Original Article

Percentile Curves of Normal Values of Echocardiographic Measurements in Normal Children from the Central-Southern Region of the State of São Paulo, Brazil

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Objective: To asses the values of echocardiographic measurements in normal children without cardiopathy and to build percentile curves, relating them to the body surface (BS, m^2).

Methods: We analyzed M-mode echocardiographic measurements for children between one and 144 months of age. We assessed right ventricular diastolic diameter (RVDd, mm) and left ventricular diastolic diameter (LVDd, mm), LV systolic diameter (LVSd, mm), right ventricular outflow tract diameter (RVOT, mm), aortic diameter (AoD, mm) and left atrial diameter (LAD, mm); left ventricular ejection fraction (LVEF, %); percentage of variation of left ventricular diameter (ΔLV, %); interventricular septum diastolic thickness (IVSDT, mm) and LV posterior wall diastolic thickness (PWDT, mm); left ventricular mass (LVM, g) and LV mass index (LVMI, g/m2).

Results: At the end of the study, 595 children (326 male) were assessed. The values of echocardiographic measurements showed a good correlation with BS and allowed the constructing of percentile curves (3%, 25%, 50%, 75% and 97%). Statistically significant differences between the genders were evidenced for the following variables: LVSd, LVDd, RVOT, AoD, LVM and LVMI, and the highest values were observed in male children.

Conclusion: The percentile curves of the values obtained can be used as a reference to assess children with suspicion of cardiopathy or to follow-up on those with diagnosed cardiopathy or under treatment with potentially cardiotoxic drugs.

Key words: Echocardiography, child, reference values, body surface area.

Echocardiography allows the non-invasive assessment of the dimensions and anatomy of the heart and its functional characteristics[1,2]. Because of these aspects this exam has become key to diagnose, assess the repercussions and follow-up on children and adolescents with suspicion of or with cardiopathy[2-6]. Many studies have used echocardiography to establish standards of normalcy for cardiac measurements in the population[7-13].

The values currently used as a reference of normalcy for cardiac dimensions in children derive from studies of the 1970s and 80s which included a small sample of infants, pre-school children and adolescents[1,5,14-18]. It is known that the major limitation of studies with population samples of children to obtain normalcy values is the fact that the results may be influenced by the number of individuals and by the characteristics of the population studied[19]. Therefore, it is necessary to estabilish values of reference based on a larger number of children including all age groups, and to take racial factors into account, as these factors can influence the values of cardiac measurements.

In our country, most echocardiographic services[20,21] use North-American standards as a reference for the values of echocardiographic measurements in children, which may lead to interpretation errors when assessing Brazilian children, since environmental, social, economic and racial factors can influence the anthropometric standards of a population[22].

The objectives of this study were to establish values for echocardiographic measurements in a sample of normal (eutrophic) and healthy children, correlating them with body surface (BS) and building percentile curves that relate the echocardiographic values studied with BS.

Methods

The study was approved by institution's Research Ethics Committee.

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We studied normal children aged between one and 144 months who attended the Pediatric Cardiology Division between January 1991 and December 2001, at central-

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southern region of the State of São Paulo-Brazil. The patients did not have heart disease or history of heart involvement due to infections, neuromuscular conditions or metabolic disorders, and did not have phenotypical characteristics of genetic syndromes. The children had come to the facility due to heart murmur and presented normal electrocardiographic and radiological tests. The echocardiographic exam was performed to definitely rule out the diagnosis of cardiopathy.

Data relative to gender, age, weight, height and echocardiographic measurement values were collected on the day the echocardiographic test was performed. Weight and height were used to calculate the BS in square meters (m^2), obtained using the DuBois & DuBois formula[23]. The body mass index (BMI), in kilograms per square meter (Kg/m^2), was calculated using Quetelet's index[24].

Children with protein energy malnutrition (PEM)[25,26] and obesity[25,26] were excluded as these conditions may influence cardiac measurements[27-34].

Echocardiographic tests were performed by two echocardiographers and 85% were performed by one of them. Interobserver variation verified in the Echocardiography Service of this hospital is below 10% and intraobserver variation is lower than 5% for the values of echocardiographic measurements used.

Echocardiographic images were obtained in standard precordial positions[1,35], following the recommendations of the *American Society of Echocardiography*[36]. The following pieces of echocardiographic equipment were used: one manufactured by Advanced Technology Laboratories, model Ultramark 8®, and the other manufactured by Hewlett Packard, model Sonos 2000®, with 3.0, 3.5 and/or 5.0 MHz transducers according to the child's age and weight, with simultaneous monitoring of one electrocardiographic lead. Approximately 80% of the tests were performed with the second piece of equipment.

The echocardiographic tests were performed on most of the children when they were awake and calm. Whenever necessary, we administered an oral 20 to 40 mg/Kg dose of chloral hydrate for sedation. This dose has no significant cardiovascular action[37].

After the standard complete echocardiographic test, with the ruling out of heart conditions, we obtained a transverse parasternal view to take the measurements used in the construction of the percentile curves. The echocardiographic measurement values and their derivatives were analyzed in the M-mode after the images had been guided by the bi-dimensional mode (Figs. 1 and 2). We considered the mean of three measurements for each echocardiographic variable assessed online. The measurements used were: right ventricular diastolic diameter (RVDd, mm), left ventricular systolic diameter (LVSd, mm) and diastolic diameter (LVDd, mm), left ventricular ejection fraction (LVEF, %), percentage of variation of left ventricular diameter (ΔLV, %), interventricular septum diastolic thickness (IVSDT, mm) and LV posterior wall thickness (PWDT, mm), right ventricular outflow tract diameter (RVOT, mm), aortic diameter (AoD, mm), left atrial diameter (LAD, mm), LV mass (LVM, g) and muscle mass index (LVMI, g/m^2). LV muscle mass (LVM) was estimated using the *Penn Convention*[38] formula adjusted for children[6] and LV mass index was (LVMI) was obtained by dividing LVM by BS. To calculate ΔLV and LVEF we used the following formulae: $\Delta LV (\%) = [(LVDd - LVSd) / LVDd] \times 100$ and $LVEF (\%) = [(LVDd^3 - LVSd^3) / LVDd^3] \times 100$[39].

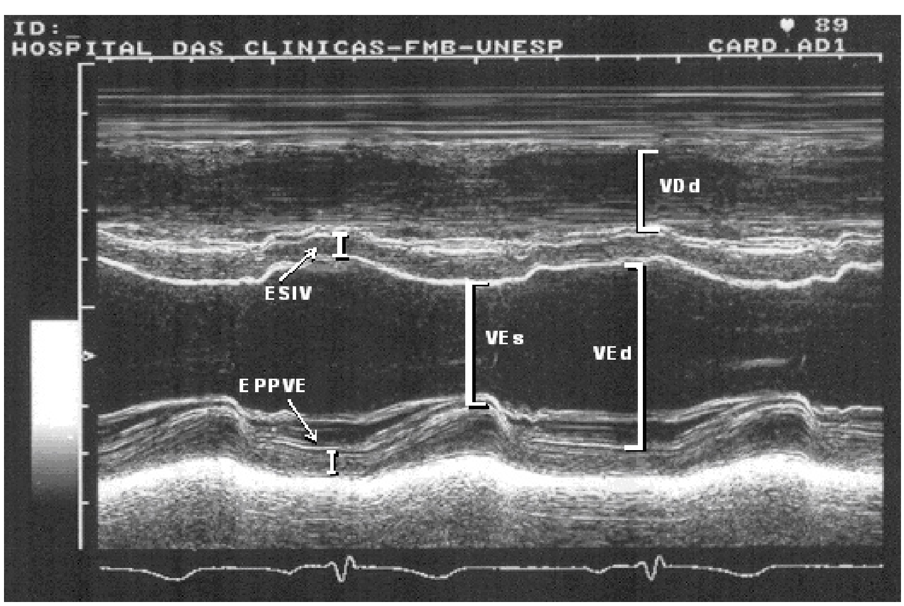

Fig. 1 – Illustration showing the sites where the measurements of the diastolic diameter of the right ventricle/RVDd (VDd in the figure) and left ventricle/LVDd (VEd in the figure), LV systolic diameter/LVSd (VEs in the figure), and diastolic thickness of interventricular septum/IVSDT (ESIV in the figure) and of the LV posterior wall/LVPWT (EPPVE in the figure) were taken.

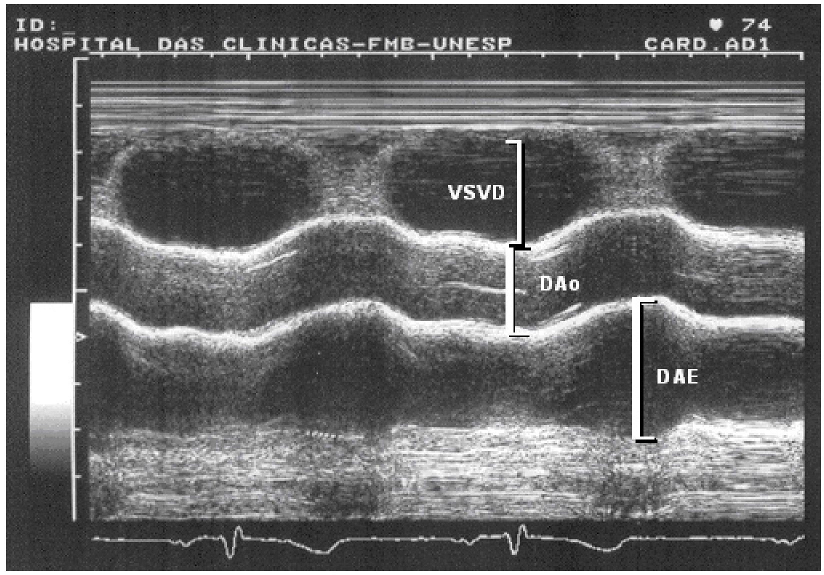

Fig. 2 – *Illustration showing the sites where the measurements of the diameter of the right ventricular outflow tract/RVOT (VSVD in the figure), of the aorta/AoD (DAo in the figure) and of the left atrium /LAd (DAE in the figure) were taken.*

	Overall (n = 595)	Male (n = 326)	Female (n = 269)
Age (months)	60.9 ± 40.1	60.8 ± 39.8	60.9 ± 40.5
Weight (Kg)	19.4 ± 9.3	19.5 ± 9.3	19.4 ± 9.4
Height (m)	1.05 ± 0.24	1.05 ± 0.24	1.05 ± 0.25
BS (m2)	0.74 ± 0.27	0.74 ± 0.27	0.74 ± 0.28
BMI (kg/m2)	16.6 ± 1.68	16.6 ± 1.61	16.6 ± 1.77
RVDd (mm)	13.2 ± 2.9	14.0 ± 3.8	13.7 ± 3.5
LVSd (mm)	20.8 ± 4.2	21.2 ± 4.4	20.3 ± 4.0*
LVDd (mm)	34.9 ± 3.5	35.5 ± 6.2	34.1 ± 5.8*
IVSDT (mm)	5.3 ± 0.9	5.4 ± 0.9	5.3 ± 0.8
PWDT (mm)	5.3± 0.9	5.4 ± 0.9	5.3 ± 0.9
RVOT (mm)	19.5 ± 3.9	19.9 ± 4.0	18.9 ± 3.6*
AoD (mm)	18.5 ± 3.6	18.9 ± 3.7	17.9 ± 3.3*
LAD (mm)	25.7 ± 4.7	26.0 ± 4.8	25.3 ± 4.7
LVM (g)	58.0 ± 26.8	60.6 ± 28.3	54.8 ± 24.6*
LVMI (g/m2)	76.6 ± 15.1	79.2 ± 15.0	73.5 ± 14.6*
LVEF (%)	78.5 ± 5.4	78.5 ± 5.6	78.5 ± 5.1
ΔLV (%)	40.5 ± 5.0	41.0 ± 5.0	40.0 ± 5.0

** $p < 0.05$ (male vs female). BS = body surface; BMI = body mass index; RVDd = right ventricular diameter; LVSd = left ventricular systolic diameter; LVDd = left ventricular diastolic diameter; IVSDT = interventricular septum diastolic thickness; PWDT = left ventricular posterior wall diastolic thickness; RVOT = right ventricular outflow tract diameter; AoD = aortic diameter; LAD = left atrial diameter; LVM = left ventricular mass; LVMI = left ventricular mass index; LVEF = left ventricular ejection fraction; ΔLV = Percentage of variation of left ventricular diameter; n = number of children; Kg = Kilogram; g = gram; m = meter; mm = millimeter; % = percentage.*

Table 1 – Values of means and standard deviations for age, anthropometric and echocardiographic measurements of all the children assessed, separated per gender.

Ecocardiographic measurements	Age			Weight			Height			BS		
	O	M	F	O	M	F	O	M	F	O	M	F
RVDd	0.63	0.63	0.64	0.64	0.64	0.65	0.63	0.64	0.64	0.64	0.64	0.65
LVSd	0.82	0.84	0.85	0.81	0.83	0.83	0.82	0.84	0.85	0.82	0.84	0.84
LVDd	0.88	0.91	0.91	0.89	0.91	0.91	0.90	0.92	0.92	0.90	0.92	0.92
IVSDT	0.80	0.83	0.82	0.81	0.84	0.83	0.81	0.84	0.83	0.81	0.84	0.83
PWDT	0.83	0.87	0.87	0.84	0.87	0.87	0.84	0.87	0.87	0.84	0.87	0.88
RVOT	0.71	0.75	0.74	0.72	0.76	0.76	0.71	0.76	0.76	0.72	0.76	0.76
AoD	0.86	0.86	0.85	0.86	0.85	0.84	0.87	0.86	0.85	0.87	0.86	0.85
LAD	0.79	0.81	0.79	0.81	0.82	0.81	0.80	0.82	0.80	0.81	0.82	0.81
LVM	0.91	0.93	0.93	0.92	0.93	0.93	0.92	0.94	0.94	0.92	0.94	0.94
LVMI	0.33	0.43	0.44	0.32	0.41	0.42	0.32	0.42	0.43	0.32	0.42	0.42

BS = body surface; RVDd = right ventricular diameter; LVSd = left ventricular systolic diameter; LVDd = left ventricular diastolic diameter; IVSDT = interventricular septum diastolic thickness; PWDT = left ventricular posterior wall diastolic thickness; RVOT = right ventricular outflow tract diameter; AoD = aortic diameter; LAD = left atrial diameter; LVM = left ventricular mass; LVMI = left ventricular mass index.

Table 2 – Values of Pearson's correlation coefficients of echocardiographic measurements relative to age, weight, height and body surface (BS) of all the children studied (O), and separately per gender male (M) and female (F).

The values of echocardiographic measurements were correlated with BS and enabled the construction of percentile curves (3%, 25%, 50%, 75% and 97%). We used the echocardiographic measurements of at least 20 children in each BS range to build the percentile curves.

Statistical analysis - The comparison between genders was carried out using Student's *t* test[40].

The associations between echocardiographic measurements and BS, weight, height and age were carried out using Pearson's Correlation Coefficient and the respective statistical test for equality of the coefficients obtained in both genders[40]. The study of the profile of echocardiographic variables was complemented with the construction of percentile curves, of which we highlight the following percentiles: 3%, 25%, 50%, 75% and 97%.

Considering that this is a transversal study, we stipulated a minimum of 500 children for a sample error of 2%. All statistical analyses were performed considering a level of significance of 5% ($p < 0.05$).

Results

At the end of the study, 595 children met the inclusion criteria, of which 326 (54.8 %) were male and 269 (45.2 %) were female. Sedation was necessary in approximately 10% of the children in the age group between six months and two years old. Interobserver variation was 8% and intraobserver variation was 5% for the values of echocardiographic measurements used.

The weight varied from 3.4 to 53.0 Kg; height varied from 0.51 to 1.60 meter and BS varied from 0.20 to 1.53 m^2. Table 1 presents the mean values and their respective standard deviations relative to age, weight, height, BS, BMI and echocardiographic measurements and those of their derivatives. It also presents the variation and comparison of these variables relative to gender. We observed statistically significant differences between the genders relative to LVSd, LVDd, AoD, RVOT, LVM and LVMI.

Table 2 presents the values of Pearson's Correlation Coefficients of echocardiographic measurements relative to weight, height, age and BS of all the children studied and according to gender. With the exception of LVMI, LVEF and ΔLV, all the echocardiographic measurements analyzed presented a good correlation with weight, height, BS and age. None of the echocardiographic measurements assessed in this study presented a good correlation with BMI. Pearson's Correlation Coefficients between the values of echocardiographic measurements and age, weight, height, BS and gender did not present statistically significant differences between them.

Table 3 presents the values of the 3%, 50% and 97% percentiles of each echocardiographic variable analyzed for BS adjusted at every 0.1 m^2 from 0.2 m^2 onwards considering all the children studied.

Tables 4 and 5 present the values of the 3%, 50% and 97% percentiles of the echocardiographic variables which presented statistically significant differences between the genders, considering male children (Tab. 4) and female children (Tab. 5) separately.

Figures 3 to 11 show the percentile curves (3%, 25%, 50%, 75% and 97%) of the echocardiographic variables analyzed relative to BS, considering all the children in the study.

Discussion

The reference values of echocardiographic measurements for children which are currently used in Brazil are based on standards of normalcy of populations of other countries[1,16], and it's important to establish national standards.

BS (m2)		RVDd (mm)	LVSd (mm)	LVDd (mm)	LVEF (%)	Δ LV (%)	IVSDT (mm)	PWDT (mm)	LVM (g)	LVMI (g/m2)	RVOT (mm)	AoD (mm)	LAD (mm)
0.2	**P50**	**9.0**	**19.5**	**32.0**	**81.9**	**43.0**	**3.7**	**3.7**	**12.0**	**53.5**	**13.0**	**11.5**	**16.0**
0.3	P3	9.3	17.3	29.0	66.8	31.0	3.4	3.5	12.7	44.3	11.0	11.0	14.0
	P50	**11.9**	**19.8**	**32.3**	**80.8**	**42.0**	**4.0**	**4.0**	**19.7**	**65.2**	**13.5**	**13.0**	**18.0**
	P97	14.5	21.6	35.5	88.7	52.0	4.9	4.5	32.0	101	16.9	15.0	22.0
0.4	P3	9.5	17.5	29.3	74.6	37.0	3.6	3.7	20.6	50.7	12.5	12.0	16.0
	P50	**12.3**	**19.9**	**32.9**	**79.9**	**41.0**	**4.3**	**4.3**	**28.3**	**70.4**	**15.0**	**15.0**	**21.0**
	P97	14.9	21.8	36.2	86.2	48.0	5.3	5.0	43.4	104	20.0	17.0	25.4
0.5	P3	9.6	17.5	29.6	71.7	34.0	3.7	3.9	25.7	52.1	13.4	13.0	18.0
	P50	**12.6**	**20.0**	**32.9**	**80.4**	**42.0**	**4.6**	**4.7**	**35.6**	**69.8**	**17.0**	**16.0**	**23.0**
	P97	15.8	21.9	36.4	87.5	50.0	5.7	5.5	51.0	98.6	22.0	18.7	27.0
0.6	P3	9.7	17.9	29.8	69.3	33.0	4.0	4.2	29.2	50.7	14.5	14.0	20.0
	P50	**12.7**	**20.1**	**33.1**	**79.1**	**41.0**	**5.0**	**5.0**	**45.3**	**75.8**	**18.0**	**17.0**	**24.5**
	P97	17.0	22.7	36.8	85.2	47.0	6.0	5.9	63.8	106.4	23.0	20.6	29.0
0.7	P3	9.8	18.0	30.0	67.5	31.0	4.2	4.4	35.8	46.8	15.5	15.0	21.5
	P50	**13.0**	**20.7**	**33.4**	**77.8**	**39.0**	**5.2**	**5.4**	**52.7**	**74.0**	**19.0**	**18.0**	**26.0**
	P97	18.1	23.8	37.5	86.3	48.0	6.2	6.2	73.0	99.0	25.0	22.0	31.0
0.8	P3	9.8	18.0	31.1	68.8	32.0	4.3	4.7	41.9	49.8	16.5	16.0	22.5
	P50	**13.4**	**21.3**	**34.6**	**79.0**	**41.0**	**5.5**	**5.7**	**64.5**	**79.1**	**20.0**	**19.0**	**27.5**
	P97	19.2	24.7	39.0	86.5	49.0	6.5	6.6	83.2	105.5	26.3	23.1	32.2
0.9	P3	9.9	18.0	31.2	68.8	32.0	4.8	4.9	52.6	57.9	17.0	17.0	24.0
	P50	**13.8**	**21.8**	**35.7**	**79.0**	**41.0**	**5.9**	**5.9**	**71.4**	**79.0**	**21.0**	**20.0**	**28.5**
	P97	20.1	26.1	40.5	85.2	47.0	6.9	6.8	97.3	106.2	27.8	23.9	33.4
1.0	P3	9.9	18.1	31.5	68.8	32.0	5.0	5.2	58.0	55.3	17.5	18.2	25.0
	P50	**14.2**	**21.9**	**36.1**	**77.3**	**39.0**	**6.2**	**6.1**	**79.7**	**79.7**	**22.0**	**21.0**	**29.5**
	P97	21.0	28.9	42.0	85.5	48.0	7.2	7.0	110.0	119.6	28.3	25.0	34.7
1.1	P3	9.9	18.3	31.7	62.5	28.0	5.5	5.5	69.5	62.0	18.1	19.0	26.0
	P50	**14.8**	**22.6**	**36.4**	**77.3**	**39.0**	**6.3**	**6.4**	**90.3**	**80.2**	**22.5**	**22.0**	**31.0**
	P97	21.8	30.1	43.5	86.4	49.0	7.3	7.1	121.0	104.0	28.4	26.1	35.7
1.2	P3	10.1	18.5	31.8	68.3	32.0	5.8	5.8	78.6	62.5	18.7	20.2	27.0
	P50	**15.3**	**23.5**	**37.0**	**78.4**	**40.0**	**6.5**	**6.7**	**101.2**	**82.2**	**23.0**	**23.0**	**32.0**
	P97	22.3	30.4	45.5	85.9	48.0	7.5	7.2	130.1	111.2	28.7	26.8	36.5
1.3	P3	10.2	18.6	31.8	72.3	35.0	6.0	6.0	85.0	62.5	20.5	20.7	28.0
	P50	**15.7**	**23.8**	**38.0**	**78.9**	**40.0**	**6.7**	**6.9**	**112.0**	**74.0**	**24.5**	**23.5**	**33.0**
	P97	22.8	30.7	47.4	88.9	52.0	7.6	7.3	138.3	113.4	29.0	27.2	37.5
1.4	P3	10.5	18.7	32.5	69.3	33.0	6.1	6.5	93.7	66.5	21.0	21.0	29.5
	P50	**16.4**	**24.2**	**40.0**	**77.9**	**40.0**	**7.0**	**7.0**	**124.0**	**89.9**	**25.0**	**24.2**	**34.0**
	P97	23.1	30.8	48.0	83.8	45.0	7.8	7.4	140.5	100.4	30.5	27.5	39.2
1.5	**P50**	**18.0**	**28.0**	**44.0**	**74.2**	**36.0**	**7.0**	**6.0**	**104.0**	**99.3**	**27.0**	**26.0**	**34.5**

BS = body surface; RVDd = right ventricular diameter; LVSd = left ventricular systolic diameter; LVDd = left ventricular diastolic diameter; LVEF = left ventricular ejection fraction; ΔLV = Percentage of variation of left ventricular diameter; IVSDT = interventricular septum diastolic thickness; PWDT = left ventricular posterior wall diastolic thickness; LVM = left ventricular mass; LVMI = left ventricular mass index; RVOT = right ventricular outflow tract diameter; AoD = aortic diameter; LAD = left atrial diameter .

Table 3 - 3%, 50% and 97% percentiles of the values of echocardiographic measurements relative to the body surface of all the children studied.

The analysis of the values of echocardiographic measurements according to the gender showed significant differences relative to LVSd, LVDd, RVOT, AoD, LVM and LVMI, with higher values for male children. Considering that there were no differences relative to age group, anthropometry and its derivatives studies, it is possible to conclude that these differences are gender-related, as is the case in other studies[41-43] Lester et al[41] studied 202 North American subjects from 25 days to 23 years of age, of which 125 were male (69 white and 56 black) and 77 were female (34 white and 43 black). The authors observed that the values of echocardiographic measurements were significantly higher for male children, when the BS was above one square meter. We also observed significant differences between the white and black races, with larger cardiac dimensions for black individuals. Nagasawa et al[42] studied 437 Japanese children, of which 264 were male and 173 were female, between one month and 17 years of age, with a history of Kawasaki disease without heart lesions. During the 6.7 year clinical follow-up, 1,595 echocardiographic tests were performed in this group of subjects. Analyzing the velocity of LVDd increase, the authors observed similar values for the velocity of growth and increase of LVDd measurement in both genders up to 10 years of age. Beyond this age, LVDd values were significantly higher for male subjects. In 2002, Nagasawa & Arakaki[43] assessed the diastolic and systolic thickness of the interventricular septum and of the LV posterior wall of 251 Japanese children, of which 128 were male and 123 were female, between one month and 18 years of age. The subjects were normal (eutrophic)and with no cardiopathy and were submitted to an echocardiographic test due to an innocent heart murmur. The authors reported that the values of some echocardiographic measurements were significantly higher in male children, particularly for BS above one square meter.

On the other hand, other studies carried out in other countries and in Brazil[5,13,17,18] found no significant differences between the values of cardiac measurements when the measurements for male and female were compared. Other Brazilian studies[5,17,18] assessed children within the same age groups as ours, but included samples with a small number of children. Therefore, there is controversy around the question of whether there is a difference between the values of cardiac measurements obtained by echocardiography when male and female children are compared. Our study comprised a representative population sample with a greater number of children in each age group analyzed as compared to the other studies mentioned above[5,17,18], which has probably enabled us to identify significant differences between both genders.

However, the difference of the values of the means of LVSd, LVDd, AoD and RVOT between both genders was small (Tab. 2), with higher values for male children. Although the differences between the values of echocardiographic measurements were statistically significant, from a biological point of view we can admit that this difference has little relevance, and that it is difficult to take it into consideration in our daily practice.

No significant differences were observed between the values of Pearson's correlation coefficients when we correlated the values of echocardiographic measurements studied with age, weight, height and BS. The same was observed when the values of Pearson's correlation coefficients were analyzed according to the gender, which is in agreement with the studies carried out by Rogé et al[1] and Kampmann et al[13].

There is no consensus in the literature about which anthropometric parameter presents a better correlation with the cardiac measurements assessed by echocardiography. Some studies show a better correlation with BS[6,34] and others with height[5,17,18]. In our study, we showed that for normal healthy children it makes no difference whether we correlate the values of echocardiographic measurements with age, weight, height or BS.

We used BS as an independent variable for the following reasons: there was no significant difference in the values of correlation coefficients between the values of echocardiographic measurements and age, weight, height and BS; the hemodynamic measurements are usually expressed relative to the BS; for determining the child's nutritional condition we need to know the weight and height that are in turn factored into the calculation of the BS; the currently available equipment calculates the BS; and also because several studies show a good correlation between cardiac dimensions and BS[13].

The comparison between the means of the 3% and 97% percentiles of the values of echocardiographic measurements of this study with the most widely used references[1,16] shows that the values of the echocardiographic measurements are very close. However, the number of individuals studied by these authors[1,16] was smaller than the number of children we studied. Additionally, the study by Rogé et al[1] was carried out before the publication of the recommendations of the *American Society of Echocardiography* [36].

The values of echocardiographic measurements found in our study are comparable to those obtained by Kampmann et al[13]. This similarity is possibly due to the inclusion of normal subjects in both studies, although there probably are racial differences between the two populations. It is also probable that, regardless of racial differences, cardiac measurements are proportionate with BS. The limits of the percentile curves and the mean values of the echocardiographic measurements we obtained are also passive of overlapping. Kampmann et al[13] obtained correlation coefficients with higher values than those found in our study. However, those authors used only the values corresponding to the 50% percentile of the echocardiographic variable for the calculation of the correlation coefficients, thus introducing a potential bias, since the dispersion of data was excluded from the calculation of the correlation coefficient.

We calculated the correlations considering all the individual values of each echocardiographic variable and also obtained a good correlation for several echocardiographic measurements, particularly for LVM, LVDd, AoD, PWDT, LVSd, LAD and IVSDT. We did not observe significant differences when the values of Pearson's correlation coefficients, using all the children in the study, were compared to those verified when children were analyzed separately according to gender. This finding shows that, although the values of some echocardiographic measurements presented significant differences, when the

BS (m2)		LVSd (mm)	LVDd (mm)	LVM (g)	LVMI (g/m2)	RVOT (mm)	AoD (mm)
0.2	**P50**	**11.0**	**20.0**	**11.8**	**53.5**	**13.0**	**11.0**
	P3	9.8	20.4	15.0	46.7	12.0	11.4
0.3	**P50**	**13.0**	**24.0**	**19.1**	**65.4**	**14.0**	**13.0**
	P97	17.0	26.6	28.6	88.2	15.0	14.0
	P3	13.8	25.6	22.0	53.3	13.6	14.0
0.4	**P50**	**16.0**	**28.0**	**27.7**	**71.8**	**15.0**	**15.0**
	P97	19.4	31.6	42.6	103.0	20.0	17.0
	P3	15.0	27.6	27.7	54.1	13.1	13.1
0.5	**P50**	**17.0**	**30.5**	**35.6**	**71.3**	**18.0**	**16.0**
	P97	21.0	34.0	47.7	94.2	22.0	20.9
	P3	17.2	30.0	29.8	50.8	15.0	16.0
0.6	**P50**	**20.0**	**34.0**	**47.7**	**77.2**	**18.0**	**17.5**
	P97	22.0	37.0	60.6	94.1	23.0	20.0
	P3	17.0	31.0	39.5	57.7	15.7	14.1
0.7	**P50**	**22.0**	**36.0**	**55.3**	**78.3**	**19.0**	**18.0**
	P97	26.0	40.0	75.1	105.3	23.0	22.0
	P3	19.0	34.0	50.1	65.0	18.0	17.0
0.8	**P50**	**22.5**	**37.3**	**67.4**	**85.6**	**21.0**	**20.0**
	P97	27.0	41.0	83.5	105.9	27.0	22.0
	P3	18.5	33.0	53.9	59.0	18.0	18.0
0.9	**P50**	**23.0**	**39.0**	**72.9**	**82.6**	**21.0**	**21.0**
	P97	26.0	43.0	101.3	107.9	29.0	24.0
	P3	20.0	36.7	68.1	67.2	18.4	17.2
1.0	**P50**	**25.0**	**41.0**	**84.9**	**85.3**	**23.0**	**22.0**
	P97	29.3	46.3	117.6	114.2	28.0	25.0
	P3	22.0	37.8	76.1	67.6	18.0	20.0
1.1	**P50**	**26.5**	**43.0**	**93.6**	**85.7**	**22.0**	**23.5**
	P97	30.0	46.3	114.9	104.3	27.0	28.3
	P3	22.5	39.3	79.5	65.2	19.1	21.5
1.2	**P50**	**27.5**	**44.5**	**102.8**	**85.3**	**23.5**	**24.0**
	P97	30.0	47.5	129.1	108.0	27.0	27.5
	P3	23.2	42.4	92.3	69.5	23.4	22.0
1.3	**P50**	**27.5**	**46.0**	**122.2**	**93.6**	**27.0**	**24.5**
	P97	30.0	48.8	141.6	110.6	30.6	28.2
	P3	23.5	41.5	95.2	68.9	23.5	24.1
1.4	**P50**	**29.5**	**47.5**	**128.3**	**94.7**	**27.5**	**26.0**
	P97	30.9	48.9	139.7	100.1	30.9	27.0
1.5	**P50**	**28.5**	**47.5**	**130.0**	**84.6**	**31.5**	**27.0**

BS = body surface; LVSd = left ventricular systolic diameter; LVDd = left ventricular diastolic diameter; LVM = left ventricular mass; LVMI = left ventricular mass index; RVOT = right ventricular outflow tract diameter; AoD = aortic diameter.

Table IV - 3%, 50% and 97% percentiles of the values of echocardiographic measurements that presented statistically significant differences relative to the body surface of male children.

BS (m2)		LVSd (mm)	LVDd (mm)	LVM (g)	LVMI (g/m2)	RVOT (mm)	AoD (mm)
0.2	**P50**	**13.0**	**23.0**	**18.0**	**75.4**	**13.0**	**12.0**
	P3	11.6	19.5	11.4	40.7	9.7	10.6
0.3	**P50**	**14.0**	**23.5**	**20.4**	**62.7**	**13.0**	**13.0**
	P97	17.4	29.0	32.9	102.8	16.0	15.0
	P3	13.8	23.8	20.5	50.9	12.8	12.8
0.4	**P50**	**16.0**	**28.0**	**29.3**	**69.8**	**16.0**	**15.0**
	P97	19.4	31.9	43.5	105.2	19.4	17.0
	P3	15.0	26.0	24.4	51.3	13.9	13.0
0.5	**P50**	**18.0**	**30.0**	**35.6**	**68.4**	**18.0**	**15.0**
	P97	20.2	33.1	46.9	99.7	22.1	17.1
	P3	15.9	28.7	31.2	56.2	14.9	14.0
0.6	**P50**	**19.5**	**32.0**	**43.2**	**74.0**	**18.0**	**16.5**
	P97	23.9	37.0	66.5	107.0	21.3	19.1
	P3	18.0	29.2	32.6	44.4	15.1	15.1
0.7	**P50**	**21.0**	**35.0**	**50.2**	**71.5**	**18.0**	**17.5**
	P97	24.0	38.0	65.8	95.9	23.7	20.8
	P3	18.0	29.5	41.2	49.6	16.0	12.0
0.8	**P50**	**21.5**	**37.0**	**60.1**	**77.7**	**20.0**	**19.0**
	P97	26.0	40.5	80.3	98.6	25.5	21.3
	P3	19.8	32.9	52.4	57.8	14.9	17.9
0.9	**P50**	**22.5**	**38.0**	**69.0**	**74.1**	**20.0**	**20.0**
	P97	26.1	40.0	76.5	89.1	25.1	24.0
	P3	17.3	34.2	52.3	52.4	17.5	18.5
1.0	**P50**	**24.0**	**40.0**	**77.3**	**76.0**	**21.0**	**21.0**
	P97	26.9	42.9	112.0	109.9	24.0	25.0
	P3	18.5	34.0	59.5	53.9	19.5	19.5
1.1	**P50**	**24.0**	**41.0**	**78.8**	**72.3**	**23.0**	**21.0**
	P97	31.0	43.5	99.7	88.5	27.5	23.5
	P3	22.0	39.3	85.4	69.1	17.1	19.5
1.2	**P50**	**24.5**	**42.0**	**100.7**	**82.1**	**22.0**	**22.0**
	P97	28.5	47.0	126.5	104.2	28.7	24.0
	P3	24.1	39.8	88.1	37.9	20.3	19.5
1.3	**P50**	**24.5**	**42.0**	**110.8**	**70.7**	**24.5**	**23.0**
	P97	28.0	47.4	126.2	82.3	28.8	25.0
	P3	24.4	43.1	101.2	74.6	20.3	21.0
1.4	**P50**	**28.5**	**45.5**	**120.6**	**86.8**	**23.0**	**23.5**
	P97	29.0	47.9	128.0	92.9	29.4	26.0

BS = body surface; LVSd = left ventricular systolic diameter; LVDd = left ventricular diastolic diameter; LVM = left ventricular mass; LVMI = left ventricular mass index; RVOT = right ventricular outflow tract diameter; AoD = aortic diameter.

Table V - 3%, 50% and 97% percentiles of the values of echocardiographic measurements that presented statistically significant differences relative to the body surface of female children.

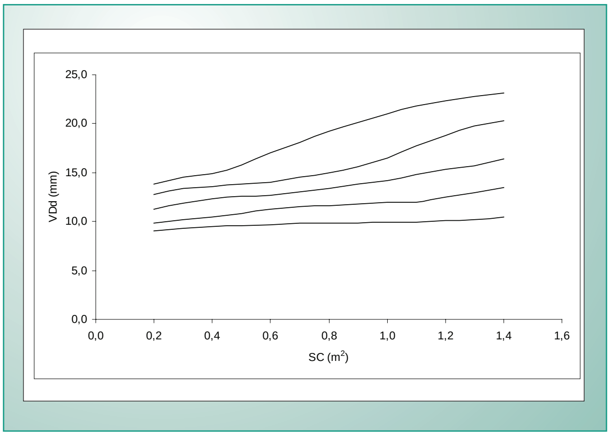

Fig. 3 – Percentile curves of the diastolic diameter of the right ventricle/RVDd (VDd in the graph) relative to the body surface/BS (SC

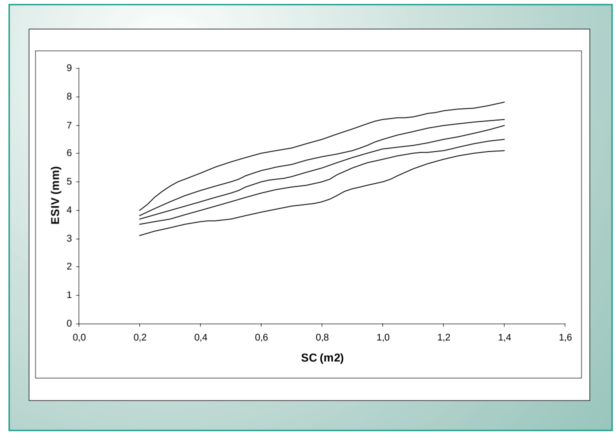

Fig. 6 – Percentile curve for interventricular septum diastolic thickness/IVSDT (ESIV in the graph) relative to body surface/BS (SC in the graph)

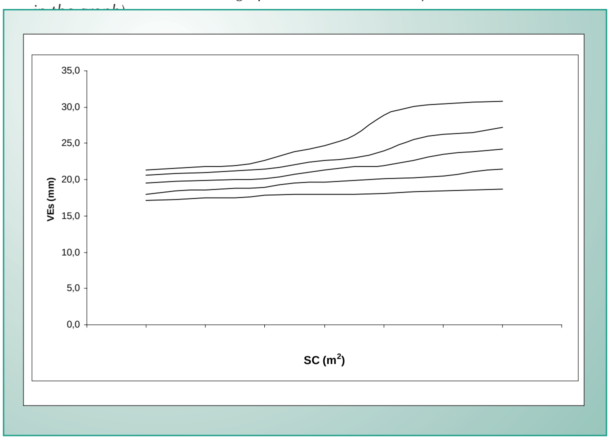

Fig. 4 - Percentile curves for left ventricular systolic diameter/LVSd (VEs in the graph) relative to the body surface/BS (SC in the graph)

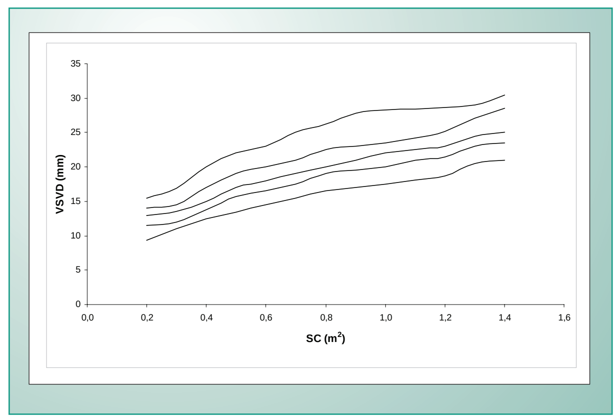

Fig. 8 – Percentile curves for the right ventricular outflow tract diameter/RVOT (VSVD in the graph) relative to body surface/BS (SC in the graph)

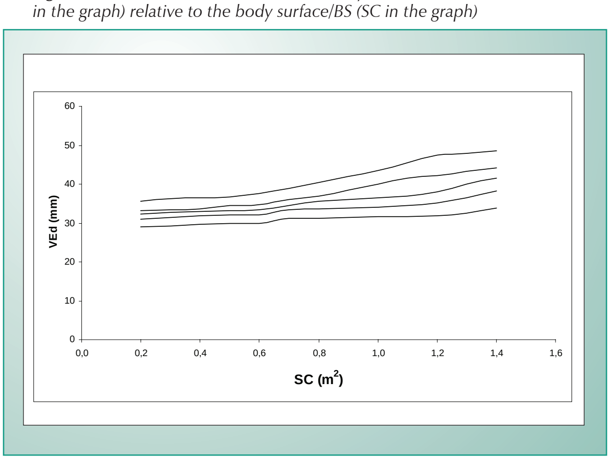

Fig. 5 – Percentile curves for the LV diastolic diameter/LVDd (VEd in the graph) relative to the body surface/BS (SC in the graph)

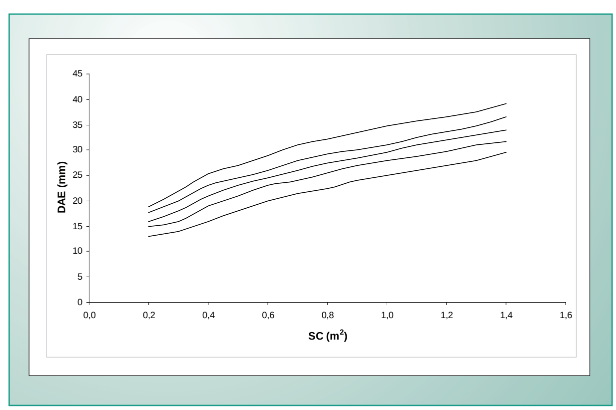

Fig. 10 – Percentile curves for the diameter of the left atrium/LAD (DAE in the graph) relative to body surface/BS (SC in the graph)

children are separated per gender, these differences did not change the values of Pearson's correlation coefficients in a significant manner.

The 3% and 97% percentiles were chosen as the lower and upper limits, respectively, for the construction of the percentile curves, as they fall approximately within two standard deviations of mean according to the Gaussian distribution curve[40]. Additionally, we built 25%, 50% and 75% percentile curves so that these curves may be used in the future to monitor cardiac remodeling during the clinical treatment of children with congenital or acquired cardiopathy, and to follow their surgical repair, or heart involvement as a result of other conditions such as malnutrition, obesity and systemic arterial hypertension.

Since we observed statistically significant differences between the genders for the LVSd, LVDd, RVOT, AoD, LVM

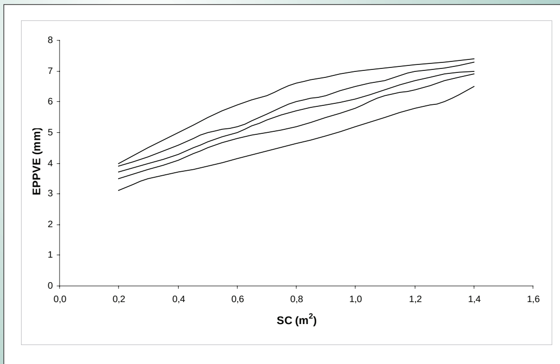

Fig. 7 – Percentile curve for LV posterior wall diastolic thickness/PWDT (EPPVE in the graph) relative to body surface/BS (SC in the graph)

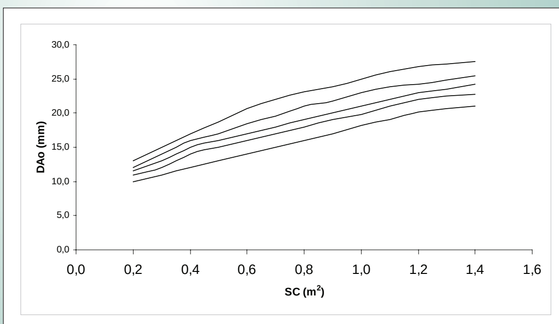

Fig. 9 – Percentile curves for the diameter of the aortic valve/AoD (DAo in the graph) relative to body surface/BS (SC in the graph)

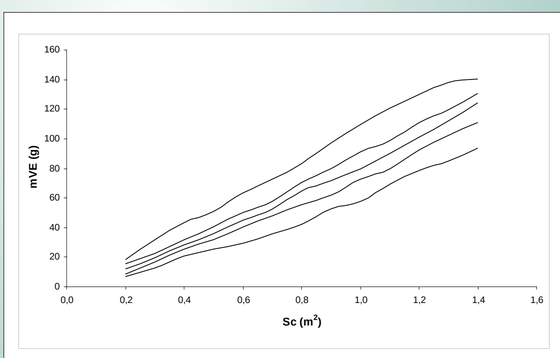

Fig. 11 – Percentile curves for LV muscle mass/LVM (MVE in the graph) relative to body surface/BS (SC in the graph)

and LVMI echocardiographic variables, the values of the 3%, 50% and 97% percentiles of these variables relative to the BS are presented in separate tables (Tabs. 4 and 5).

Clinical implications - This is a study on effectiveness, since it was carried out in situations that occur everyday, with children with heart murmur who were assessed to rule out cardiopathy.

The results verified add data and contribute to better determine the lower and upper limits of cardiac dimensions and of cardiac performance indexes obtained by echocardiography in normal children between one and 144 months of age.

Considering that the values of the measurements and the indexes of cardiac performance were established based on normal children without cardiopathy, we can admit than it can be used as parameters of reference during the follow-up of children with cardiopathy, and of those who have undergone surgical treatment. Additionally, the data are useful to assess the cardiac dimensions and the degree of heart involvement in children with PEM, obesity and systemic arterial hypertension, conditions which are currently very common in Brazil.

Percentile curves allow the quantification of the degree of deviation from normalcy, and allow the assessment, as time elapses, of the changes that are characteristic of cardiac remodeling in children with primary cardiopathy, and of those associated with systemic diseases. Therefore, the percentile curves allow the more accurate quantification of the degree of deviation from normalcy and the identification of risk factors and cardiovascular prognosis relative to several conditions that affect children in the age group studied.

This study also allows the validation of the studies carried out by Rogé et al[1] and Henry et al[16], for Brazil. These two studies are the most widely used as reference for values of echocardiographic measurements in our country. Additionally, the results obtained enabled the construction of percentile curves for values of cardiac measurements relative to the BS, which provides more information to the literature relative to the study by Kampmann et al[13].

In summary, the results show statistically significant differences between genders for the following cardiac measurements: LVSd, LVDd, LVM, LVMI, RVOT and AoD, indicating that, in children, gender should be considered when echocardiographic measurements are analyzed. The values found overlap those reported for other ethnic groups of normal children in the same age group. The percentile curves built in this study provide more data to the literature and enable the monitoring of cardiac remodeling in children with cardiopathies and/or systemic diseases involving the heart.

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Potential Conflict of Interest

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

Referências

1. Rogé CL, Silverman NH, Hart PA, Ray RM. Cardiac structure growth pattern determined by echocardiography. Circulation. 1978;57:285-90.
2. Phoon CKL, Divekar A, Rutkowski M. Pediatric echocardiography: applications and limitations. Curr Probl Pediat. 1999;29:162-85.
3. Henry WL, Ware J, Gardin JM, Hepner SI, McKay J, Weiner M. Echocardiographic measurements in normal subjects. Growth-related changes that occur between infancy and early adulthood. Circulation. 1978;57:278-85.
4. Feigenbaum H. Echocardiography. 3rd ed. Philadelphia: Lea & Febiger,

1981.

5. Schneider C, Cabizuca SV, Benchimol CB, Matsunaga LA, Ginefra P, Albanezi Filho FA, et al. Padrões ecocardiográficos normais em crianças da cidade do Rio de Janeiro. I. Relação entre medidas ecocardiográficas e padrões antropométricos. Arq Bras Cardiol. 1986;47:139-92.

6. Huwez FU, Houston AB, Watson J, McLaughlin S; Macfarlane PW. Age and body surface area related to normal upper and lower limits of M mode echocardiographic measurements and left ventricular volume and mass from infancy to early adulthood. Br Heart J. 1994;72:276-80.

7. Devereux RB, Liebson PR; Horan MJ. Recommendations concerning use of echocardiography in hypertension and general population research. Hypertension. 1987; 9 (Suppl. II): 97-104.

8. Savage DD, Garrison RJ, Kannel WB, Andersosn SJ. Considerations in the use of echocardiography in epidemiology: The Framingham Study. Hypertension. 1987;9(Suppl. II): 40-44.

9. Ascione L, De Leva F, Cuomo S, Caso MSP, Cioppa L, Mininni N. Reference values for the echocardiographic calculation of left ventricular mass in normal children between the ages of 0 and 6 years. G Ital Cardiol. 1992;22:829-34.

10. Dai S, Ayres NA, Harrist, RB, Bricker T, Labarthe DR. Validity of echocardiographic measurement in an epidemiological study – Project HeartBeat. Hypertension. 1999;34:236-41.

11. Kampmann C. Echokardigrafishce Normwerte im Kinderslater. In: Schmalilzl KJG, ed. Kardiale Ultraschalldiagmostik, Handbuch und Atlas. Berlin: Blackwell Wissenschaft, 1994. p.389-91.

12. Schvartzman PR, Fucks FD, Mello AG, Coli M, Schvartzman M, Moreira LB. Valores normais de medidas ecocardiográficas. Um estudo populacional. Arq Bras Cardiol. 2000;75:107-14.

13. Kampmann C, Wiethoff CM, Wenzel A, Stolz G, Betancor M, Wippermann CF, et al. Normal values of M mode echocardiographic measurements of more than 2000 healthy infants and children in central Europe. Heart. 2000;83:667-72.

14. Epstein ML, Goldberg ST, Allen HD, Konecke L, Wood J. Great vessel, cardiac chamber and wall growth patterns in normal children. Circulation. 1975;51:1124-9.

15. Gutgesell HP, Paquet M, Duff DR, McNamara DG. Evaluation of left ventricular size and function by echocardiography. Results in normal children. Circulation. 1977;56:457-62.

16. Henry WL, Gardin JM, Ware JH. Echocardiographic measurements in normal subjects from infancy to old age. Circulation. 1980;62:1054-60.

17. Schneider C, Cabizuca SV, Benchimol CB, Matsunaga LA, Ginefra P, Albanesi Filho FM, et al. Padrões ecocardiográficos normais em crianças da cidade do Rio de Janeiro. II. Medidas dos diâmetros, dimensões, espessuras de estruturas cardíacas e movimentos valvulares. Arq Bras Cardiol. 1986;47:253-8.

18. Schneider C, Cabizuca SV, Benchimol CB, Matsunaga LA, Ginefra P, Albanesi Filho FM, et al. Padrões ecocardiográficos normais em crianças da cidade do Rio de Janeiro. III. Avaliação das dimensões e funções do ventrículo esquerdo. Arq Bras Cardiol. 1986;47:335-40.

19. DerSimoniam R, Levine RJ. Resolving discrepancies between a meta-analysis and a subsequent large controlled trial. JAMA. 1999;282:664-70.

20. Morcef FAP. Ecocardiografia uni-bidimensional, transesofágica e Doppler. 2a ed. Rio de Janeiro: Livraria e Editora Revinter; 2001.

21. Martins TC, Soares AM. Ecocardiograma normal em crianças. In: Ramires JAF ed. Cardiologia em Pediatria: temas fundamentais. São Paulo: Roca; 2000. p. 53-81.

22. Marcondes E, Berquó ES, Yunes J, Luongo J, Martins JS. Estudo antropométrico de crianças brasileiras de zero a doze anos de idade. Anais Nestlé. 1971; 84: 10-5.

23. DuBois D, DuBois EF. A formula to estimate the approximate surface area if height and weight be known. Arch Intern Med. 1916;17:863-71.

24. Garrow JS, Webster J. Quetelet´s index (W/H2) as a measure of fatness. Int J Obes. 1985;9:147-53.

25. World Health Organization. Physical status: the use and interpretation of antropometry. Genebra; 1995. Technical Report Series 854.

26. Must A, Dallal GE, Dietz WH. Reference data for obesity: 85th and 95th percentiles of body mass index (wt/ht2) – a correction. Am J Clin Nutr. 1991;54:773.

27. Singh GR, Malathi KE, Kasliwal RR, Ommar A, Padmavati S, Ramji S. An evaluation of cardiac function in malnourished children by non-invasive methods. Indian Pediatr. 1989; 26:875-81.

28. Kothari SS, Patel TM, Shetalwad AN, Patel TK. Left ventricular mass and function in children with severe protein energy malnutrition. Int J Cardiol. 1992:35:19-25.

29. Phornphatkul C, Pongprot Y, Suskind R, George V, Fuchs G. Cardiac function in malnourished children. Clin Pediatr. 1994;33:147-54.

30. Gelb BD, Abdenur J. Metabolic heart disease. In: Garson A, Bricker TJ, Fisher DJ, Neish JR (eds.). The science and practice of pediatric cardiology.2nd ed. Baltimore: Williams & Wilkins; 1998. p. 1913.

31. Öcal B, Ünal S, Zorlu P, Tezic HT, Oguz D. Echocardiographic evaluation of cardiac functions and left ventricular mass in children with malnutrition. J Paediatr Child Health. 2001; 37:14-7.

32. Okoshi MP, Okoshi K, Pai VD, Pai-Silva MD, Matsubara LS, Cicogna AC. Mechanical, biochemical, and morphological changes in the heart from chronic food-restricted rats. Can J Physiol Pharm. 2001;79:754-60.

33. Fioretto JR, Queiroz SS, Padovani CR, Matsubara LS, Okoshi K, Matsubara BB. Ventricular remodeling and diastolic myocardial dysfunction in rats submitted to protein-calorie malnutrition. Am J Physiol Heart Circ Physiol. 2002;282:H1327-33.

34. de Simone G, Daniels SR, Devereux RB, Meyer RA, Roman MJ, De Vittis O, et al. Left ventricular mass and body size in normotensive children and adults: Assessment of allometric relations and impact of overweight. J Am Coll Cardiol. 1992;20:1251-60.

35. Popp RL. Echocardiographic assessment of cardiac disease. Circulation. 1976;54:538-41.

36. Sahn DJ, DeMaria A, Kisslo J, Weyman A. The Committee on M-Mode standardization of the American Society of Echocardiography. Recommendations regarding quantitation in M-mode Echocardiography: results of a survey of echocardiographic measurements. Circulation. 1978;58:1072-83.

37. Coté CJ. Sedação no paciente pediátrico – uma revisão. In: Wetzel RC, ed. Clínicas Pediátricas da América do Norte. Rio de Janeiro: Interlivros; 1994. p. 35-66.

38. Devereux RB, Reichek N. Echocardiographic determination of left ventricular mass in man: anatomic validation of the method. Circulation. 1977;55:613-8.

39. Pombo JF, Troy BL, Russel RO Jr. Left ventricular volumes and ejection fraction by echocardiography. Circulation. 1971;43:26-33.

40. Zar JH. Biostatistical analysis. 4th ed. New Jersey: Prentice-Hall, 1999.

41. Lester LA, Sodt PC, Hutcheon N. M-mode echocardiography in normal children and adolescents: some new perspectives. Pediatr Cardiol. 1987;8:27-33.

42. Nagasawa H, Arakaki Y, Yamada O, Nakajima T, Kamiya T. Longitudinal observations of left ventricular end-diastolic dimension in children using echocardiography. Pediatr Cardiol. 1996; 17:169-74.

43. Nagasawa H, Arakaki Y. Identification of gender differences in the thickness of the left ventricular wall by echocardiography in children. Cardiol Young. 2002; 12:37-43.