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Original Article
Small Animal Diseases

Clinical-laboratory evaluation of overweight and obese cats seen in routine clinical practice[1]

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ABSTRACT.- Araujo SL, Martins PL, Pereira THS, Silva ING, Morais GB, Evangelista JSAM. **Clinical-laboratory evaluation of overweight and obese cats seen in routine clinical practice.** *Pesquisa Veterinária Brasileira 45:e07448, 2025*. Faculdade de Medicina Veterinária, Universidade Estadual do Ceará, Av. Dr. Silas Munguba 1700, Itaperi, Fortaleza, CE 60714-903, Brazil. E-mail: steffi.araujo@hotmail.com

Feline obesity has become an increasingly common problem worldwide over the past decade. Excess weight in cats may predispose them to a range of conditions such as insulin resistance, type 2 diabetes mellitus, and hepatic lipidosis. However, few studies have conducted clinical-laboratory profiles of overweight and obese cats. Therefore, the aim of this study was to describe and correlate clinical and laboratory alterations in overweight and obese cats, comparing them with lean cats. Fifty-three cats were evaluated and divided into obese (OB), overweight (SP), and control (CT) groups. After a clinical assessment, the clinically selected cats underwent morphometric measurements and hematological and biochemical tests; their owners were also instructed to complete a questionnaire. Our primary findings included an increase in mean corpuscular volume and total proteins, a decrease in red blood cell count, and an increase in circulating concentrations of total cholesterol, triglycerides, and urea in the OB group; the SP group exhibited an increase only in total cholesterol and urea. Furthermore, the OB and SP groups exhibited a higher frequency of *ad libitum* feeding, were more likely to receive premium food, and generally had lower activity levels. We concluded that being overweight or obese altered the cats' hematological and biochemical parameters. Moreover, factors related to the feeding and environmental management of cats may predict an increased risk of being overweight.

INDEX TERMS: Obesity, feline, hyperlipidemia, adiposity.

RESUMO.- [**Avaliação clínico-laboratorial de gatos com sobrepeso e obesos atendidos na rotina clínica**] Em gatos, a obesidade tornou-se um problema global com prevalência crescente nos últimos 10 anos. O excesso de peso na espécie felina pode predispor a uma série de condições como a resistência à insulina, a diabetes mellitus tipo 2 e a lipidose hepática. Poucos estudos traçaram um perfil clínico-laboratorial de gatos com sobrepeso e obesos. Com isso, o objetivo deste trabalho foi descrever e correlacionar as alterações clínicas e laboratoriais em gatos com sobrepeso e obesos comparando-as com gatos magros. Foram avaliados 53 gatos, divididos nos grupos: obeso (OB), sobrepeso (SP) e controle (CT). Após realizar uma avaliação clínica, os gatos clinicamente selecionados foram direcionados para mensuração de medidas morfométricas, coleta de exames hematológicos e bioquímicos e preenchimento de questionário aplicado ao tutor. Os principais achados foram aumento VCM (volume corpuscular médio) e proteínas totais, redução do número de hemácias, aumento das concentrações circulantes de colesterol total, triglicerídeos e ureia no grupo OB, enquanto o grupo SP mostrou aumento somente de colesterol total e ureia. Ademais, os grupos OB e SP apresentaram maior frequência de alimentação *ad libitum*, categorizada como *premium* e gatos com menor nível de atividade. Assim, conclui-se que o sobrepeso e a obesidade alteraram parâmetros hematológicos e bioquímicos. Além disso, fatores relacionados ao manejo alimentar e o ambiental dos gatos podem ser preditivos para um risco aumentado de excesso de peso.

TERMOS DE INDEXAÇÃO: Obesidade, felinos, hiperlipidemia, adiposidade.

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INTRODUCTION

Obesity is defined as the accumulation of excessive amounts of adipose tissue in the body and can cause an energy imbalance (Zoran 2010). An animal is considered overweight when its body weight is 15% above an ideal body weight; it is considered obese when its weight is more than 30% above an ideal body weight (Burkholder 2000, Bjornvad et al. 2011). In cats, obesity has become prevalent in recent years and has been identified as the second most common feline disease after dental disease (Cave et al. 2012, O'Neill et al. 2023). Recent studies have indicated a 3% increase in the incidence of obesity in cats in the last 10 years, and it is estimated that 61% of cats in the United States are overweight (Ward 2022).

Overweight cats have a decreased quality of life (Hanford & Linder 2021) and an increased risk of a number of diseases such as lower urinary tract disease (Lekcharoensuk et al. 2000, Lund et al. 2005), hepatic lipidosis (Nicoll et al. 1998, Sandøe et al. 2014), insulin resistance/diabetes mellitus (Lund et al. 2005, Hoenig et al. 2007), orthopedic disease, and non-allergic skin disease. They also exhibit increased surgical and anesthetic risks (Brodbelt et al. 2007). Middle-aged and older male neutered cats are at greatest risk of obesity (Lund et al. 2005, Backus et al. 2007, Chiang et al. 2022).

The most widely accepted and practical method for assessing body condition in cats is the body condition score (BCS), proposed by Laflamme (1997). This subjective method pertains to a 9-point scale, corresponding to underweight (BCS 1-4), ideal weight (BCS=5), overweight (BCS 6-7) and obese (BCS 8-9). Other methods of assessing body condition include feline body mass index (FMI) or body fat percentage (BF) and dual-energy X-ray (DEXA) (Mawby et al. 2004). Identification and quantification of obesity is a key factor in choosing appropriate dietary management. Cats diagnosed as overweight require clinical evaluation and should be placed on a weight loss program with an appropriately formulated weight-reduction diet (Burkholder 2000).

Hematological changes in obese cats include increased mean corpuscular volume (MCV), red blood cell distribution width (RDW), serum biochemical changes such as increased HDL cholesterol and triglycerides and decreased gamma-glutamyl transferase (GGT) activity (Zapata et al. 2017, Martins et al. 2022).

Obesity in cats is prevalent in clinical practice and is related to a range of other comorbidities. Here, we describe morphometric measurements of cats and food and environmental management of those animals to correlate laboratory alterations within groups of overweight and obese cats treated at the "Hospital Veterinário 'Professor Sylvio Barbosa Cardoso'" (Professor Sylvio Barbosa Cardoso Veterinary Hospital – HVSBC), Fortaleza, Ceará, Brazil.

MATERIALS AND METHODS

Ethical approval. This study was approved by the Ethics Committee for Animal Use of the "Universidade Estadual do Ceará" (CEUA-UECE) (protocol number: 23062020/2020). All animal owners signed an informed consent form and authorized the collection of biological samples from their animals and the use of data in publications.

We studied 53 cats of both sexes, 24 males and 29 females, aged between one and seven years. The cats were divided into three groups: an overweight group (SP) composed of 21 cats, diagnosed by morphometric measurements of BCS 6-7 and BF above 15%; an obese group (OB) composed of 16 cats, diagnosed by morphometric measurements of BCS above 8-9 and BF > 30%; and a control group (CT) composed of 16 cats with BCS = 5 and BF < 15%. All animals were clinically evaluated at the HVSBC at the UECE from 2021 to 2023.

Body condition was measured according to the 9-point BCS described by Laflamme (1997). The parameters used to determine body condition followed the scheme shown in Figure 1. We measured FMI or BF from rib cage measurements: the circumference at the point of the ninth cranial rib in centimeters (cm) and the leg index measurement (MIP) (i.e., the distance between the patella and the calcaneal tubercle of the left hind limb) in cm. We calculated BF using the equation below, proposed by Burkholder (2000) and modified:

$$\%\mathrm{BF} = \left(\frac{\left(\frac{\text{Rib cage}}{0.7062} \right) - MIP}{0.9156} \right) - MIP$$

Cats with endocrine, hepatic, nephropathic, infectious diseases, pancreatitis and neoplasias were excluded from this study; we also excluded cats that had recently received systemic or topical glucocorticoids. The exclusionary criteria were based on clinical and laboratory tests: complete blood count, urinalysis, serum biochemical profile, serum glucose level, and urine summary. Clinically healthy cats from the HVSBC clinical routine were selected to compose the CT group.

All of the cats underwent a medical history, anamnesis, general physical examination, and morphometric measurements (BCS, thoracic circumference, pelvic circumference and leg index) by the same trained veterinarian. The data obtained were attached to a clinical record completed at the time of the clinical evaluation. The cats' owners answered questions about animal management and the home environment, and the responses were included in each cat's clinical record. These questions pertained to lifestyle (indoor or outdoor), diet (dry food, wet food, or both), food category (maintenance, premium, or super premium), feeding frequency (two, three, four, or five or more times per day, or *ad libitum*), level of physical activity (very little, little, active or very active) and level of environmental enrichment at home (low, medium, or high).

The collections were performed after a 12-hour fast, and the samples were obtained via puncture of the jugular vein

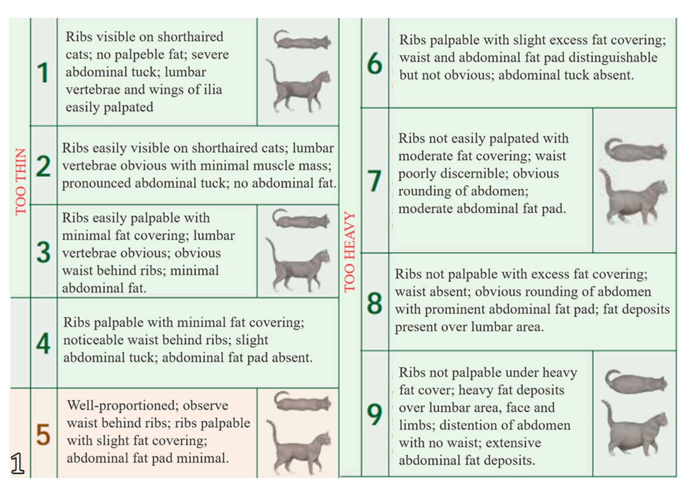

Fig.1. Schematic of the 9-point ECC proposed by Laflamme (1997). Modified by WSAVA (2020).

with the aid of a 5 mL syringe coupled to a 25 × 7-gauge needle. The samples were stored in 0.5 mL microtubes with EDTA and sodium fluoride, which were used to obtain complete blood count and glucose dosing, respectively. Four milliliter (4 mL) tubes free of EDTA were used to measure serum levels of total bilirubin and fractions (direct and indirect), total cholesterol, triglycerides, urea, creatinine, albumin, ALT, AST, and ALP. After approximately 30 minutes, the samples obtained in tubes without EDTA were centrifuged at 2,000 g rotations for 10 minutes (Baby I Centrifuge, FANEM®, São Paulo, Brazil), and serum aliquots were obtained and sent to the laboratory for clinical analysis.

The whole blood and serum samples were processed at the Veterinary Clinical Laboratory of HVSBC at FAVET-UECE. Serum biochemistry measurements were performed using enzymatic or kinetic colorimetric methods following the manufacturers' recommendations. The results were read and obtained using an automatic analyzer (Roche®, Rotkreuz, Switzerland). The hematological examination was performed using Poch100iv-Diff (Roche®, Rotkreuz, Switzerland) equipment.

All data were grouped, and descriptive statistics were performed to obtain means and standard deviations. For the statistical analysis, we used Prisma software version 8.0.1 for Windows (GraphPad, San Diego, California, USA). Data normality was assessed using the Shapiro-Wilk test, and equality of variances was evaluated using the Levene test. Differences between groups were assessed using Analysis of Variance (ANOVA); we used Tukey's post-hoc test for normally distributed data. In cases of heteroscedasticity, we used the Brown–Forsythe test and the Holm–Sidak post-hoc test. In cases of non-normally distributed data, we used the Kruskal–Wallis test and Dunn's post-hoc test. We presumed that p-values less than 0.05 indicated statistical significance.

RESULTS

The three groups (SP, OB, and CT) were significantly different in weight, BCS, and BF ($p < 0.05$) (Fig.2-4).

Cats in the OB group exhibited a lower mean number of red blood cells, a higher MCV, and a higher level of total proteins than those in the SP group. Cats in the SP group exhibited lower mean total leukocytes and segmented leukocytes than those in the CT and OB groups. No significant differences were found in the other hematological variables evaluated (Table 1).

Cats in the OB group also exhibited higher total cholesterol, triglycerides, and urea concentrations than cats in the SP and CT groups (Fig.2-4). Cats in the CT group had higher mean total bilirubin and indirect bilirubin than cats in the SP and OB groups (Fig.5-7). We did not find significant differences in the other biochemical parameters (Table 1). Hematological and biochemical alterations remained within the reference ranges for cats; the exception was triglycerides and urea, which exhibited a higher mean in the OB group (Table 1).

We observed that 93.75% of the cats in the OB group, 90.00% in the SP group, and 81.25% in the CT group were indoor animals. The majority (75.50%) of the cats in the OB group ate a mixed diet (dry + wet); the majority of cats in the SP group (65.00%) were fed only dry food. In the CT group, 62.50% of the cats were fed mixed food (dry + wet). The majority of the cats in the OB and SP groups received premium-category food (75.00% and 60.00%, respectively); 62.50% of cats in the CT group were fed food in the maintenance category. The most common feeding frequency in the OB group was four times per day and *ad libitum* (37.5% for each); cats in the SP group were most likely to be fed *ad libitum* (40.00%). Cats in the CT group were most likely to be fed three times per day (37.50%).

Cats in the OB and SP groups were found to be mostly inactive (62.50% and 55.00%, respectively). Cats in the CT group were mostly active (62.50%). Cats in the OB group presented low environmental enrichment in 56.25% of homes; cats in the SP and CT groups presented high environmental enrichment (55.00% and 93.75%, respectively).

DISCUSSION

Studies evaluating clinical and laboratory changes associated with different stages of obesity in felines are scarce, especially in Brazil and the Northeast region. We compared hematological and biochemical variables and social and dietary habits of healthy, overweight, and obese cats routinely treated at the Veterinary Hospital of the UECE. We found a significant

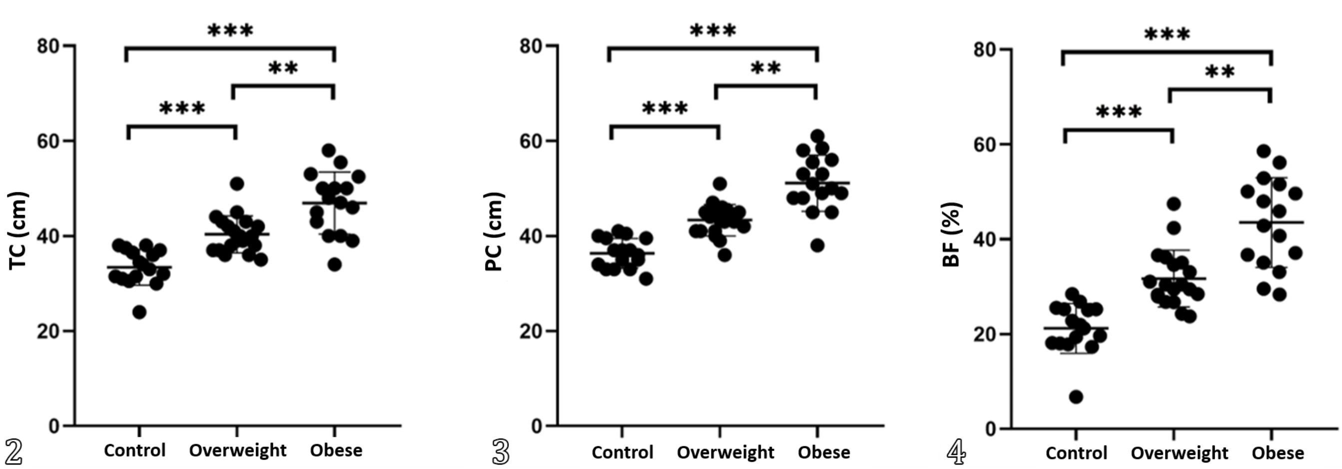

Fig.2-4. Values of (**2**) thoracic circumference (TC), (**3**) pelvic circumference (PC), and (**4**) body fat percentage (BF) of the control, overweight, and obese groups. Bars indicate means and standard deviations. Statistically significant differences between the groups are indicated by $p < 0.01$ (**) and $p < 0.001$ (***).

Table 1. Mean ± SD and range [minimum-maximum] of blood count and serum biochemistry values in cats of the control, overweight and obese groups

Parameters	Control (n=16)	Overweight (n=19)	Obese (n=16)
Red blood cells ($x10^6$ per mm^3)	8.95 ± 1.18 a [5.77-10.90]	9.04 ± 1.27 a [7.26-12.04]	7.72 ± 0.32 b [6.07-10.47]
Hemoglobin (g/%)	13.62 ± 1.63 [10.60-17.60]	13.80 ± 1.55 [10.80-17.10]	12.67 ± 2.11 [9.20-16.70]
Hematocrit (%)	39.69 ± 4.79 [28.00-50.00]	40.47 ± 4.33 [32.00-49.00]	37.38 ± 5.81 [26.00-49.00]
MCV (μm^3)	44.48 ± 2.86 b [39.30-48.50]	45.06 ± 4.30 b [39.60-54.10]	48.51 ± 3.54 a [42.40-54.30]
MCHC (%)	34.33 ± 1.43 [32.20-37.80]	34.07 ± 1.06 [30.70-35.80]	33.82 ± 1.56 [30.60-35.50]
Leukocytes ($x10^3$ per mm^3)	14.13 ± 5.94 a [6.20-31.00]	9.70 ± 3.54 b [5.00-15.70]	11.54 ± 3.15 a,b [6.10-16.40]
Myelocytes ($x10^3$ per mm^3)	0.00 ± 0.00 [0.00-0.00]	0.00 ± 0.00 [0.00-0.00]	0.00 ± 0.00 [0.00-0.00]
Metamyelocytes ($x10^3$ per mm^3)	0.00 ± 0.00 [0.00-0.00]	0.00 ± 0.00 [0.00-0.00]	0.00 ± 0.00 [0.00-0.00]
Blood rods ($x10^3$ per mm^3)	0.00 ± 0.00 [0.00-0.00]	0.00 ± 0.00 [0.00-0.00]	0.00 ± 0.00 [0.00-0.00]
Segmented ($x10^3$ per mm^3)	9.85 ± 5.86 a [3.21-28.52]	6.15 ± 2.34 b [2.85-10.13]	8.15 ± 2.72 a,b [3.97-12.79]
Eosinophils ($x10^3$ per mm^3)	1.16 ± 0.94 [0.00-3.59]	0.83 ± 0.72 [0.08-2.71]	0.71 ± 0.54 [0.00-1.91]
Basophilis ($x10^3$ per mm^3)	0.00 ± 0.00 [0.00-0.00]	0.00 ± 0.00 [0.00-0.00]	0.03 ± 0.08 [0.00-0.29]
Lymphocytes ($x10^3$ per mm^3)	2.42 ± 0.98 [0.93-4.00]	2.31 ± 1.17 [0.59-4.20]	2.18 ± 1.10 [0.94-5.15]
Monocytes ($x10^3$ per mm^3)	0.70 ± 0.44 [0.25-1.71]	0.51 ± 0.37 [0.07-1.57]	0.47 ± 0.37 [0.00-0.98]
Platelets ($x10^3$ per mm^3)	199.94 ± 89.29 [68.00-400.00]	192.53 ± 97.27 [64.00-480.00]	222.06 ± 113.12 [52.00-380.00]
Total proteins (g/dL)	7.39 ± 0.49 b [6.60-8.40]	7.63 ± 0.50 a,b [6.60-8.60]	8.00 ± 0.52 a [6.80-8.80]
Albumin (g/dL)	2.66 ± 0.24 [2.30-3.00]	2.73 ± 0.21 [2.30-3.00]	2.69 ± 0.31 [2.00-3.20]
Bilirubin (mg/dL)	0.25 ± 0.09 a [0.10-0.40]	0.17 ± 0.08 b [0.06-0.40]	0.18 ± 0.07 a [0.10-0.31]
Direct bilirubin (mg/dL)	0.12 ± 0.05 [0.06-0.18]	0.13 ± 0.04 [0.05-0.15]	0.11 ± 0.04 [0.04-0.15]
Indirect bilirubin (mg/dL)	0.13 ± 0.09 a [0.02-0.30]	0.05 ± 0.06 b [0.00-0.15]	0.09 ± 0.14 a,b [0.00-0.50]
AST (UI/L)	36.10 ± 11.62 [23.00-59.50]	32.00 ± 7.20 [23.00-43.00]	30.75 ± 6.19 [26.00-39.00]
ALT (UI/L)	81.88 ± 45.74 [39.00-225.50]	65.50 ± 31.04 [36.00-167.00]	71.44 ± 39.15 [23.00-146.00]
Alkaline phosphatase (U/L)	53.29 ± 31.98 [20.00-131.00]	31.11 ± 11.45 [4.00-55.00]	50.94 ± 36.76 [25.00-161.30]
Glucose (mg/dL)	117.30 ± 55.56 [61.50-264.00]	132.60 ± 42.36 [69.00-215.00]	125.30 ± 33.73 [79.00-175.00]
Cholesterol (mg/dL)	84.94 ± 23.49 b [50.50-124.00]	114.20 ± 35.98 a [55.00-186.00]	139.20 ± 42.88 a [79.00-210.00]
Triglycerides (mg/dL)	48.50 ± 22.41 b [23.00-90.00]	72.37 ± 27.75 a,b [19.00-130.00]	136.00 ± 118.10 a [31.00-487.50]
BUN (mg/dL)	49.94 ± 6.10 b [41.00-60.00]	57.87 ± 12.82 a [43.00-98.00]	60.53 ± 7.77 a [47.00-75.00]
Creatinine (mg/dL)	1.43 ± 0.33 [0.90-2.10]	1.58 ± 0.28 [1.10-2.20]	1.51 ± 0.31 [1.00-2.00]

MCV = mean corpuscular volume, MCHC = mean corpuscular hemoglobin concentration, BUN = blood urea nitrogen; a, b = Different letters indicate statistical differences between groups.

increase in MCV and total proteins and a reduction in the total number of red blood cells in obese cats. Second, circulating concentrations of total cholesterol and urea were higher in both obese and overweight cats; triglycerides were increased only in the OB group. Finally, obese cats presented a higher frequency of *ad libitum* feeding, categorized as premium, in addition to a lower activity level and low environmental enrichment at home. Overweight cats also presented a higher frequency of *ad libitum* feeding, categorized as premium, with lower levels of activity but average environmental enrichment.

Obesity is currently the second most common disease in cats after periodontal disease (O'Neill et al. 2023). Surveys carried out in different countries around the world in the last decade have revealed a growing prevalence of feline obesity (ranging from 15.7–63.3%) (Cave et al. 2012, Corbee 2014, Teng et al. 2017, Chiang et al. 2022). Obesity in cats results in a chronic inflammatory condition (Cottam et al. 2004) that may predispose an animal to several health-threatening conditions (e.g., orthopedic disease, dermatological problems, increased risk of death associated with sedation or anesthesia, some neoplasias, and diabetes mellitus characterized by insulin resistance and pancreatic insufficiency, and beta-cell dysfunction) (Scarlett & Donoghue 1998, Brodbelt et al. 2007, Tarkosova et al. 2016).

The overweight and obese cats in this study were all neutered and had a mean age of 4.3 years; they were predominantly female. Neutering can lead to increased food intake and decreased energy expenditure caused by the withdrawal of steroid hormones (estrogen and testosterone) from the gonads (Alexander et al. 2011, Mitsuhashi et al. 2011). Several authors have associated obesity with increasing age in cats (Courcier et al. 2010, Laflamme 2012, Mizorogi et al. 2020). However, studies have demonstrated an increased prevalence of overweight and obese cats at young ages (i.e., under 2 years) (Rowe et al. 2017). The literature indicates a higher risk of obesity in male cats (Courcier et al. 2010, Corbee 2014, Öhlund et al. 2018, Chiang et al. 2022). However, Scarlett & Donoghue (1998) attributed this association to the larger skeletal size of male cats. Hoenig & Ferguson (2002) observed that female cats required aggressive caloric restriction to maintain their body weight after neutering compared with male cats.

We used the BCS to assess the cats' overweight and obese status. In a clinical setting, this scale is the most widely accepted and practical method for assessing body condition via visual assessment and palpation (Burkholder 2000). The BCS has been validated for cats (Laflamme 1997) and has been shown to correlate well with body fat mass determined by DEXA (Mawby et al. 2004).

Obese cats (i.e., those in the OB group) exhibited increased MCV and total proteins and fewer red blood cells than cats in the SP and CT groups. However, all values were within the reference values for the feline species. Although a few studies have demonstrated hematological alterations in overweight and obese cats, Martins et al. (2022) showed hematological alterations of increased MCV and RDW in obese cats with BCS 8/9 and 9/9. Other studies that evaluated the hematological parameters of obese cats did not detect significant differences compared with lean cats (Jaso-Friedmann et al. 2008, Hoenig et al. 2013). In humans, hematological alterations such as reduced red blood cell count, hematocrit and hemoglobin and increased MCV and RDW found in obese individuals have been correlated with a higher risk of metabolic syndrome (Nebeck et al. 2012, Yan et al. 2019, Kohsari et al. 2021).

The increase in total proteins observed in the OB group may be correlated with an increase in globulin concentration since albumin concentrations remained within the reference range. Furthermore, we did not find statistically significant differences between the studied groups. Few studies of cats have focused on the relationship between obesity and the immune system, and those studies failed to demonstrate changes in the immune response of obese cats (Jaso-Friedmann et al. 2008, Tvarijonaviciutea et al. 2012). In humans, obesity is related to an increased risk of rheumatoid arthritis, psoriasis and psoriatic arthritis, multiple sclerosis and Hashimoto's thyroiditis, as well as inflammatory bowel disorders and type 1 diabetes mellitus (Emamgholipour et al. 2013, Wang et al. 2013, Lu et al. 2014, Blüher 2019). Obese humans can have severe forms of these autoimmune disorders caused by an increase in pro-inflammatory processes and increases in Th17 and Th1 immune cells (Tsigalou et al. 2020).

Obese cats presented higher levels of triglycerides and total cholesterol; cats in the overweight group exhibited only an increase in total cholesterol levels. Lipid alterations are relatively

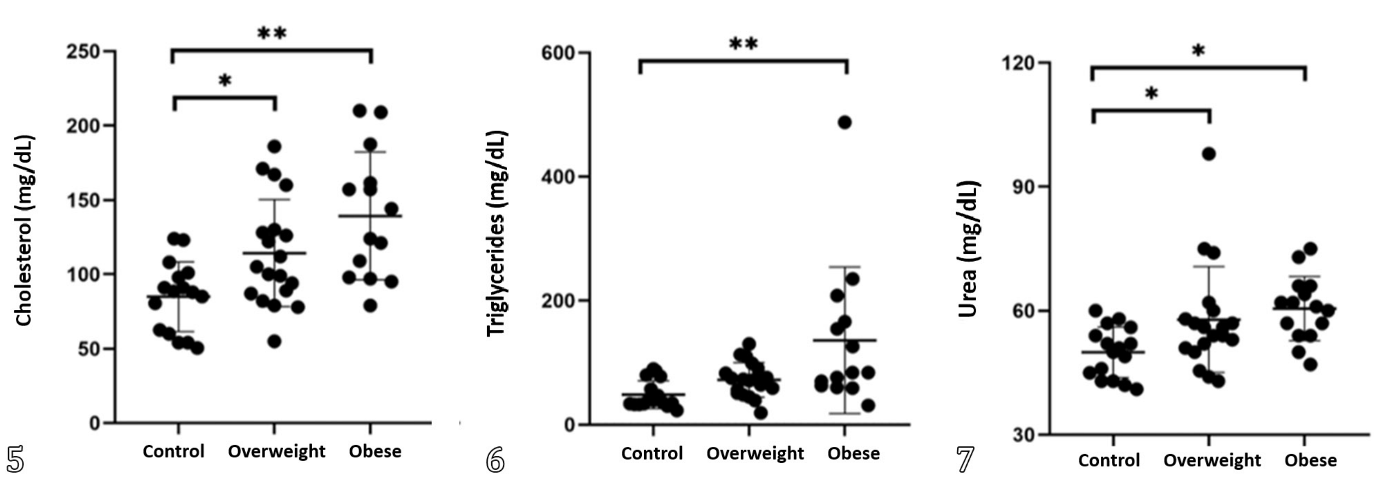

Fig.5-7. Values of (**5**) total cholesterol, (**6**) triglycerides, and (**7**) urea of cats in the control, overweight and obese groups. Bars indicate means and standard deviations. Statistically significant differences between groups are indicated by $p < 0.05$ (*) or $p < 0.01$ (**).

common in obese animals as a result of excessive ingestion of high-calorie diets containing large amounts of carbohydrates and lipids (Barrie et al. 1993, Chikamune et al. 1995, Bailhache et al. 2003, Jeusette et al. 2005, Hoenig 2006). Several studies of cats have corroborated our findings of hyperlipidemia with increased total cholesterol and triglycerides (Jordan et al. 2008, Muranaka et al. 2011, Hoenig et al. 2013, Martins et al. 2022). Furthermore, the increase in non-esterified fatty acids and changes in lipoproteins with an increase in the VLDL fraction and a decrease in HDL have already been identified in other studies (Jordan et al. 2008). It is believed that the increase in the amount of non-esterified fatty acids transported to the liver is one of the factors involved in the increased production and secretion of VLDL (Lewis et al. 2002, Taskinen 2003).

Plasma glucose concentrations in the cats in the overweight and obese groups were higher than those noted in cats in the CT group. However, the differences were not statistically significant between the groups, as observed in other studies (Muranaka et al. 2011). This fact may be due to the CT containing two cats with discrepant plasma glucose values (225 mg/dL and 264 mg/dL) due to stress hyperglycemia; a transient increase in blood glucose has been shown in sick cats and cats showing signs of fear. Stress blood glucose values can generally reach up to 285 mg/dL (Link & Rand 2008). Another hypothesis is that despite peripheral insulin resistance, obese cats are able to maintain normal plasma glucose concentrations for long periods (Clark & Hoenig 2016).

Few studies have explored changes in renal function in obese cats. Relevant investigations have failed to find changes in renal function markers such as creatinine, urea, and SDMA (Pérez-López et al. 2023). Only one study showed higher concentrations of SDMA in obese cats; however, the values were within the reference for the species (Souza et al. 2022). In our study, we observed increased urea concentrations in obese cats. However, there were no statistically significant differences in creatinine concentrations between the groups. Mizorogi et al. (2020) demonstrated an increase in urea concentrations in obese geriatric cats (> 15 years) compared with geriatric lean cats but no significant differences in creatinine levels.

Several studies have sought associations between management characteristics and the home environments of overweight and obese cats that can impact their risk of becoming obese (Lund et al. 2005, Cave et al. 2012, Öhlund et al. 2018, Wall et al. 2019, Arena et al. 2021). A questionnaire administered to owners is widely used to investigate these associations; environmental factors such as being alone at home all day, being stressed (Arena et al. 2021), living in an exclusively indoor environment, living in a monotonous environment (Wall et al. 2019), and have a low level of physical activity (Öhlund et al. 2018) were predictive factors for obesity. Factors such as being fed exclusively dry food (Öhlund et al. 2018, Wall et al. 2019), eating premium or therapeutic food (Lund et al. 2005, Cave et al. 2012), *ad libitum* or twice-daily feeding (Russell et al. 2000, Courcier et al. 2010) and having a voracious appetite (Öhlund et al. 2018) were associated with an increased risk of being overweight. Those findings corroborate what was observed in this study: obese cats presented a higher frequency of *ad libitum* feeding, their food was more likely to be categorized as premium, they had lower levels of activity, and their environmental enrichment at home was low.

CONCLUSION

Cats that are overweight or obese exhibit altered hematological and biochemical parameters. In addition, factors related to the feeding and environmental management of cats may be predictive of an increased risk of being overweight. Therefore, it is essential to recognize obesity as a serious disease that negatively impacts cats' health and well-being. Our findings highlight the need for improved communication strategies with owners to better address and ensure cats have access to weight-loss programs.

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Data availability statement.- The essential data for interpreting the results have already been made available in this paper. Additionally, there are unpublished data related to ongoing research that cannot be shared to protect future publications and the integrity of the study.

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