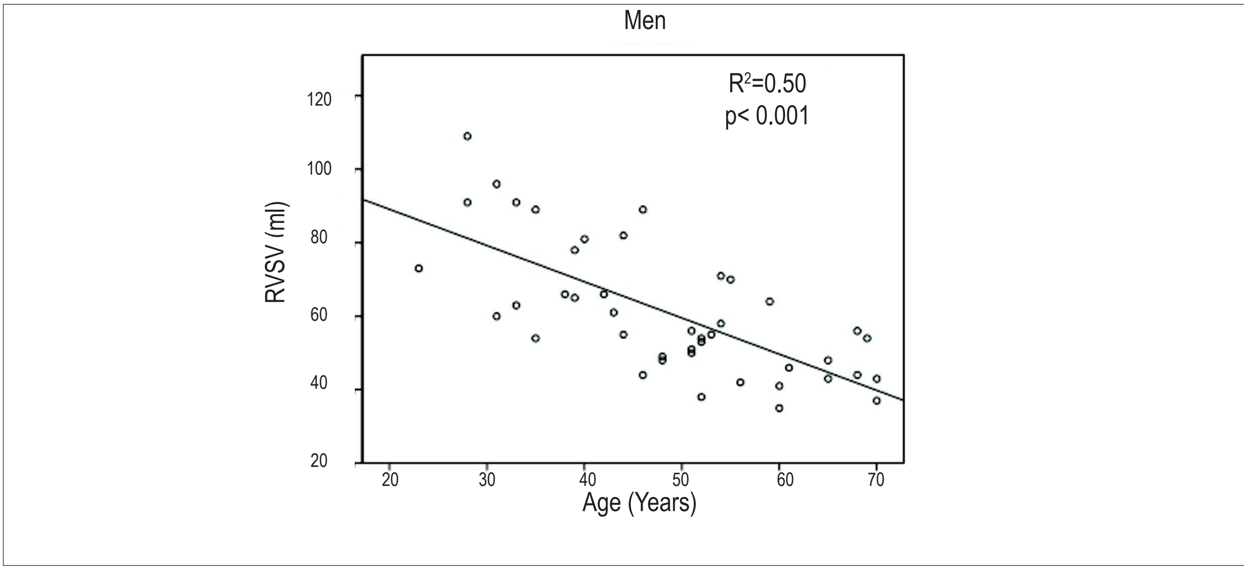

Figure 3 - *Linear dispersion and regression between the age (years) and the systolic volume of the right ventricle (mL) in men. RVSV: systolic volume of the right ventricle.*

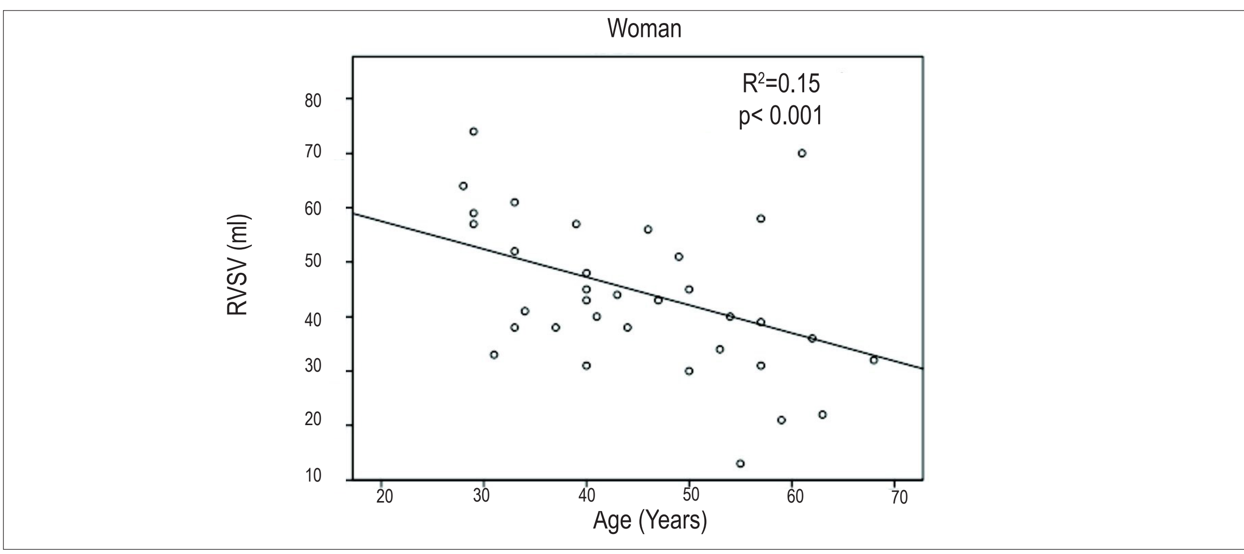

Figure 4 - *Linear dispersion and regression between the age (years) and the systolic volume of the right ventricle (mL) in women. RVSV: systolic volume of the right ventricle.*

Lorenz et al[18] have been some of the first authors to report reference values for CMR and to describe differences between genders. In a similar fashion as that of the data obtained among Brazilians of this study, the volumes and the masses adjusted for the body surface area, except for the mass of the RV, have been significantly greater in men. The averages and the SD of the masses of both the LV and the RV adjusted for the body surface area (LVMi and RVMi) have been greater than those of the Brazilians in this study (LVMi = 87 ± 12 g *versus* 52.3 ± 14 g; RVMi = 26 ± 5 g *versus* 15.2 ± 4.5 g). Yet, the average and the Adjusted SD EDv LV (iVdF LV) has been greater in the Brazilians of this study (69 ± 15.1 mL *versus* 66 ± 12 mL), but the Adjusted Dv RV (iVdF RV) has been greater among the Europeans (75 ± 13 mL *versus* 73.2 ± 16.4 mL). The differences may be justified by the use of different techniques of image acquisition (FGRE *versus* SSFP). Moon et al[19], Barkhausen et al[20], and Malayeri et al[21] have compared those two techniques and demonstrated that the properties which are inherent to each of them may lead to significant differences in the measurements of the ventricular volumes and masses amidst them.

Salton et al[22] have also described differences between genders for parameters of the LV in normotensive subjects of the Framingham Heart Study Offspring Cohort[23], demonstrating that the volumes and the masses of the LV would be significantly

Table 3 - Averages and standard deviations of the measurements of the left ventricle and right ventricle, in accordance with age, in absolute numbers, and normalized by the body surface area, in women

	Age group (average ± SD) CI 95%										
Variables	20-29 years-old (n = 10)		30-39 years-old (n = 18)		40-49 years-old (n = 11)		50-60 years-old (n = 9)		above 60 years-old (n = 5)		Value of p
Left ventricle	Average ± SD	CI 95%	Average ± SD	CI 95%	Average ± SD	CI 95%	Average ± SD	CI 95%	Average ± SD	CI 95%	
EDv (mL)	127.0 ± 19.9	113.1 - 141.6	117.6 ± 28.9	103.2 - 132.0	110.0 ± 16.3	98.9 - 121.0	101.5 ± 21.0	85.4 - 117.7	110.2 ± 42.8	57.0 - 163.3	0.24
iEDv (mL/m²)	67.2 ± 10.5	50.4 - 84.0	73.2 ± 21.0	59.9 - 86.6	63.7 ± 11.6	53.9 - 73.4	58.0 ± 9.5	50.1 - 66.0	61.3 ± 27.6	17.3 - 105.3	0.38
ESv (mL)	48.7 ± 10.3	41.2 - 56.1	40.3 ± 23.6	28.6 - 52.1	39.7 ± 8.3	34.1 - 45.3	32.2 ± 11.9	23.0 - 41.3	37.2 ± 24.3	6.9 - 67.4	0.36
iEDv (mL/m²)	25.6 ± 6.8	14.7 - 36.5	25.5 ± 19.4	13.2 - 37.8	23.8 ± 6.9	17.9 - 29.6	17.7 ± 5.9	12.7 - 22.7	19.5 ± 5.4	13.9 - 24.1	0.71
Dd (cm)	4.7 ± 0.5	3.8 - 5.5	4.9 ± 0.4	4.6 - 5.1	4.4 ± 0.2	4.2 - 4.6	4.2 ± 0.4	3.8 - 4.6	4.5 ± 0.5	3.6 - 5.5	0.02
iDd (cm/m²)	2.7 ± 0.2	2.5 - 2.9	2.8 ± 0.4	2.6 - 3.1	2.6 ± 0.3	2.3 - 2.8	2.5 ± 0.2	2.4 - 2.7	2.5 ± 0.3	2.1 - 3.0	0.21
Sd (cm)	2.9 ± 0.7	1.8 - 4.0	3.2 ± 0.8	2.7 - 3.8	2.6 ± 0.3	2.3 - 2.9	2.4 ± 0.3	2.2 - 2.7	2.6 ± 0.5	1.6 - 3.5	0.08
iSd (cm/m²)	17 ± 0.2	1.5 - 2.0	1.9 ±0.6	1.5 - 2.2	1.5 ± 0.2	1.3 - 1.7	1.4 ± 0.1	1.3 - 1.5	1.5 ± 0.3	1.1 - 1.9	0.09
EF (%)	61.7 ± 4.5	58.4 - 64.9	68.4 ± 3.8	66.5 - 70.3	64.0 ± 6.0	59.9 - 68.0	67.5 ± 8.8	60.7 - 74.3	68.8 ± 9.7	56.0 - 80.9	0.04
M (g)	76.9 ± 19.3	63.0 - 90.7	76.0 ± 13.2	69.4 - 82.6	67.5 ± 18.0	55.4 - 79.6	74.2 ± 30.1	51.0 - 97.4	83.2 ± 28.5	47.7 - 118.6	0.66
iM (g/m²)	45.4 ± 12.6	36.3 - 54.5	46.5 ± 7.4	42.9 - 50.2	39.6 ± 8.9	33.6 - 45.6	43.7 ± 17.5	30.2 - 57.1	48.3 ± 16.6	27.6 - 69.0	0.54
Right ventricle											
EDv (mL)	119.7 ± 16.9	92.7 - 146.8	109.1 ± 12.3	101.3 - 117.0	109.1 ± 13.1	98.1 - 120.1	101.7 ± 29.4	77.1 - 126.3	110.5 ± 57.2	19.4 - 201.5	0.84
iEDv (mL/m²)	74.5 ± 11.1	66.6 - 82.5	70.3 ± 11.0	64.8 - 75.8	65.6 ± 15.0	55.5 - 75.7	61.9 ± 15.9	49.6 - 74.2	69.1 ± 30.5	31.1 - 107.0	0.43
ESv (mL)	63.5 ± 7.5	51.4 - 75.5	44.2 ± 9.5	37.8 - 50.6	43.3 ± 7.9	36.7 - 50.0	39.0 ± 20.0	22.2 - 55.7	40.0 ± 20.8	6.8 - 73.1	0.07
iEDv (mL/m²)	32.2 ± 7.3	26.9 - 37.5	27.9 ± 6.5	24.5 - 31.2	24.6 ± 7.8	19.3 - 29.9	23.7 ± 11.0	15.2 - 32.2	25.4 ± 11.4	11.2 - 39.7	0.18
Dd (cm)	6.8 ± 0.6	5.8 - 7.8	3.3 ± 1.1	2.5 - 4.2	3.1 ± 0.6	2.5 - 3.6	3.3 ± 0.4	2.9 - 3.7	3.6 ± 0.7	2.5 - 4.7	0.001
iDd (cm/m²)	2.8 ± 1.1	2.0 - 3.6	2.0 ± 0.5	1.7 - 2.3	1.9 ± 0.5	1.6 - 2.3	2.0 ± 0.3	1.7 - 2.3	2.1 ± 0.3	1.7 - 2.6	0.02
Sd (cm)	3.0 ± 0.4	2.4 - 3.7	2.2 ± 0.3	1.9 - 2.4	2.1 ± 0.4	1.6 - 2.5	2.0 ± 0.4	1.6 - 2.4	2.5 ± 0.4	1.8 - 3.2	0.004
iSd (cm/m²)	1.5 ± 0.3	1.2 - 1.8	1.3 ± 0.1	1.2 - 1.5	1.2 ± 0.3	1.0 - 1.5	1.2 ± 0.2	1.0 - 1.4	1.4 ± 0.2	1.2 - 1.7	0.14
EF (%)	51.2 ± 7.9	38.6 - 63.8	58.3 ± 8.1	53.1 - 63.5	60.2 ± 7.4	54.0 - 66.4	63.8 ± 9.5	55.8 - 71.8	63.5 ± 5.9	54.0 - 72.9	0.13
M (g)	21.8 ± 7.2	15.4 - 27.1	26.4 ± 4.5	22.6 - 30.0	22.1 ± 5.8	14.1 - 25.9	31.0 ± 9.5	20.3 - 30.5	29.7 ± 10.7	18.9 - 30.5	0.44
iM (g/m²)	12.6 ± 5.0	8.6 - 17.4	16.2 ± 3.5	13.8 - 20.9	13.2 ± 3.8	10.7 - 16.6	11.7 ± 6.5	4.5 - 27.9	17.1 ± 6.2	10.6 - 22.5	0.28

SD: standard deviation; CI: confidence interval; EDv: end diastolic volume; ESv: end systolic volume; Dd: diastolic diameter; Sd: systolic diameter; EF: ejection fraction; M: mass; i: value adjusted (indexed) for the body surface area.

greater in men. The women have had the greatest EF, though with no significant difference.

Maceira et al[24,25] - using the same technique (SSFP) of imaging acquisition as adopted in this study - have published parameters adjusted for the body surfaces both for the LV and the RV, further describing not only differences between genders but, also, the influence of the age on those measurements. In the multivariate analysis, we have observed that the gender has significantly influenced the volumes and the masses of both the LV and the RV. In a similar fashion as demonstrated here, among Brazilians, the volumes have significantly decreased with the progression of age. In the multivariate analysis, the age has been an independent predictor of the volumes of the LV and of the volumes and masses of the RV. Hudsmith et al[26] have demonstrated measurements of the mass of the RV and volumes of the LV and RV significantly lower in men and women above 35 years of age when compared to the ones below 35 years of age. Nikitin et al[27] have published, likewise, volumes of the LV that were lower among the highest ages, though with no significant changes in the mass do LV. This study has shown that, apart from the volumes and diameters of the RV being significantly lower in the age group above 60 years-old, there has been a correlation of the Sv RV with the progression of the age, being more significant in the men. Those data corroborate with the results by Kawut et al[12], which have demonstrated that the progression of age is associated to lower volumes and masses of the RV, upon analyzing a significant number of subjects (n = 5.098) from the MESA study.

The myocardial volumes and the masses of the LV and RV published by Maceira et al[24,25] have been quite similar to those obtained among the Brazilians of this study. However, it should be expected that those measurements were different from the ones obtained amidst the Brazilians, mainly due to differences among heights, weights, and body surfaces of Americans and Europeans in relation to the Latin-Americans, specifically Brazilians. However, in one of the MESA sub-studies, involving 800 subjects, Natori et al[11] have shown that significant differences between ethnicities for

Table 4 - Averages and standard deviations of the measurements of the left ventricle and right ventricle, in accordance with age, in absolute numbers, and normalized by the body surface area, in men

	Age group (average ± SD) CI 95%										
Variables	20-29 years-old (n = 10)		30-39 years-old (n = 12)		40-49 years-old (n = 9)		50-60 years-old (n = 15)		above 60 years-old (n = 08)		Value of p
Left ventricle	Average ± SD	CI 95%	Average ± SD	CI 95%	Average ± SD	CI 95%	Average ± SD	CI 95%	Average ± SD	CI 95%	
EDv (mL)	165.3 ± 27.6	145.5 - 185.0	149.3 ± 22.0	135.3 - 163.2	141.3 ± 18.2	127.3 - 155.3	131.9 ± 25.9	117.5 - 146.2	121.6 ± 17.9	106.6 - 136.6	0.02
iEDv (mL/m²)	78.1 ± 10.5	61.3 - 94.8	74.9 ± 7.7	69.3 - 80.4	73.9 ± 15.0	61.3 - 86.3	68.9 ± 15.8	59.8 - 78.0	66.6 ± 9.6	58.5 - 74.6	0.44
ESv (mL)	65.2 ± 16.9	53.1 - 77.2	48.4 ± 9.9	42.1 - 54.7	51.1 ± 13.1	41.0 - 61.1	46.0 ± 12.1	39.3 - 52.6	40.4 ± 6.1	35.2 - 45.5	0.001
iESv (mL/m²)	28.3 ± 6.5	18.0 - 38.6	23.0 ± 3.7	20.3 - 25.6	27.4 ± 9.2	19.7 - 35.1	24.4 ± 7.3	20.2 - 28.6	22.1 ± 3.4	19.3 - 24.9	0.33
Dd (cm)	5.0 ± 0.2	4.7 - 5.2	5.1 ± 0.2	4.9 - 5.2	5.1 ± 0.4	4.7 - 5.4	4.8 ± 0.6	4.4 - 5.1	4.6 ± 0.7	3.9 - 5.1	0.19
iDd (cm/m²)	2.7 ± 0.3	2.4 - 2.8	2.6 ± 0.3	2.4 - 2.8	2.7 ± 0.4	2.3 - 2.9	2.6 ± 0.5	2.2 - 2.8	2.5 ± 0.4	2.1 - 2.7	0.84
Sd (cm)	3.3 ± 0.3	2.8 - 3.7	3.3 ± 0.2	3.1 - 3.4	3.4 ± 0.3	3.1 - 3.6	3.2 ± 0.5	2.8 - 3.4	3.0 ± 0.4	2.6 - 3.3	0.34
iSd (cm/m²)	1.8 ± 0.3	1.5 - 2.0	1.7 ± 0.2	1.5 - 1.8	1.7 ± 0.3	1.5 - 1.9	1.7 ± 0.3	1.4 - 1.8	1.6 ± 0.2	1.4 - 1.8	0.83
EF (%)	60.7 ± 5.2	57.0 - 64.3	67.2 ± 5.7	63.6 - 70.8	64.1 ± 6.1	59.4 - 68.8	65.4 ± 6.1	62.0 - 68.7	66.6 ± 5.6	61.9 - 71.2	0.10
M (g)	121.3 ± 29.7	100.0 - 142.5	122.3 ± 37.3	98.6 - 146.0	113.0 ± 19.3	98.2 - 127.8	110.3 ± 20.1	99.1 - 121.4	108.1 ± 18.0	93.0 - 123.2	0.45
iM (g/m²)	61.5 ± 13.1	52.1 - 70.8	61.8 ± 16.8	51.1 - 72.4	59.5 ± 8.1	53.2 - 65.7	57.9 ± 9.6	52.5 - 63.1	59.2 ± 9.7	51.1 - 67.3	0.88
Right ventricle											
EDv (mL)	172.7 ± 13.9	138.2 - 207.1	160.6 ± 30.2	139.0 - 182.1	147.1 ± 24.7	126.4 - 167.7	130.6 ± 20.6	118.7 - 142.4	118.3 ± 12.7	107.6 - 128.8	0.01
iEDv (mL/m²)	97.8 ± 14.2	86.8 - 108.6	80.5 ± 9.8	74.2 - 86.6	78.9 ± 18.1	64.9 - 92.8	70.0 ± 13.3	62.6 - 77.3	64.7 ± 6.1	59.6 - 69.8	0.001
ESv (mL)	91.0 ± 18.0	46.2 - 135.7	74.3 ± 14.6	63.8 - 84.7	61.7 ± 16.4	48.0 - 75.4	52.7 ± 11.1	46.3 - 59.1	46.4 ± 6.2	41.1 - 51.5	0.001
iESv (mL/m²)	44.3 ± 9.4	37.0 - 51.4	37.0 ± 4.9	33.9 - 40.1	33.5 ± 8.6	26.8 - 40.0	28.1 ± 6.0	24.7 - 31.4	25.4 ± 3.2	22.7 - 28.0	0.001
Dd (cm)	6.6 ± 1.9	3.4 - 9.6	3.9 ± 1.6	2.7 - 5.1	3.6 ± 0.4	3.2 - 3.9	3.7 ± 0.7	3.2 - 4.0	3.8 ± 0.3	3.4 - 4.0	0.001
iDd (cm/m²)	2.6 ± 0.8	1.9 - 3.1	2.0 ± 0.6	1.5 - 2.4	1.9 ± 0.3	1.6 - 2.0	1.9 ± 0.4	1.7 - 2.1	2.1 ± 0.2	1.9 - 2.2	0.03
Sd (cm)	3.2 ± 0.5	2.4 - 4.0	2.6 ± 3.0	2.3 - 2.7	2.6 ± 0.5	2.1 - 2.9	2.5 ± 0.4	2.2 - 2.7	2.7 ± 0.4	2.3 - 3.0	0.06
iSd (cm/m²)	1.6 ± 0.2	1.4 - 1.8	1.4 ± 0.2	1.2 - 1.5	1.3 ± 0.3	1.1 - 1.5	1.3 ± 0.2	1.1 - 1.4	1.5 ± 0.2	1.2 - 1.6	0.01
EF (%)	49.5 ± 6.6	39.0 - 59.9	53.6 ± 6.3	49.1 - 58.0	57.9 ± 9.6	49.8 - 65.9	59.4 ± 6.3	55.7 - 63.0	60.6 ± 5.0	56.4 - 64.8	0.03
M (g)	32.0 ± 10.1	24.6 - 39.7	36.1 ± 11.2	26.5 - 37.4	29.2 ± 5.9	22.4 - 36.1	27.5 ± 4.3	23.0 - 31.9	29.7 ± 4.0	19.6 - 39.7	0.54
iM (g/m²)	17.9 ± 5.3	11.4 - 23.4	18.0 ± 4.8	13.1 - 22.7	17.1 ± 3.8	12.3 - 21.8	15.1 ± 2.5	12.8 - 17.3	16.5 ± 2.2	10.9 - 22.0	0.86

SD: standard deviation; CI: confidence interval; EDv: end diastolic volume; ESv: end systolic volume; Dd: diastolic diameter; Sd: systolic diameter; EF: ejection fraction; M: mass; i: value adjusted (indexed) for the body surface area.

parameters of the LV would exist only between "white" or "black" Americans and Asian-descendant Americans, mainly Chinese. This study has shown that there have not been significant differences between the volumes and the masses of the LV of the "white" or "black" Americans and "Hispanic" Latin-Americans. In contrast, Kawut et al[12], in the MESA study, have shown that the mass and the Dv RV of "Hispanic" Latin-Americans would be significantly greater than those of the 'white", "black" or "Chinese" Americans. Thus, ethnic differences need to be considered, reference values for one specific population are important, and further studies on CMR and other methods should be carried out so that there may be an understanding of the influence played by those ethnic factors on parameters both of the LV and the RV. The results of the intra- and inter-observer variability have been comparable to those by Catalano et al[28], except for the intra-observer agreement in the obtaining of Myocardial M of the RV. Walls of the RV are thinner than those of the LV. Errors may take place in semi-automatic procedures of detection of epicardial and endocardial edges of the RV walls. As such, the measurements of Myocardial M of the RV may be less accurate and reproducible.

The main limitation of this study has been related to the difficulty upon the certainty of the inclusion only of subjects free from cardiovascular diseases, mainly amidst the elderly. That fact does not void the results, mainly because, until then, there would be adopted reference values of studies published in the United States and in Europe which, by the way, have used screening criteria of their samples which were very similar to those of this sub-study. Another limitation regarded the fact that this Brazilian sub-study of the CMR-LAC Registry had not been designed to detect differences between ethnicities in the parameters analyzed.

Conclusion

This Brazilian sub-study of the *CMR-LAC Registry* has described, for the first time, measurements of

Table 5 - Intra-observer variability in the acquisition of the measurements of the left ventricle and of the right ventricle

Measurements	Average (SD)	Difference	ICC (CI 95%)	Value of p
EDv LV (mL)	128.3 (± 29.5)	0.92	0.98 (0.97 - 0.99)	< 0.001
ESv LV (mL)	45.1 (± 16.6)	0.43	0.94 (0.90 - 0.98)	< 0.001
Dd LV (cm)	4.7 (± 0.5)	0.11	0.84 (0.74 - 0.94)	< 0.001
Sd LV (cm)	3.0 (± 0.5)	0.06	0.90 (0.83 - 0.97)	< 0.001
EF LV (%)	65.5 (± 6.2)	1.34	0.82 (0.75 - 0.89)	< 0.001
M LV (g)	95.1 (± 30.8)	1.68	0.96 (0.94 - 0.96)	< 0.001
EDv RV (mL)	126.4 (± 30.6)	0.87	0.96 (0.94 - 0.98)	< 0.001
ESv RV (mL)	53.5 (± 18.3)	0.6	0.95 (0.92 - 0.98)	< 0.001
Dd RV (cm)	3.9 (± 1.3)	0.03	0.97 (0.95 - 0.99)	< 0.001
Sd RV (cm)	2.4 (± 0.5)	0.04	0.96 (0.93 - 0.99)	< 0.001
EF RV (%)	58.3 (± 8.0)	0.43	0.92 (0.86 - 0.98)	< 0.001
M RV (g)	26.1 (± 6.1)	0.33	0.22 (0.10 - 0.34)	NS

SD: standard deviation; Difference: difference between the measurements obtained by the observers 1 and 2; ICC: intraclass correlation coefficient; CI: confidence interval; EDv: end diastolic volume; LV: left ventricle; ESv: end systolic volume; Dd: diastolic diameter; Sd: systolic diameter; EF: ejection fraction; M: mass; RV: right ventricle.

Table 6 - Inter-observer variability in the acquisition of the measurements of the left ventricle and of the right ventricle

Measurements	Average (SD)	Difference	ICC (CI 95%)	Value of p
EDv LV (mL)	132.1 (± 25.6)	2.11	0.93 (0.83 - 0.97)	< 0.001
ESv LV (mL)	49.5 (± 12.3	1.6	0.90 (0.76 - 0.96)	< 0.001
DdF LV (mm)	4.9 (± 0.6)	0.19	0.78 (0.63 - 0.93)	0.02
DsF LV (mm)	3.3 (± 0.5)	0.08	0.88 (0.82 - 0.94)	0.01
EF LV (%)	62.6 (± 4.4)	0.93	0.79 (0.47 - 0.91)	0.001
M LV (g)	109.7 (± 24.3)	2.68	0.86 (0.66 - 0.94)	< 0.001
EDv RV (mL)	129.5 (± 35.1)	2.89	0.91 (0.83 - 0.99)	< 0.001
ESv RV (mL)	51.1 (± 11.4)	1.22	0.86 (0.65 - 0.94)	< 0.001
Dd RV (cm)	4.3 (± 1.5)	0.06	0.90 (0.83 - 0.970	0.01
Sd RV (cm)	2.5 (± 0.6)	0.05	0.91 (0.85 - 0.96)	0.001
EF RV (%)	62.7 (± 4.3)	0.91	0.80 (0.50 - 0.92)	< 0.001
M RV (g)	27.5 (± 6.4)	1.84	0.63 (0.43 - 0.85)	0.02

SD: standard deviation; Difference: difference between the measurements obtained by the observers 1 and 2; ICC: intraclass correlation coefficient; CI: confidence interval; EDv: end diastolic volume; LV: left ventricle; ESv: end systolic volume; Dd: diastolic diameter; Sd: systolic diameter; EF: ejection fraction; M: mass; RV: right ventricle.

morphological and functional parameters of the heart obtained by CMR in subjects with no factors of risk and with no cardiomyopathies established, whilst differences in the measurements of the LV and RV were observed as a function of age and gender.

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Author contributions

Conception and design of the research, Obtaining funding: Macedo R, Fernandes JL, Rochitte CE, Coelho OR, Diniz RVZ; Acquisition of data: Macedo R, Fernandes JL, Andrade SS, Rochitte CE, Maciel FC, Alves GSP, Diniz RVZ; Analysis and interpretation of the data: Macedo R, Fernandes JL, Andrade SS, Rochitte CE, Diniz RVZ; Statistical analysis: Macedo R, Fernandes JL, Rochitte CE, Lima KC, Maciel ACC, Diniz RVZ; Writing of the manuscript and Critical revision of the manuscript for intellectual content: Macedo R, Fernandes JL, Rochitte CE, Diniz RVZ.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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