Measurement of M-mode Echocardiographic Parameters in Healthy Adult Persian Cats

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ABSTRACT

Accurate echocardiographic assessment of cardiac function and establishing a diagnosis requires knowledge of normal echocardiographic indices. Although several studies have addressed the normal echocardiographic values in different breeds of dogs and cats, no study has specifically measured these variables in a population of Persian cats. We performed two-dimensional and M-mode echocardiography on a total of 76 healthy, adult Persian cats without sedation. The 16 echocardiographic indices were then compared between male and female cats. Our findings indicate a significant difference in end-diastole left ventricular free wall thickness between females and male Persian cats (female: 6.38 vs male: 7.11 mm; p-value = 0.01). Also, the heart rate, end-diastole left ventricular free wall thickness, and end-diastole left ventricular volume were lower in females compared to males, although the difference was barely significant (all p values = 0.05). Considering the popularity of Persian cats as pets and their susceptibility to cardiomyopathy diseases, the findings of this study may be used as a basis for further research on abnormal cardiac conditions in this breed of cats.

Key Words: echocardiography, normal value, Persian cat.

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INTRODUCTION

Echocardiography constitutes an essential tool for diagnosing congenital and acquired diseases of the heart as it allows for thorough evaluation and understanding of the cardiac function. Therefore, it is of utmost importance to have accurate and reliable normal values of echocardiographic variables to enable comparison in cases suspected of cardiac diseases.

Cardiomyopathies are the most common diseases of the heart in cats; their prevalence is reported as high as 66%, with hypertrophic cardiomyopathy (HCM) being the most frequent [1-3]. Furthermore, among all cat breeds, the Sphynx, Ragdoll, Persian, and Maine Coon cats have been reported to be the most susceptible to cardiomyopathies [4].

Numerous studies have been undertaken to determine normal echocardiographic values in cats and dogs [5-13]. In the beginning in the early 1980s, these studies have progressed to address the effect of different variables such as sex, weight, age, sedation, and anesthesia, and their findings show that some echocardiographic values are indeed influenced by the abovementioned variables [14-21]. Earlier studies were conducted on populations of cats and dogs regardless of their breed; however, over time and with advances in echocardiography, some researchers have reported echocardiographic values in different dog breeds, with results indicating significant differences between different breeds [18, 19, 22-27]. These findings led to more extensive studies; currently, specific echocardiographic reference values are available for at least 26 dog breeds [5, 18, 19, 23, 24, 26-28]. On the other hand, similar studies in cats are more limited [29-35].

In 2005, normal values of M-mode echocardiography were first reported in Maine Coon cats, indicating significant

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differences in some parameters compared to the domestic short-haired (DSH) cats [29]. Subsequent studies on different breeds including Sphynx [30, 31], British Shorthair [32], Turkish Van [33], Bengal [34], and Indonesian domestic cats [35] indicate significant differences in certain echocardiographic values between these breeds and DSH cats.

Persian cats are among the oldest and best-known breeds of cats. This breed was introduced to Europe in the 16th century and is currently one of the most popular pets in Iran and many other countries. Its calm personality has made it quite appropriate for apartment life. The life span of a Persian cat is approximately 10 years, but it may live up to 19 years under optimal conditions.

Considering the paucity of studies on normal echocardiographic values in Persian cats, the current study was undertaken to determine the two-dimensional and motion (M-mode) echocardiographic values without sedation in healthy, adult Persian cats in two veterinary care centers in Tehran, Iran.

METHODS AND MATERIALS

Sample:

We recruited a total of 76 clinically healthy, young adult Persian cats (41 males and 35 females) which were referred to the small animal polyclinics of the Veterinary Sciences Faculty, Science and Research Branch of the Islamic Azad University, Tehran, and the Central Veterinary Hospital, Tehran, during summer and fall of 2017.

Clinical Assessment:

Initially, the cats were assessed in terms of their appearance, and those complying with the current standards of the purebred Persian cat were admitted to the study. Subsequently, a questionnaire was assigned to each cat to gather information on sex, age, weight, and body score as well as the results of clinical, electrocardiographic and echocardiographic studies.

An internist proceeded to interview the owners regarding the health history of the animals, performed a general physical examination and cardiopulmonary auscultation, and documented the findings in the questionnaires. To further verify the cardiac health of the subjects, the animals underwent electrocardiography (ECG-1103 GVet, Carewell, Shenzhen, China) in a completely quiet environment at an appropriate temperature, and the findings were interpreted by an internist specializing in small animals.

It must be noted that no form of sedation or anesthesia was used in any stage of the evaluation, and the animals were restrained on the table with the help of an assistant pulling the arms anteriorly. Electrocardiography was performed on a table with insulated padding. To reduce the animal's stress, it was lightly strained on the table for 5 to 10 minutes before ECG.

The results of clinical examination and ECG were meticulously documented. An animal with an abnormal finding in any item (e.g. heart murmurs on auscultation, signs of cardiomyopathy on ECG) was removed from the study. It is noteworthy that in addition to the above, any finding suggestive of congenital or acquired cardiac disease on echocardiography would also remove the animal from the final analysis.

Echocardiographic assessment:

Animals considered healthy according to clinical examination and ECG study were prepared for echocardiography. The animal was first shaved in the right axillary area and placed on an echocardiography table. Echocardiography was undertaken in a quiet environment using a portable Mindray M5 Ultrasound system with a 7MHz Micro-convex probe (Mindray Bio-Medical Electronics Co., China) and portable Titan Ultrasound system with 5-8 MHz Micro-convex probe (SonoSite, WA, USA). Echocardiography was performed on the right side on standard longitudinal and transverse axes of the heart in two-dimensional, motion, and Doppler (color, pulsed) modes.

A total of 16 echocardiographic parameters were assessed in this study, namely: heartbeats per minute, aortic root diameter, left atrial diameter in ventricular systole, left atrial diameter to aortic diameter ratio, interventricular septum thickness in diastole, interventricular septum thickness in systole, end-diastole left ventricular internal diameter, end-systole left ventricular internal diameter, left ventricular free wall thickness in diastole, left ventricular free wall thickness in systole, end-diastole left ventricular internal volume, end-systole left ventricular internal volume, E-point septal separation, stroke volume, ejection fraction, and left ventricular fractional shortening in M-mode echocardiography.

Statistical Analysis:

All data were collected on standard forms and analyzed. Continuous variables were described using mean and standard deviation. The student's t-test was used to compare echocardiographic variables between the two sexes. All statistical analyses were performed using Statistical Package for Social Sciences version 18 (SPSS, IBM, USA).

RESULTS

A total of 76 adult Persian cats (42 males and 35 females) underwent echocardiography. The cats were aged 1-7 years, with a mean ± standard deviation (SD) of 3.21 ± 1.63 years. The age of females ranged from 1 to 7 years (mean, 3.22 ± 1.67 years) and that of males ranged from 1 to 6.5

years (mean, 3.20 ± 1.63 years). The animals weighed 2.2 to 7.1 Kg (mean, 3.96 ± 1.11 Kg). The females weighed 2.2 to 5.6 Kg (mean, 3.52 ± 0.86 Kg) while the males weighed 2.3 to 7.1 Kg (mean, 4.33 ± 1.18 Kg), indicating a significant difference (p-value = 0.01). Table 1 presents the age and weight variables for the study samples.

Table 1: Age and weight variables in the sample of 76 Persian cats

Variable	N	Mean	*SD*	Range	
				Min	Max
Age (years)	76	3.21	1.63	1	7
Weight (kg)	76	3.96	1.11	2.2	7.1

Table 2 presents the measurements of echocardiographic variables in the entire population of 76 Persian cats.

Table 2: Echocardiographic indices in Persian cats (n = 76)

Variable	mean	SD	SE	Range		95% CI
				Min	Max	
HR (bpm)	**168.1**	**28.7**	**3.3**	**105**	**230**	**161.6 – 174.7**
AOD (mm)	**8.76**	**1.22**	**0.14**	**6.3**	**11.3**	**8.49 – 9.05**
LAD (mm)	**10.29**	**1.49**	**0.17**	**6.8**	**14.0**	**9.95 – 10.63**
LAD/AOD	**1.17**	**0.09**	**0.01**	**1.01**	**1.46**	**1.15 – 1.19**
IVSd (mm)	**4.18**	**0.94**	**0.10**	**2.8**	**7.9**	**3.97 – 4.40**
IVSs (mm)	**6.54**	**0.97**	**0.11**	**4.8**	**9.4**	**6.33 – 6.77**
LVIDd (mm)	**14.59**	**1.79**	**0.20**	**10.1**	**18.7**	**14.19 – 15.01**
LVIDs (mm)	**7.12**	**1.39**	**0.16**	**3.6**	**9.5**	**6.80 – 7.44**
LVPWd (mm)	**4.04**	**0.83**	**0.09**	**2.3**	**6.6**	**3.85 – 4.24**
LVPWS (mm)	**6.77**	**1.34**	**0.15**	**4.2**	**10.4**	**6.47 – 7.08**
EDV (ml)	**5.80**	**1.81**	**0.20**	**2.11**	**10.70**	**5.39 – 6.22**
ESV (ml)	**0.86**	**0.42**	**0.04**	**0.12**	**1.79**	**0.77 – 0.97**
EPSS (mm)	**1.24**	**0.46**	**0.05**	**0.3**	**2.1**	**1.14 – 1.35**
SV (ml)	**4.93**	**1.60**	**0.18**	**1.90**	**8.96**	**4.57 – 5.30**
EF (%)	**84.95**	**5.80**	**0.66**	**76.19**	**96.41**	**83.63 – 86.28**
FS (%)	**51.16**	**7.64**	**0.87**	**41.44**	**70.27**	**49.42 – 52.91**

All measurements were compared between male and female cats (Table 3). The mean heart rate of all cats was 168.1 beats/min, which was higher for the females compared to males (175.0 vs 162.2; p-value = 0.05). The mean end-diastole left ventricular free wall thickness was 4.04 mm for all cats, which was 3.84 mm in females and 4.21 mm in males, indicating a barely significant difference (p-value = 0.05). Furthermore, the end-systole left ventricular free wall thickness was 6.77 mm for all cats, which was significantly lower in females compared to males (6.38 vs 7.11 mm; p-value = 0.01). Also, the mean end-diastole left ventricular

Volume was 5.80 mL for all cats, which was smaller in females compared to males (5.38 vs 6.16 mL; p-value = 0.05).

Table 3: Echocardiographic indices by sex in female (n = 35) and male (n = 41) Persian cats

Variable	Female			Male			P-Value
	Mean ± SD	Range	95% CI	*Mean ± SD*	Range	95% CI	
HR (bpm)	**175 ± 25.99**	**116 – 229**	**166.07 – 183.93**	**162.29 ± 29.81**	**105 – 230**	**152.88 – 171.70**	0.05
AOD (mm)	**8.58 ± 1.01**	**6.5 – 11.3**	**8.23 – 8.93**	**8.92 ± 1.36**	**6.3 – 11.2**	**8.49 – 9.35**	0.22
LAD (mm)	**9.96 ± 1.24**	**6.8 – 12.7**	**9.54 – 10.39**	**10.56 ± 1.64**	**7.1 – 14.0**	**10.04 – 11.08**	0.08
LAD/AOD	**1.15 ± 0.07**	**1.04 – 1.40**	**1.13 – 1.18**	**1.18 ± 0.10**	**1.01 – 1.46**	**1.15 – 1.21**	0.37
IVSd (mm)	**3.98 ± 0.76**	**2.80 – 5.70**	**3.71 – 4.24**	**4.36 ± 1.04**	**2.9 – 7.9**	**4.03 – 4.69**	0.11
IVSs (mm)	**6.33 ± 0.86**	**5.00 – 8.30**	**6.03 – 6.62**	**6.73 ± 1.03**	**4.8 – 9.4**	**6.40 – 7.06**	0.08
LVIDd (mm)	**14.24 ± 1.36**	**12.0 – 17.30**	**13.77 – 14.71**	**14.89 ± 2.05**	**10.1 – 18.7**	**14.24 – 15.54**	0.10
LVIDs (mm)	**6.99 ± 1.23**	**4.7 – 9.5**	**6.56 – 7.41**	**7.23 ± 1.52**	**3.6 – 9.5**	**6.75 – 7.71**	0.45
LVPWd (mm)	**3.84 ± 0.62**	**2.5 – 5.2**	**3.63 – 4.06**	**4.21 ±0.95**	**2.3 – 6.6**	**3.91 – 4.51**	0.05
LVPWS (mm)	**6.38 ± 1.05**	**4.2 – 8.3**	**6.01 – 6.74**	**7.11 ± 1.48**	**4.8 – 10.4**	**6.64 – 7.58**	0.01
EDV (ml)	**5.38 ± 1.37**	**3.36 – 8.77**	**4.90 – 5.85**	**6.16 ± 2.07**	**2.11 – 10.70**	**5.51 – 6.81**	0.05
ESV (ml)	**0.79 ± 0.34**	**0.25 – 1.49**	**0.67 – 0.91**	**0.93 ± 0.48**	**0.12 – 1.79**	**0.77 – 1.08**	0.16
EPSS (mm)	**1.20 ± 0.52**	**0.3 – 2.0**	**1.02 – 1.38**	**1.28 ± 0.39**	**0.5 – 2.1**	**1.15 – 1.40**	0.49
SV (ml)	**4.58 ± 1.25**	**3.02 – 7.90**	**4.15 – 5.01**	**5.23 ± 1.82**	**1.90 – 8.96**	**4.65 – 5.80**	0.09
EF (%)	**85.12 ± 5.39**	**77.70 – 93.97**	**83.27 – 86.98**	**84.80 ± 6.18**	**76.19 – 96.41**	**82.85 – 86.76**	0.81
FS (%)	**50.95 ± 6.98**	**42.85 – 64.38**	**48.55 – 53.35**	**51.34 ± 8.25**	**41.44 – 70.27**	**48.74 – 53.95**	0.94

DISCUSSION AND CONCLUSION

Since no study has been conducted so far to determine normal echocardiographic values specifically in Persian cats, the current study reports these values in 76 healthy Persian cats and compares the findings between males and females.

The mean heart rate of Persian cats in this study was 168.1 ± 28.7 bpm. Although it is in the normal range reported for cats in general (120 – 240 bpm) [36], it is relatively lower compared to most previous studies [6, 8, 9, 14, 37]. For instance, Chetboul *et al.* reported a mean heart rate of 184 ± 33 bpm in their study on 100 cats of different breeds [8]. Because heart rate is closely related to environmental factors (particularly stress level) and is variable over time, the lower values observed in our study may reflect the attempts made in the present study to perform echocardiography with the least amount of stress for the animals. Nevertheless, further studies are required to corroborate whether the heart rate is indeed lower in Persian cats compared to other breeds.

We observed a higher heart rate in female cats compared to the males, although the difference was barely significant (p-value = 0.05). This observation may be due to the difference in weight between male and female cats, as previous studies suggest an inverse relationship between body weight and heart rate [15].

The mean aortic diameter was 8.8 ± 1.2 mm, and the mean left atrial diameter was 10.3 ± 1.5 mm. Some previous studies have indicated that these two variables are related to body weight [29, 33]. Similarly, our findings are comparable to the reports of Allen [9] (AO 9.0 ± 0.7 mm; LAD 10.0 ± 0.7 mm) and Fox *et al.* [6] (AO 9.4 ± 1.1 mm; LAD 10.3 ± 1.4 mm) which were conducted on cats with mean body weights similar to our study population.

The mean aortic diameter to the left atrial diameter ratio was 1.2 ± 0.1 in our study, which is consistent with most previous reports [6, 9, 12, 13, 16]. Although previous studies have reported various values of aortic diameter and left atrial diameter, their ratio has been fairly consistent in all studies. This ratio helps make judgments about the size of the left atrium, with ratios above 1.3 indicating left atrial dilation [38], although some researchers consider values as high as 1.7 to be normal [39].

We found mean interventricular septum thickness values of 4.2 ± 0.9 mm at end-diastole and 6.5 ± 0.9 mm at end-systole, which are lower compared to the values reported by Moise*et al.* [13] (IVSd 5.0 ± 0.7 mm; IVSs 7.6 ± 1.2 mm) and Chetboul *et al.* [8] (IVSd 4.6 ± 0.6 mm; IVSs 7.4 ± 1.3 mm). The interventricular septum and the left ventricular free wall are thicker during systole compared to diastole, reflecting the relaxation of muscles during diastole to allow filling with blood, and their contraction during systole [40].

In our study, the left ventricular free wall thickness was slightly smaller compared to the thickness of interventricular septum, averaging 4.0 ± 0.8 mm at end-diastole and 6.8 ± 1.3 at end-systole. These observations are similar to those of Jacobs *et al.* [14] (LVPWs 6.8 ± 0.7 mm), Sisson *et al.* [12] (LVPWd 4.1 ± 0.7 mm; LVPWs 6.8 ± 1.1 mm) and Allen [9] (LVPWs 4.0 ± 0.4 mm), but smaller compared to the findings of Moise*et al.* [13] (LVPWd 4.6 ± 0.5 mm; LVPWs 7.8 ± 1.0 mm) and Chetboul *et al.* [8] (LVPWd 4.3 ± 0.7 mm; LVPWs 7.5 ± 1.1 mm).

Moreover, we observed greater end-diastole free wall thickness in males compared to females, although the difference was barely statistically significant (p-value = 0.05). On the other hand, the end-systole free wall thickness in males and females was 7.1 ± 1.5 mm and 6.4 ± 1.0 mm, respectively, indicating a statistically significant difference (p-value = 0.01).

Previous studies on certain dog breeds, such as German Shepherds and Beagles, have noted a significant difference in the left ventricular free wall thickness between males and females [18, 24], associating it with the higher body weight in males which may result in larger cardiac mass and changes in echocardiographic indices. Also, some studies have reported the impact of body weight on the left ventricular free wall thickness [15, 29]. Similarly in our study, the higher values of these echocardiographic indices in males may reflect the weight difference between male and female cats. Moreover, the lower values of end-diastole and end-systole left ventricular free wall and interventricular septum thickness observed in our study in comparison to the values reported by Chetboul *et al.* [8] and Moise*et al.* [13] might be because the mean weight of animals in our study was lower compared to the two mentioned studies.

In our study, the mean left ventricular internal diameter was 14.6 ± 1.8 mm at end-diastole and 7.1 ± 1.4 mm at end-systole. Also, the mean left ventricular volume was 5.8 ± 1.8 mL at end-diastole and 0.9 ± 1.4 mL at end-systole. The end-diastole left ventricular volume was higher in male cats, although the difference was only barely significant (p-value = 0.05). Stroke volume, representing the volume of blood leaving the heart following each heartbeat, is defined as the difference between end-diastole and end-systole left ventricular volume. The mean stroke volume in our study was 4.9 ± 1.6 mL. Few studies have reported these indices, and their results are similar to ours [33, 35].

E point septal separation is a general and consistent measurement of the mitral valve and represents the shortest distance between the mitral E point and the interventricular septum. The mean EPSS in our study was 1.2 ± 0.5 mm. In cats, values smaller than 4 mm are considered normal [41].

Left ventricular ejection fraction (EF) constitutes an important index for cardiac assessment and is measured with M-mode echocardiography. It represents the percent of the blood in the left ventricle that is ejected with each contraction. The mean EF in our study was 84.9% ± 5.8%. Although most researchers have not addressed this index, two studies [17, 33] have reported EF values of 79% ± 3% and 82.1% ± 1.3% in cats which are higher compared to the normal EF values in dogs [42].

Fractional shortening (FS) denotes the size change in the left ventricle from diastole to systole; it represents the shortening of left ventricle muscles and is expressed in percent. In addition to measuring cardiac contractile force, FS is a measure of cardiac function [39]. It is influenced by preload, afterload, and heart contractility. Age, sex and body surface area do not affect FS, although heart rate may have an impact on it [39]. Increased preload, decreased afterload, and myocardial hypertrophy increase FS, while systolic dysfunction and compromised heart contractility decrease FS [3, 28, 39]. The fractional shortening reportedly ranges from 45% to 55% [43], and it is influenced by stress and sedation [28, 43]. In our study, mean FS was 51.2% ± 7.6%, with no significant difference between males and females. Although our finding is consistent with most previous studies [8, 12, 14], Moise *et al.* [13] and Litster*et al.* [16] have reported higher FS values in their studies – 55% ± 10.2% and 59.8% ± 11.6%, respectively.

In conclusion, a limited number of studies have attempted to specifically determine to reference echocardiographic values for different breeds of cats, and, to the best of authors' knowledge, no study has been undertaken so far to address this issue in Persian cats. These echocardiographic indices vary substantially between different reports. The animal's breed seems to be one of the factors influencing echocardiographic measurements, as even the shape of the heart on two-dimensional echocardiography may appear differently depending on the breed [30]. Therefore, it is essential to determine these indices for each specific breed to guide comparison and accurate interpretation by the clinician.

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