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Obesity outcomes on electrocardiographic, echocardiographic, and blood pressure parameters in cats[1]

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ABSTRACT.- Martins P.L., Araújo S.L., Pereira T.H.S., Silva I.N.G., Morais G.B. & Evangelista J.S.A.M. 2024. **Obesity outcomes on electrocardiographic, echocardiographic, and blood pressure parameters in cats.** *Pesquisa Veterinária Brasileira 44:e07391, 2024.* Graduate Program in Veterinary Sciences, Universidade Estadual do Ceará, Av. Dr. Silas Munguba 1700, Campus do Itaperi, Fortaleza, CE 60740-000, Brazil. E-mail: patricia.lustosa88@gmail.com

Obesity is considered a chronic inflammatory process that is related to metabolic impairment, respiratory distress, and cardiovascular disease. In cats, few studies have evaluated the implications of obesity on the cardiovascular system, and the existing literature is controversial. Therefore, the aim of this study is to detect pressure, electrocardiographic, and morphofunctional changes in overweight and obese cats. After clinical and laboratory evaluation, 45 animals were selected for the study. Cats were separated according to body condition score (BCS) into three groups (control, overweight, and obese). All animals underwent blood pressure measurement, electrocardiogram, and transthoracic echocardiogram. Results are presented as mean ± standard deviation (SD). Data were considered statistically significant at $p<0.05$. GraphPad Prism® 7.04 software was used for statistical analyses. Mean arterial pressure in obese cats was higher than in animals with ideal weight (CT 123.60 ± 8.97mmHg vs OB 143.00 ± 22.12mmHg, $p<0.0138$), but hypertension was not detected. On the electrocardiogram, P wave duration (CT 33.67 ± 1.56ms vs OB 37.76 ± 2.76ms; $p<0.0003$) and QRS complex (CT 48.14 ± 2.56ms vs OB 54.48 ± 5.51ms; $p<0.002$) were significantly higher in the obese group. There were no significant echocardiographic changes. There was a direct correlation between blood pressure and BCS (r:0.36, $p<0.01$). The P wave was positively correlated with the BCS (r:0.56, $p<0.0001$). Likewise, the QRS complex correlated directly with the BCS (r:0.52, $p<0.0003$). The results indicate cat obesity can directly affect the cardiovascular system, promoting pressure and electrocardiographic changes. Therefore, monitoring the cardiovascular system of cats with obesity is essential.

INDEX TERMS: Obesity, cat, blood pressure, heart, electrocardiogram, echocardiogram.

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RESUMO.- [**Implicação da obesidade nos parâmetros eletrocardiográficos, ecocardiográficos e pressão arterial em gatos.**] A obesidade é considerada um processo inflamatório crônico que está relacionada ao comprometimento metabólico, dificuldade respiratória e doenças cardiovasculares. Em gatos, poucos estudos avaliaram as implicações da obesidade no sistema cardiovascular e a literatura é controversa. Portanto, o objetivo deste trabalho é detectar as alterações pressóricas, eletrocardiográficas e morfofuncionais em gatos com sobrepeso e obesidade. Quarenta e cinco animais, após avaliação clínica e laboratorial, foram selecionados para o estudo. Os gatos foram separados conforme o escore de condição corporal (ECC) em três grupos (controle, sobrepeso e obesidade). Todos os animais realizaram mensuração de pressão arterial, eletrocardiograma e ecocardiograma transtorácico. Os resultados foram apresentados como média ± desvio padrão (DP). Os dados foram considerados estatisticamente significativos se p<0,05. O software GraphPad Prism® 7.04 foi usado para análises estatísticas. A pressão arterial média dos gatos obesos era maior que nos animais com peso ideal (CT 123,60 ± 8,97mmHg vs OB 143,00 ± 22,12mmHg, p<0,0138), porém não se detectou hipertensão. No eletrocardiograma, a duração da onda P (CT 33,67 ± 1,56ms vs OB 37,76 ± 2,76ms; p<0,0003) e complexo QRS (CT 48,14 ± 2,56ms vs OB 54,48 ± 5,51ms; p<0,002) foi significativamente maior no grupo obeso. Não houve alterações ecocardiográficas significativas. Houve correlação direta da pressão arterial com o ECC (r:0,36, p<0,01). A onda P correlacionou-se positivamente com o ECC (r:0,56, p<0,0001). Do mesmo modo, o complexo QRS se correlacionou diretamente com o ECC (r:0,52, p<0,0003). Os resultados indicam que a obesidade em gatos pode afetar diretamente o sistema cardiovascular, promovendo alterações pressóricas e eletrocardiográficas. Sendo assim, é indispensável o acompanhamento do sistema cardiovascular dos gatos com obesidade.

TERMOS DE INDEXAÇÃO: Obesidade, gato, pressão arterial, coração, eletrocardiograma, ecocardiograma.

INTRODUCTION

In humans, the cardiovascular effects of obesity include systemic hypertension, cardiac remodeling, and systolic and diastolic dysfunction (Csige et al. 2018, Koliaki et al. 2019). Several studies have shown that obesity in dogs and cats is related to metabolic impairment, respiratory distress, and cardiovascular disease (German 2006, Zoran 2010, Chandler 2016).

Excess body fat is considered a chronic low-grade inflammatory process (Trayhurn 2005), as the levels of some inflammatory markers such as C-reactive protein, IL-6, and TNF-α are increased in obese people (German et al. 2010). In humans, this chronic state of inflammation can cause changes, such as insulin resistance, dyslipidemia, atherosclerosis, hypertrophic cardiomyopathy, increased risk of hypertension, and osteoarthritis (Lee & Pratley 2005, Bastard et al. 2006, Shen et al. 2021). There is an association between obesity and hemodynamic overload since, in obesity, the metabolic demand is increased, and, concomitantly, there is an increase in blood volume that generates an increase in preload (Vasan 2003, Frohlich & Susic 2008, Csige et al. 2018). The normal compensatory response to an increase in cardiac output and stroke volume should be a drop in peripheral vascular resistance, which is generally inappropriate in obese people, contributing to the occurrence of systemic arterial hypertension (Messerli et al. 1981, Achari & Jain 2017, Shen et al. 2021). In veterinary medicine, it is known that obese dogs have an increase in heart rate (HR) and a small to moderate increase in blood pressure compared to dogs with normal body conditions. Additionally, obese dogs show increased left ventricular free wall thickness at end-diastole and systole compared to lean dogs (Chandler 2016). However, despite changes described in dogs, the increase in blood pressure in obese cats is still controversial, and there are few published studies on cardiovascular changes in obese cats. Furthermore, little evidence reveals that obesity is significantly associated with hypertension, but its effect is small (Bodey & Mitchell 1996).

Cats with obesity are occasionally brought in for appointments with cardiologists due to noticeable enlargement of the heart on x-rays. These animals present a slight increase in cardiac silhouette measurements due to pericardial fat, which requires echocardiography to differentiate the adipose tissue from the myocardium (Lister & Buchanan 2000). It is known that body weight significantly affects echocardiographic measurements, as demonstrated by Häggström et al. (2016) in a study with 19,866 cats. However, the authors only evaluated body weight as an influence on cardiac dimensions, not allowing the influence of obesity on these parameters to be noted. Souza et al. (2020) showed an increase in the left ventricular free wall in diastole (PLVEd) in obese cats compared to cats at ideal weight. Furthermore, a positive correlation between PLVEd and weight and body condition score (BCS) was noted, corroborating the possible impact of excess body fat on the cardiovascular system.

Cardiac arrhythmias have been described in obese human subjects and are often accompanied by left ventricular hypertrophy or sleep apnea syndrome (Fraley et al. 2005). The electrocardiographic changes in small animals are low QRS complex voltage and increased P wave duration (Pereira-Neto et al. 2010). However, the literature on the effects of obesity on the electrical physiology of the heart in cats is limited. Therefore, the objective of this study is to evaluate the effects of obesity on systolic blood pressure and electrocardiographic and echocardiographic parameters in cats.

MATERIALS AND METHODS

Animal Ethics. This study was submitted for approval by the Ethics Committee for the Use of Animals (CEUA) of the "Universidade Estadual do Ceará" (UECE) under protocol number 31062020/2020.

Animals. The present study was carried out with 45 cats without racial predisposition, ages ranging from 1 to 7 years, males and females, from the clinical and outpatient routine of the Professor Sylvio Barbosa Cardoso Veterinary Hospital of the "Faculdade de Veterinária" (Faculty of Veterinary Medicine - FAVET) of the UECE, Fortaleza, Brazil. All animals were clinically evaluated, weighed and classified using the predetermined nine-point scale according to Laflamme (1997). These were divided into three groups: control group (CT) – cats with a normal body score (BCS = 5); overweight group (SP) – cats with a body score compatible with overweight (ECC = 6-7); and an obese group (OB) – cats with a body score compatible with obesity (ECC = 8-9).

Blood samples were collected for hematological and biochemical analysis during the animals' clinical evaluation. Blood collection was performed by venipuncture. The samples were centrifuged at 2,000x spins for ten minutes, and the serum obtained was used for initial screening. A complete blood count, alanine aminotransferase (ALT), alkaline phosphatase (AF), creatinine, urea, albumin, total cholesterol, triglycerides, glucose, and total thyroxine (T4) were performed. Animals that were not healthy in the clinical evaluation or had pre-existing diseases, such as chronic kidney disease, diabetes mellitus or hyperthyroidism, were excluded.

Body fat percentage. The percentage of body fat (BF%) is determined through morphometric measurements, which are determined clinically based on calculations. The BF% percentage was calculated using the rib cage circumference measurement (TC) and the leg index measurement (MIP), following the equation proposed by Butterwick (2000).

$$\%GC = \left\{ \frac{\left[\left(\frac{CT}{0,7076} \right) - MIP \right]}{0,9156} \right\} - MIP$$

Measurement of systolic blood pressure. Systolic blood pressure (SBP) was measured during the physical assessment using the Doppler method. The cats were acclimatized for 15 minutes in a quiet environment with little noise. They were then positioned in the right lateral decubitus position, and the cuff was positioned on the thoracic limb in the middle third of the radio-ulna. The choice of cuff corresponded to approximately 30% of the limb circumference. Seven measurements were taken in succession, and the average was recorded; extreme values were excluded.

Transthoracic echocardiography. The animals underwent echocardiographic examination using an ultrasound (D5 vet, VINNO Technology LTD©, Suzhou) with Doppler function and a 3-8MHz frequency sector transducer. The animals were restrained manually without sedatives on an examination table. They were placed in left and right lateral decubitus. The left and right thoracic regions were shaved, and aqueous gel was applied to conduct the ultrasound waves better. The acquisition of images and echocardiographic measurements were carried out by a single evaluator, and the parameters were obtained using the arithmetic mean of three measurements.

The left ventricular internal diameter (LVSD), thickness of the interventricular septum (SIV) and left ventricular free wall (LVLP) (cm) were evaluated, with all variables being verified at the end of diastole and systole. The cutoff point for hypertrophy was SIV and PLVE values in diastole above 0.6cm, as described by Fuentes et al. (2020). These parameters were calculated from images obtained in M-mode in the right parasternal window of the short axis of the left ventricle (LV) at the level of the papillary muscles. From these indices, shortening fractions (FS%) and ejection fractions (EF%) were calculated (Thomas et al. 1993). The dimensions of the aortic root (Ao), left atrium (LA), and the LA/Ao ratio were performed in two-dimensional mode (B-Mode) in a right sternal window, cardiac short axis (Abbott & MacLean 2006). Flows from the semilunar (pulmonary and aortic) and transmitral valves were obtained by pulsed spectral Doppler. The peak velocity of the E wave and mitral A wave were measured in the left parasternal window, apical four-chamber view (4C), and then the E/A ratio was calculated. The isovolumetric relaxation time (IVRT) was also obtained in the left parasternal window but in an apical five-chamber view (5C). Using tissue Doppler (TDI) in the annular region of the parietal leaflet of the mitral acquired through the left parasternal window in a 4C view, the E and A waves were obtained, as well as the E/A ratio.

Electrocardiography. The electrocardiographic evaluation was performed with a portable 12-lead computerized electrocardiograph (Incardio, Inpulse®). The animals were positioned in the right lateral decubitus position, and the electrodes were positioned according to the recommendations of Tilley & Gompf (1977). After monitoring, the tracings were archived for later analysis using specific software (Incardio Duo, Inpulse®). Bipolar leads (DI, DII and DIII) and increased unipolar leads (aVR, aVF and aVL) were evaluated. The parameters analyzed were rhythm, HR, mean electrical axis of the QRS complex in the frontal plane, durations of P, PR, QRS, and QT in milliseconds (ms), and amplitudes of P, R, S and T in millivolts (mV).

Statistical analysis. The results were presented as mean ± standard deviation (SD). All data were subjected to the Shapiro-Wilks test for normality analysis. Comparisons between groups were performed by single-factor analysis of variance (one-way ANOVA), followed by Tukey's test when data were considered normal. Data with non-normal distribution were analyzed using the Kruskal-Wallis test, followed by the Dunn test. The Pearson coefficient was used to correlate the various morphophysiological parameters. Results with a value of $p<0.05$ were considered statistically significant. For statistical analysis, GraphPad Prism® 7.04 software was used.

RESULTS

Of the 45 animals selected, all (100%) were mixed breed: 25 females (55.55%) and 20 males (44.45%). Regarding age, the mean for the CT group was 2.62±1.85 years, 3.91±1.79 years for the SP group, and 4.39±1.98 years for the OB group. There was no significant difference regarding the age of the animals. Regarding body weight, the mean TC was 4.02±0.75kg, 5.04±0.73kg in SP, and 5.91±1.07kg in OB. Mean body fat in CT was 22.25±3.67%, 32.94±6.82% in SP, and 43.92±8.88% in OB. A statistical difference was observed for weight and body fat between the groups (Table 1).

Of the 45 animals evaluated, 40 cats (88.88%) had indoor breeding habits, that is, without access to the street, and of these, 12 cats (30%) belonged to the CT group, 17 (42.50%) to the SB group and 11 (27.5%) in the OB group. Five cats (11.12%) were not neutered, with two (40%) participating in the CT group and three in the OB group. Regarding reproductive status, all (100%) cats in the OB group were castrated, and only one animal (5.88%) in the SP group was intact. In the CT group, 11 cats (78.57%) were neutered and three (21.42) were intact. Regarding the type of food provided by owners, ten cats (71.42%) in the CT group ate dry and wet food (mixed format), and four (28.58%) exclusively ate dry food. Ten animals (58.82%) in the SP group were fed dry formulation, and seven (41.17%) were mixed. Ten cats (71.42%) in the OB group ate dry food, and four (28.58%) received mixed food.

Table 1. Mean ± SD and range [minimum-maximum] of values for age, weight, systolic blood pressure (SBP) and body fat (BF) of cats in the control, overweight and obese group

Parameters	Control (n=14)	Overweight (n=17)	Obese (n=14)
Age (years)	2.62 ± 1.85 [1.00-6.00]	3.91 ± 1.79 [0.67-7.00]	4.39 ± 1.98 [1.00-7.00]
Weight (Kg)	4.02 ± 0.75 c [2.60-4.95]	5.04 ± 0.73 b [4.00-6.75]	5.91 ± 1.07 a [4.00-8.00]
BF (%)	22.25 ± 3.67 c [17.30-28.44]	32.94 ± 6.82 b [23.75-47.44]	43.92 ± 8.88 a [29.53-58.57]
SBP (mmHg)	123.60 ± 8.97 b [112.90-142.10]	130.40 ± 18.02 a,b [104.10-163.10]	143.00 ± 22.12 a [117.90-198.60]

SD = standard deviation; a,b,c = different letters on the same line indicate a statistically significant difference ($p<0.05$).

The mean SBP obtained in CT was 123.60 ± 8.97mmHg, 130.40 ± 18.02mmHg in SP and 143.00 ± 22.12mmHg in OB. The OB group had a statistically higher SBP than the control group ($p<0.0138$) (Fig.1-3). Two patients in the SP group and two in the OB group had SBP greater than 160mmHg. All animals were generally calm and collaborative during the procedure.

The parameters obtained by electrocardiography for the three groups are described in Table 2. All animals had sinus rhythm and HR within the normal range described for the species. The amplitudes of the R and T waves were within normal limits. The amplitude of the S wave was lower in obese cats compared to control animals (CT 0.03 ± 0.03mV vs OB -0.01 ± 0.05mV, $p<0.044$).

There was no statistical difference for the mean electrical axis of the QRS in the frontal plane. However, one patient in the SP group and two in the OB group presented a deviation of the cardiac axis to the left due to blockage of the left anterior fascicle. The PR and QT interval of all cats evaluated were within normal limits, with no significant difference between the groups. The ST segment proved to be isoelectric and without statistical relevance between the groups.

The duration of the P wave for the obese group was significantly longer than that of the control group (CT 33.67 ± 1.56ms vs OB 37.76 ± 2.76ms; $p<0.0003$) and the overweight group (SP 34.39 ± 1.72ms vs OB 37.76 ± 2.76ms; $p<0.002$) (Fig.1-3). Cats in the OB group had P wave duration values above the reference. Regarding the duration of the QRS complex,

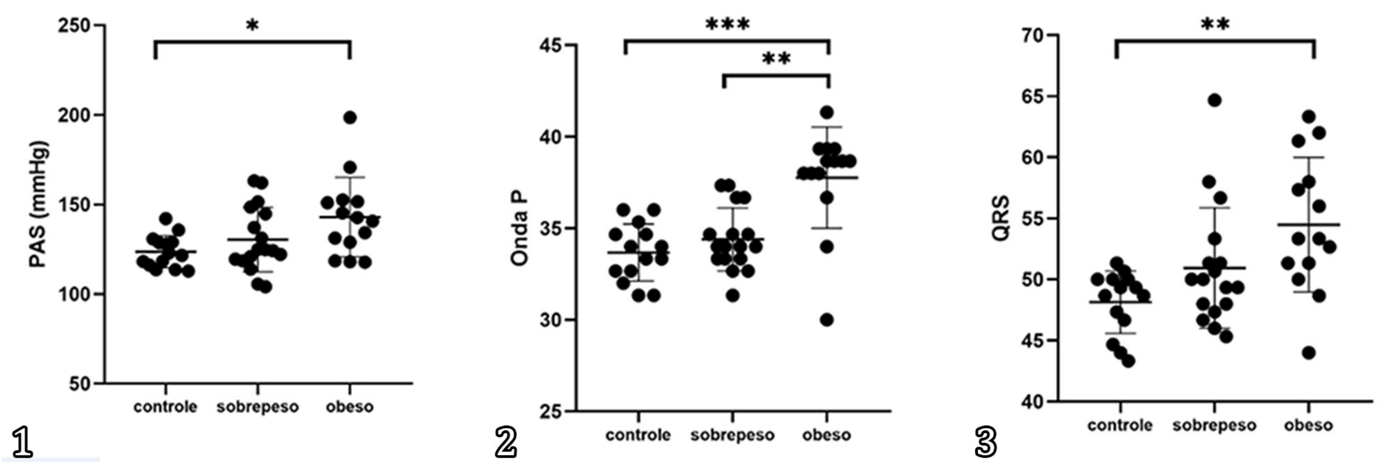

Fig.1-3. Graphic representation of means and standard deviations (**1**) of systolic blood pressure, (**2**) P wave and (**3**) QRS complex. Results were compared using ANOVA followed by Tukey. $p<0.05$ (*); $p<0.01$ (**); $p<0.001$ (***).

Table 2. Mean ± SD and range [minimum-maximum] of electrocardiogram parameter values in cats from the control, overweight and obese groups

Parameters	Control (n=14)	Overweight (n=17)	Obese (n=14)
Duration			
Wave P	33.67 ± 1.56 b [31.33-36.00]	34.39 ± 1.72 b [31.33-37.33]	37.76 ± 2.76 a [30.00-41.33]
PR Interval	64.62 ± 9.98 [50.67-83.33]	68.71 ± 10.98 [54.00-90.00]	67.67 ± 8.05 [51.33-79.33]
QRS complex	48.14 ± 2.56 b [43.33-51.33]	50.94 ± 4.93 a,b [45.33-64.67]	54.48 ± 5.51 a [44.00-63.33]
QT Interval	155.10 ± 10.68 [138.70-175.70]	154.70 ± 17.68 [126.70-190.70]	167.40 ± 17.64 [120.00-186.00]
Amplitude			
Onda P	0.09 ± 0.04 [0.05-0.16]	0.08 ± 0.02 [0.04-0.11]	0.07 ± 0.01 [0.05-0.10]
Onda R	0.34 ± 0.16 [0.14-0.59]	0.25 ± 0.13 [0.06-0.49]	0.23 ± 0.15 [0.02-0.55]
Onda T	0.08 ± 0.03 [0.05-0.16]	0.05 ± 0.05 [-0.05-0.15]	0.05 ± 0.05 [-0.11-0.11]
QRS axis	79.24 ± 15.84 [56.67-107.30]	52.20 ± 44.91 [-62.33-89.00]	57.02 ± 50.07 [-56.67-107.70]
P axis	73.79 ± 9.43 [58.00-84.33]	74.24 ± 7.41 [57.33-85.33]	72.24 ± 7.16 [55.33-83.00]
HR	186.90 ± 18.74 [146.00-212.00]	183.80 ± 31.84 [110.00-240.00]	179.70 ± 21.26 [155.00-222.00]

SD = standard deviation; a,b = different letters on the same line indicate a significant statistical difference (p<0.05).

the mean values were greater than the standardized values for the species, with only the OB group being significantly longer than the control group (CT 48.14 ± 2.56ms vs OB 54.48 ± 5.51ms; $p<0.002$) (Fig.1-3). Three cats had QRS complex duration greater than 60ms, one belonging to the SP group and two to the OB group.

None of the cats evaluated had congenital defects. In the M-mode morphometric assessment of the left ventricle, the average values obtained for SIV, PLVE and DIVE, in systole and diastole, did not exceed normal values. However, one animal from the SP group and another from the OB group showed measurements above 0.6cm for the SIV in diastole. As for PLVE in diastole, two patients in the OB group had a value above 0.6cm. The LA size, Ao and LA/Ao ratio results were normal in all groups. Systolic assessment using ejection fraction and shortening was normal for all animals in the study.

The parameters related to diastolic function (E/A ratio, IVRT, E/A ratio) showed no statistical difference; however, one cat in the OB group had a TRIV greater than 60ms. Furthermore, wave inversion was observed in the OB group, indicating early diastolic dysfunction. Aortic and pulmonary flows were normal in all groups and without statistical significance. The findings of the echocardiographic study of the three groups are summarized in Table 3.

Correlations of the parameters age, weight, BF, and BCS were made using the measurements of SBP, P wave, and QRS complex. SBP demonstrated a direct correlation with BCS, but there was a weak association (r:0.36, $p<0.01$). The P wave on the electrocardiogram demonstrated a weak positive correlation with age (r:0.35, $p<0.02$). On the other hand, there was a positive and moderate correlation with BCS (r:0.56, $p<0.0001$), weight (r:0.43, $p<0.004$), and CG (r:0.48, $p<0.002$). Regarding the QRS complex, a weak positive association was observed with GC (r:0.37, $p<0.01$) and a moderate correlation with ECC (r:0.52, $p<0.0003$).

DISCUSSION

The study animals were classified according to a nine-point scale developed by Laflamme (1997). However, although the scale correlates well with estimated body fat mass using the DEXA methodology (double x-ray emission densitometry), it is not possible to differentiate between lean mass and fat mass. Therefore, the body fat percentage was calculated to reduce individual interference. Thus, the percentage of BF in overweight and obese cats was 32.94 ± 6.82% and 43.92 ± 8.88%, respectively, proving the excess body fat in these animals. In human subjects, obesity is defined when the percentage of BF exceeds 25% in men and 30% in women (Swainson et al. 2017); however, there is no well-defined value in the literature for cats, with values lower than 20% considered normal (Brooks et al. 2014, Witzel et al. 2014, Santarossa et al. 2018, Fabretti et al. 2020).

Hypertension was not observed in the OB group, although a slight increase in SBP was noted. An interesting finding was that, despite the absence of hypertension, animals with significant obesity had significantly higher blood pressure values than overweight and ideal-weight animals. We hypothesize that, as in human subjects, obesity promotes activation of the sympathetic nervous system (SNS) and the renin-angiotensin-aldosterone system (RAAS), generating some degree of endothelial dysfunction (Engeli et al. 1999, Gorzelniak et al. 2002). However, more studies in this area are necessary. It is worth noting that two animals belonging to the OB group had blood pressure values above 160mmHg and, despite being collaborative during the measurement, "white coat syndrome" or situational hypertension cannot be ruled out. This type of hypertension develops as a result of the pressor effects of adrenergic stimulation in situations that promote excitement, fear, or anxiety, with this unpredictable effect on blood pressure (Belew et al. 1999, Payne et al. 2016, Acierno et al. 2018). Furthermore, hypertension secondary to

Table 3. Mean ± SD and range [minimum-maximum] of echocardiogram parameter values in cats from the control, overweight and obese groups

Parameters	Control (n=14)	Overweight (n=17)	Obese (n=14)
LA – short axis	1.19 ± 0.12 [1.00-1.47]	1.21 ± 0.10 [0.95-1.33]	1.19 ± 0.13 [1.00-1.43]
Ao – short axis	0.81 ± 0.07 [0.71-0.92]	0.84 ± 0.11 [0.67-1.05]	0.82 ± 0.09 [0.67-1.00]
LA/Ao	1.48 ± 0.15 [1.27-1.81]	1.45 ± 0.11 [1.27-1.66]	1.47 ± 0.18 [1.14-1.75]
IVSd	0.42 ± 0.08 [0.27-0.55]	0.44 ± 0.08 [0.36-0.69]	0.48 ± 0.10 [0.29-0.64]
IVSs	0.67 ± 0.11 [0.44-0.89]	0.70 ± 0.08 [0.54-0.82]	0.72 ± 0.12 [0.50-0.89]
LVFWd	0.39 ± 0.04 [0.32-0.45]	0.40 ± 0.06 [0.30-0.52]	0.44 ± 0.09 [0.31-0.64]
LVFWs	0.66 ± 0.09 [0.47-0.76]	0.64 ± 0.10 [0.43-0.74]	0.70 ± 0.11 [0.53-0.89]
LVIDd	1.49 ± 0.14 [1.20-1.65]	1.48 ± 0.14 [1.11-1.73]	1.48 ± 0.17 [1.24-1.84]
LVIDs	0.75 ± 0.11 [0.60-0.90]	0.73 ± 0.10 [0.50-0.89]	0.72 ± 0.13 [0.43-0.92]

SD = standard deviation; a,b = different letters on the same line indicate a significant statistical difference ($p<0.05$); LA = left atrium, Ao = aorta, IVSd = interventricular septum in diastole, IVSs = interventricular septum in systole, LVFWd = free wall of the left ventricle in diastole, LVFWs = free wall of the left ventricle in systole, LVIDd = internal diameter of the left ventricle in diastole, LVIDs = diameter of the left ventricle in systole.

subclinical renal injury is possible, even with animals being subjected to screening tests with biomarkers of renal function and urinalysis.

We observed a direct correlation between blood pressure and BCS, suggesting that adiposity can impact the cardiovascular system. The correlation between hypertension and obesity in cats has been continually sought; however, there is still no categorical data. Jordan et al. (2008) demonstrated that obese cats develop lipoprotein changes similarly to humans but without the development of atherosclerosis and hypertension. Whittemore et al. (2017) evaluated the blood pressure of cats with different body score conditions and found no association between hypertension and obesity. This finding is contradicted by Zeugswetter et al. (2018), who, using a similar methodology, showed an increase in SBP in obese animals. Another study, through a review of medical records, detected that obesity in cats was directly correlated with hypertension, in addition to 13 other diseases (Teng et al. 2018).

In our study, QRS complex duration values for all groups exceeded normal values for cats. This can be explained by the fact that our records have been computerized. Camacho et al. (2010) showed that the use of computerized electrocardiography provided significantly increased values of QRS complex and P wave duration but did not modify the wave amplitude values or the mean electrical axis in the frontal plane. This fact was attributed to the greater precision of the computerized measurement.

The electrocardiographic evaluation showed sinus rhythm in 100% of the cats. The duration of the P wave and the QRS complex of obese cats was significantly longer, but there were no abnormalities in the echocardiographic evaluation. This can be explained by the P wave duration, which has low sensitivity for predicting left atrial enlargements (Schober et al. 2007). In humans, the electrocardiographic findings described in obese individuals include prolongation of the P wave duration, PR and QRS intervals, low QRS voltage, and cardiac axis deviation (Germano 2015). Studies carried out with obese dogs observed increased P wave duration (Pereira-Neto et al. 2010, Partington et al. 2022); however, few studies relate to the feline species. This data may indicate changes in electrical conduction in cats with extreme obesity, but more studies are needed to confirm this hypothesis.

The implications of obesity on the cardiovascular system of cats, which were assessed using echocardiography, have not yet been fully established, and studies on the subject are scarce. No changes in morphometric measurements of the heart, assessed by transthoracic echocardiography, were found in this study. Some studies have identified associations between echocardiographic measurements and body weight but have not considered BCS (Freeman et al. 2013, Häggström et al. 2016, Karsten et al. 2017). A previous study found that obese cats had larger cardiac radiographic measurements; however, when subjected to echocardiographic evaluation, they had normal hearts (Lister & Buchanan 2000). Adversely, Souza et al. (2020) detected a significant increase in PLVEd in obese cats. Obesity may lead to morphometric changes in the heart, given that, although not significant, obese cats had SIV and PLVE measurements that were comparatively higher than the controls. A limitation of the study was the small sample size, which could directly impact sample significance. Furthermore, we cannot rule out that there were selection biases due to the subjectivity inherent in the group selection method, allowing obese cats to be characterized as overweight.

CONCLUSION

Obesity can cause increases in blood pressure and electrocardiographic changes in cats. Therefore, these patients must be monitored for hypertension and changes in cardiac electrophysiology. Furthermore, excess fat can likely promote changes in cardiac morphometry, requiring larger studies.

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