Ciências Agrárias
SEMINA

DOI: 10.5433/1679-0359.2021v42n6p3305

Feline obesity: risk factors and clinical and metabolic findings

Obesidade felina: fatores de risco, achados clínicos e metabólicos

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Highlights

Obesity can cause a series of metabolic and mechanical effects on the body.
Most overweight animals stayed indoor and guardians did not change toys frequently.
Overweight cats had low levels of physical activities and hypercholesterolemia.

Abstract

Excess body fat can cause a series of metabolic and mechanical effects on the body. Therefore, this study aimed to verify the clinical, metabolic, and risk factors of overweight (OW) cats. For the acceptance of participation in the research, the tutors were asked to answer a questionnaire containing 34 questions and to point out the body condition score (BCS) on a sheet containing nine images of different scores (1 to 9 on a 9-point scale). Thereafter, the body evaluations were performed as a classification of the BCS on a scale from 1 to 9, with an ideal score (IS) of BCS 5 and OW for BCS > 5. Further, the lean mass index and morphometric measurements (thoracic and abdominal circumferences and height and length of the patella to calcaneal tuberosity) were performed to estimate the percentage of body fat. Systolic blood pressure was measured using the non-invasive Doppler method and blood was collected for hemogram and serum biochemistry (creatinine, urea, alanine aminotransferase, alkaline phosphatase, gamma-glutamyl transferase, glucose, triglycerides, and cholesterol). After these analyses, we sought to guide and raise the awareness of the tutors to promote the correct nutritional and environmental management of the animals. Thirty adult cats were divided into two groups, based on the classification of the BCS, with eight having an IS and 22 being OW. The OW group was found to have a low level of physical activity, hypercholesterolemia, and higher values of body characteristics. Additionally, there was a median agreement between the perceptions of

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Received: Mar. 25, 2021 - Approved: May 22, 2021

the clinician and the tutors. Therefore, it was concluded that the main laboratory alteration found in the obese cats was hypercholesterolemia, which was a critical parameter. It was observed that a low degree of physical activity could cause excess weight gain. It was found that the guardians of the cats with ideal weight underestimated the BCS, which could contribute to the supply of excess food and consequently, obesity. Thus, this study was sought to guide and raise the awareness of tutors, to promote the correct nutritional and environmental management thereby providing welfare and quality of life to the animals.
Key words: Clinic. Cats. Overweight. Quality of life.

Resumo

O excesso de gordura corporal pode ocasionar uma série de efeitos metabólicos e mecânicos no organismo. Portanto, o objetivo deste artigo foi verificar os achados clínicos, metabólicos e fatores de risco em felinos acima do peso ideal. A partir da aceitação da participação na pesquisa, os tutores foram convidados a responder um questionário contendo 34 perguntas e também apontar o escore de condição corporal (ECC) em uma folha contendo nove imagens de diferentes escores (1 a 9 em uma escala de 9 pontos). Posterior a isso, foram realizadas as avaliações corporais como classificação do ECC na escala de 1 a 9, sendo escore ideal (ECC 5) e acima do peso (ECC > 5), índice de massa magra, aferição das medidas morfométricas (circunferência torácia e abdominal, estatura e comprimento da patela a tuberosidade calcânea), com o intuito de estimar o percentual de gordura corporal. Bem como, foram realizadas a aferição da pressão arterial sistólica pelo método Doppler não invasivo e a coleta de sangue para hemograma e bioquímica sérica (creatinina, ureia, alanina aminotransferase, fosfatase alcalina, gama glutamil transferase, glicose, triglicerídeos e colesterol). Posterior a esses procedimentos buscou-se orientar e conscientizar os tutores, com o intuito de promover o correto manejo nutricional e ambiental dos animais. Participaram 30 felinos adultos, que foram agrupados em dois grupos, após a classificação do ECC, sendo EI escore ideal (n=8) e AP acima do peso (n=22). Foi possível verificar no grupo AP baixo nível de atividade física, hipercolesterolemia e valores superiores nas características corporais, bem como, concordância mediana entre a percepção do clínico e dos tutores. Portanto, conclui-se, neste estudo, que a principal alteração laboratorial encontrada em gatos obesos foi a hipercolesterolemia, sendo de grande importância avaliar este parâmetro. E, observou-se que o baixo grau de atividade física pode ocasionar o excesso de peso. Logo, verificou-se que tutores de gatos no peso ideal subestimaram o ECC, o que pode contribuir para o fornecimento de excesso de alimento e, consequentemente, a obesidade. Assim, buscou-se orientar e conscientizar os tutores, a fim de promover o correto manejo nutricional e ambiental e assim proporcionar bem-estar e qualidade de vida aos animais.
Palavras-chave: Clínica. Gatos. Excesso de peso. Qualidade de vida.

Introduction

Excess weight gain or obesity occurs when food intake exceeds the daily energy needs of the animal, thereby triggering a chronic positive energy balance (Okada, Kobayashi, Sawamura, & Arai, 2017). Therefore, excessive accumulation of body fat can cause a series of changes in the individual's body, as the adipose tissue has the ability to synthesize and secrete various hormones, including adipokines (Mccool, Rudinsky, Parker, & Gilor, 2018). Adipokines influence physiological processes of the body,

such as the inflammatory process, immunity, and glucose and lipid metabolism. However, the increase in adipose tissue predisposes to the elevation of some adipokines and a decrease in adiponectin, causing changes in the metabolism of the animal (Clark & Hoening, 2016).

In addition to the metabolic effects, obesity also promotes mechanical changes by influencing the quality and life expectancy of the animal and also the occurrence of obesity-associated comorbidities (Flanagan, Bissot, Hours, Moreno, & German, 2018), which includes diabetes mellitus (DM), hepatic lipidosis, lameness, dyslipidemia, systemic arterial hypertension, urinary tract disease, oral cavity diseases, and dermatological disorders. (Tarkosova, Story, Rand, & Svoboda, 2016). The diagnosis of the body condition can be performed using techniques that aim to determine the number of body structures, such as dual-energy X-ray absorptiometry (DEXA); however, it is rarely used in the clinical routine because it necessitates the patient to undergo general anesthesia. (Tarkosova et al., 2016). However, there are methods for easy application in the clinical routine that are based on the classification of the individual's degree of obesity through the assessment of the body condition score (BCS) on a scale of 1 to 9, verification of the loss of lean mass through the index of muscle mass (MMI), and measurement of morphometric measurements (Laflamme, 2006; Freeman et al., 2011).

In this context, the importance of diagnosis, treatment and studies in this area is emphasized to promote a better quality of life for patients, as well as assist in the awareness of tutors to contribute to the reduction of risk factors and assist in the prevention of obesity in felines. With this in mind, the objective of this study was to verify the clinical and metabolic findings and risk factors in overweight (OW) cats.

Material and Methods

This study was approved by the local animal experimentation ethics committee and the research ethics committee. As an inclusion criterion, adult cats with body condition scores (BCS) 5 and BCS > 5 were used according to the Laflamme (1997), regardless of sex and reproductive status. In order to promote a peaceful environment for patients, Feliway® CLASSIC spray was sprayed on the table, 15 min prior to each consultation, where the animals would be handled. Cat-friendly practices were followed during handling. At the beginning of the service, there was a brief explanation of the study and the distribution of the informed consent form (ICF) to the tutors.

After acceptance of participation, a questionnaire was supplied to the tutors, which contained 34 objective questions related to the nutritional, environmental, and behavioral management of animals. Each tutor was asked to choose their feline's body condition score (BCS) from a sheet containing nine images of different scores on a scale of 1 to 9 (Laflamme, 2006; Freeman et al., 2011) to check the tutor's perception of the animal's BCS.

Thirty healthy, mixed-breed, adult cats, randomly selected and treated at the veterinary clinic hospital of the Federal University of Pelotas (HCV-UFPEL), were included in the study. They were classified based on their body scores. The initial review (age, sex, and reproductive status), detailed anamnesis,

general physical examinations, and specific assessments related to the nutritional status, such as patient weight and analysis of the BCS through body inspection and palpation, classified on a scale from 1 to 9, with BCS 5 being ideal (Laflamme, 1997; Mawby et al., 2004; Freeman et al., 2011). Thereafter, an evaluation of the muscle mass index (MMI) was performed through visual analysis and palpation of the temporal, scapular, vertebral muscles, and ilium wings (Freeman et al., 2011; Barbosa, Botelho, Alves, & Souza, 2018). The morphometric measurements including the thoracic circumference (TC) in the ninth intercostal space, abdominal circumference (AC), the distance between the patella and calcaneal tuberosity, and height were performed with the aid of a measuring tape. Subsequently, the percentage of body fat (BFP) was estimated by using the formula: [GC = (CT/0.7067) – DCP/0.9156) – DCP], where CT = chest circumference and DCP = size of the patella to the calcaneus (Butterwick, 2000), and the feline body mass index (FBMI) adapted to the human BMI as FBMI = weight/height (kg/m)] (Shields, Tremblay, Gorber, & Janssen, 2012).

SBP was verified by the non-invasive method with the veterinary portable vascular Doppler (MedMega DV610V) in all animals in the left thoracic limb, five times. Thereafter, the two extreme values were excluded and the average of the remaining three values was calculated as the mean SBP. For the measurement, we tried to use a headset coupled to the Doppler, and some patients were wrapped in a cover to provide comfort and minimize stress.

For blood collection, we sought to minimize physical restraint and wrapped the patient in a blanket to reduce the collection stress and provide comfort. The animals underwent fasting for 8 h. Following this, a 23G scalp was used for venipuncture to collect 5 ml blood from the veins of choice in order: femoral, cephalic, and jugular veins. Blood count and serum biochemistry analyses [creatinine, urea, alanine aminotransferase (ALT), alkaline phosphatase (AP), gammaglutamyltransferase (GGT), glucose, triglycerides, and cholesterol] were performed. Complete blood count was estimated using the automatic hematology analyzer (Sysmex pocH-100 iv DiFF®) and the leukocyte differential was obtained by counting the cells using optical microscopy. Biochemical tests were performed using the semi-automatic analyzer (Bioclin BA-88A®), and Labtest® biochemical reagents were used.

After the procedures, the tutors were guided on the ways of environmental enrichment, such as the introduction of toys that stimulate hunting, body mobility, and caloric expenditure. In addition, guidance was provided on the nutritional management, distribution of food, and importance of weighing food to provide the correct amount of energy required by the animal.

The statistical analysis of the questionnaire, completed by the tutor, was performed using the OpenEpi program (Dean, Sullivan, & Soe, 2013), and the Pearson chi-square test was used to verify whether there was an association between the variables. To analyze the agreement between the BCS scores based on the tutors' perception and the clinician's classification, descriptive statistics, and the kappa coefficient were used by the online kappa calculator. The values of the body characteristics were calculated using the GraphPad Prism 7.0 program, in which

blood pressure and biochemical test results were first analyzed by the Shapiro-Wilk test, to verify the normality of the data; thereafter, the difference between the means was assessed using Student's t-test.

Results and Discussion

From this study, it was possible to identify certain risk factors in the study population. OW animals showed low physical activity ($p = 0.0038$) and hypercholesterolemia ($p = 0.0116$).

Profile of the studied population

Analysis of the studied population revealed that eight animals had an IS of BCS 5 (IS group) and 22 animals were in OW group. All animals were castrated and mixed-breed with an average age of 4 ± 3.4 years in the IS group and 6.5 ± 3.2 years in the OW group. In the IS group, four (50%) were males and four (50%) females, while in the OW group 10 (46%) were males and 12 (54%) were females. Tarkosova et al. (2016) has reported some risk factors for the development of obesity, including sex, reproductive status, age, and race. Thus, male, castrated, middle-aged cats have a greater predisposition, with the breed being a factor that may vary according to the location (Mendes, Passos, Gáleas, Secchin, & Aptekann, 2013; Alves, Barbosa, Cheren, Silva, & Souza, 2017).

Analysis of the questionnaire

Based on the responses to the questionnaire, it was possible to identify from the descriptive statistics that the majority of tutors from both groups provided dry and moist industrialized foods, at will. They did not graduate the portion of the daily food, and the amount was chosen on owns' account (Table 1). The type of food, form of distribution and the amount of food provided to the animal could contribute to weight gain (Verbrugghe, 2019). Thus, in this study, some of the risk factors related to nutritional management were verified, including the way of making the food available and choosing the quantity. Similar results are reported in previous studies that have verified certain risk factors for the development of obesity, such as highly palatable diets with high energy density, premium dry processed foods, and foods provided at will (German et al., 2011; Laflamme, 2012).

Regarding the environmental management, it was found that the majority of the cats in both groups lived at home, did not have access to the street, lived with other animals (feline and/or dog), used a litter, and had scratching posts and toys, which the tutors did not replace frequently (Table 1). The environment where the animal lived was closely related to the well-being and quality of life; therefore, it would be of great importance to carry out environmental management aimed at the feline's environmental needs. In addition, it would be necessary to provide a suitable and attractive environment that could meet the five pillars of a healthy environment for felines, such as the promotion of different areas, including areas of rest, food, water intake, and to place the box sand (Ellis et al., 2013). Thus, it was possible to analyze some of the risk factors related to environmental management.

Table 1
Variables related to the nutritional and environmental management of felines, in the ideal score and overweight groups as per the tutors' responses on the questionnaire

Variables		IS n (%)	OW n (%)
What food is provided	Dry feed only	3 (10)	10 (33.3)
	Dry and pasty feed	5 (16.7)	12 (40)
Frequency of food distribution	Freely	5 (16.7)	18 (60)
	Two times a day or more	3 (10)	4 (13.3)
Usually graduates the food	Yes	2 (6.6)	4 (13.3)
	Not	6 (20)	18 (60)
The amount of food was chosen as	I decided	7 (23.3)	17 (56.6)
	Veterinary guidance	1 (3.3)	5 (16.6)
In the case of other cats, each had a bowl of food and water	Yes	3 (10)	10 (33.3)
	Not	3 (10)	9 (30)
How do you consider the feline's body condition	Lean	1 (3.3)	-
	Ideal weight	5 (16.6)	2 (6.6)
	OW	2 (6.6)	20 (66.6)
The environment of the feline	House	5 (16.6)	13 (43.3)
	Apartment	3 (10)	9 (30)
Had street access	Yes	1 (3.3)	2 (6.6)
	Not	7 (23.3)	20 (66.6)
Had other animals at home	Yes	7 (23.3)	19 (63.3)
	Not	1 (3.3)	3 (10)
What is the source of water	Canister	7 (23.3)	19 (63.3)
	Source	1 (3.3)	3 (10)
Had sandbox	Yes	8 (26.6)	21 (70)
	Not	-	1 (3.4)
In the case of more cats, there were litter boxes	Yes	6 (28.5)	15 (71.5)
	Not	-	3 (10)
Had toys	Yes	7 (23.3)	21 (70)
	Not	1 (3.3)	1 (3.3)
The toys were changed	Yes	4 (13.3)	7 (23.3)
	Not	4 (13.3)	15 (50)
Had scratching posts	Yes	6 (20)	13 (43.3)
	Not	2 (6.6)	9 (30)

IS = ideal score; OW = overweight.

Among the animals, 20 (66.6%) lived indoors and 15 (50%) of their tutors did not change the toys. Thus, the tutors did not stimulate the physical mobility, caloric expenditure, or predatory behavior of the felines (Ellis et al., 2013; Dantas, Delgado, Johnson, & Buffington, 2016). Öhlund et al. (2017) found certain significant risk factors associated with the development of DM in cats, such as the intake of dry commercial food, increased body weight, and indoor animals. Therefore, we sought to guide tutors, emphasizing the importance of promoting an attractive environment with resources and opportunities that could encourage daily physical exercise and predatory behavior through play.

Regarding the level of physical activity, the OW group exhibited a lower rate of physical activity with 13 (43.3%) cats ($p = 0.0038$) compared to the IS group. In both groups, most animals were able to move freely around the house and had a high place to control the environment. All animals in both the groups were able to clean themselves normally, except three (10%) of the cats in the OW group, who were unable to clean themselves frequently (Table 2). In both groups, the animals were close to the tutors, usually at night; however, the tutors of 11 (36.6%) of the animals in the OW group did not have time to interact and encourage play (Table 2). The low physical activity of these animals might be associated with the minimal daily interaction between the guardian and feline and the low stimulus for playing. Therefore, we sought to guide the tutors on the strategies and forms of environmental enrichment aimed at physical exercise and caloric expenditure and also explained the need for the tutor and animal interaction (Ellis et al., 2013; Dantas et al., 2016; Sadek et al., 2018).

With regard to the alteration of the animals' locomotion, the majority of the tutors in both groups reported that the felines had no alterations during locomotion; however, five (16.6%) of the OW animals had at some point alteration during locomotion in a home environment, for example, getting up and/or down on furniture, without complaining of lameness. In addition to promoting metabolic changes, excess weight can also cause joint overload and the occurrence of locomotor diseases such as the partial or total rupture of the cruciate ligament, dislocation of the patella, and arthritis (Lund, Armstrong, Kirk, & Klausner, 2005).

In addition, most of the animals in both groups were adopted as young, did not show signs of aggression during play or with people and animals, did not vocalize frequently, and did not exhibit any behavioral changes. However, tutors of six (20%) of the animals reported some behavioral change after the visit or interaction with strangers, such as stress, anxiety, and in some cases excessive fear, possibly due to some trauma. The presence of behavioral changes could be related to the negative experiences lived in the early stages of life, the lack of socialization to different environments, people, and objects, as well as the lack of environmental enrichment at home. Thus, we sought to guide the tutors with ways to minimize the stress during the arrival of strangers in the environment, such as promoting positive reinforcement during socialization with different people and/or environments (Heath, 2018; Amat, Camps, & Manteca, 2016; Ellis et al., 2013).

Table 2
Parameters analyzed referring to the daily life and behavior of the felines in the ideal score and the overweight groups

Variables		IS n (%)	OW n (%)
Level of physical activity, *p= 0.0038	Active	8 (26.6)	9 (30)
	Little active	-	13 (43.3)
Locomotion difficulty	Yes	-	5 (16.6)
	Not	8 (26.8)	17 (56.6)
Could get around the house	Yes	8 (26.6)	21 (70)
	Not	-	1 (3.3)
Could clean itself	Yes	8 (26.6)	19 (63.4)
	Not	-	3 (10)
The age when it was adopted	Puppy	6 (20)	15 (50)
	Adult	2 (6.6)	7 (23.3)
Aggressive while playing	Yes	3 (10)	7 (23.3)
	Not	5 (1.7)	15 (50)
Behavior when someone strangers home	Don´t Interact	1 (3.3)	7 (23.3)
	Interact	5 (1.7)	8 (26.6)
	Disappear	2 (6.6)	7 (23.3)
Aggressive towards people	Yes	-	2 (6.6)
	Not	8 (26.6)	20 (66.6)
Aggressive towards animals	Yes	-	4 (13.3)
	Not	8 (26.6)	18 (60)
Location when the tutor is at home	In another environment	-	2 (6.6)
	Next	8 (26.6)	18 (60)
	On the lap	-	2 (6.6)
Period the tutor spent more time together	A shift	7 (23.3)	18 (60)
	More than one shift	1 (3.3)	4 (13.3)
Time of interaction with the tutor	No time	2 (6.6)	11 (36.6)
	30 min	1 (3.3)	8 (26.6)
	> 30 min	5 (16.6)	3 (10)
Had a high place to observe the environment	Yes	7 (23.3)	20 (66.6)
	Not	1 (3.3)	2 (6.6)
Could jump wherever it wanted	Yes	8 (26.6)	20 (66.6)
	Not	-	2 (6.6)
Had a habit of vocalizing	Yes	3 (10)	9 (30)
	Not	5 (16.6)	13 (43.3)
Any behavioral change at some point	Yes	1 (3.3)	5 (16.6)
	Not	7 (23.3)	17 (56.6)

IS = ideal score; OW = overweight.

Comparison of the perception of the body condition score

With regard to the tutors' perception of the BCS when compared to the veterinarian's classification, there was a median agreement (κ = 0.28) (Landis & Koch, 1977). A general agreement of 30% (n = 9) and a disagreement of 70% (n = 21) in relation to the scores were also observed. When analyzing the scores in the groups separately, 25% (n = 2) correct answers were observed in the IS group and 32% (n = 7) in the OW group. Furthermore, in the IS group, it was found that about six (75%) tutors underestimated the score, indicating a score lower than that chosen by the veterinarian (p = 0.0096). In the OW group, nine (40.9%) tutors overestimated the score, and five (22.7%) underestimated the score (p > 0.05) (Table 3). Previous reports have suggested that some tutors have difficulty in pointing out the correct score for OW animals and, in most cases, underestimate the score, thus providing overfeeding. (Coucier, Higgins, Mellor, & Yam, 2010; Verbrugghe, 2019). However, in this study, most tutors recognized that the respective animals were OW and overestimated their scores. The tutors of animals in the IS group underestimated the score considering the lean and even cachectic felines. This analysis was of great importance as it helped the tutors become aware to avoid overfeeding and prevent excess weight gain of the animals.

Table 3
The perception of the body condition score based on the tutor and veterinarian and the agreement of this assessment

	Veterinary BCS $\bar{x}$ ±SD	Tutor BCS $\bar{x}$ ±SD	Concordance n (%)	p-value
IS	5 ± 0	3.5 ± 1.4	2 (20%)	0.0096*
OW	7.45 ± 1.05	7.54 ± 1.37	7 (32%)	0.8066

The data on BCS is presented as mean ± SD. *p < 0.05. IS = ideal score; OW = overweight; BCS = body condition score; $\bar{x}$ = mean; SD = standard deviation.

Body assessments

Upon inspection of body characteristics, one animal from each group was found to have a slight loss of lean mass. Eight animals were classified with an IS and 22 were OW. Out of the OW cats, 11 had a BCS of 6-7, and the rest 11 were obese with a BCS of 8-9. Despite being subjective, the assessment of BCS has become an easily applicable method in the clinical routine for the diagnosis of obesity and nutritional assessment. The reliability of this method is described on the 9-point scale compared to the percentage of fat obtained by DEXA (dual-energy X-ray absorptiometry) (Mawby et al., 2004; Okada et al., 2017). Thus, it is estimated that with each point higher than the ideal score (BCS 5), there is an increase of the ideal weight by 10% to 15% (Laflamme, 2006).

Analysis of the feline morphometric characteristics showed that the mean weight, TC, AC, FBMI, and BFP remained significantly

higher in the OW group compared to the IS group ($p < 0.05$) (Table 4). In addition, a BFP of 25.2% in the IS group and 36.3% in the OW group corroborated with the percentages described in the literature. The ideal body fat percentage for cats is reported between 25% to 30% and animals above 30% are considered OW (Aptekmann, Mendes, Passo, Secchin, & Galeas, 2014; Santarossa, Parr, & Verbrugghe, 2017; Fabretti et al., 2020). Thus, based on our results, we suggested the use of morphometric measures as an auxiliary method for the nutritional assessment, in the screening of OW animals, and during monitoring of the weight loss.

Table 4
Comparison of the body characteristics of cats between ideal score and overweight groups

Independent variables	Groups	$\bar{x}$ ±SD	p-value
Weight (kg)	IS	3.8 ± 0.5	0.0123*
	OW	5.2 ± 1.4	
Thoracic circumference (cm)	IS	35.8 ± 1.5	0.0033*
	OW	42.8 ± 5.8	
Abdominal circumference (cm)	IS	36.7 ± 3.9	0.0024*
	OW	45.7 ± 7.2	
Patella-calcaneal length (cm)	IS	14.3 ± 1.2	0.6922
	OW	14.1 ± 1.5	
Estature (cm)	IS	41.8 ± 3.7	0.4109
	OW	43.9 ± 5.6	
Body mass index (kg/m)	IS	9.2 ± 1.4	0.0210*
	OW	11.8 ± 2.6	
Body fat (%)	IS	25.2 ± 2.4	0.0006*
	OW	36.3 ± 7.8	

The data are presented as mean ± SD. *$p < 0.05$. IS = ideal score; OW = overweight; $\bar{x}$ = mean; SD = standard deviation.

Analysis of the SBP

The mean SBPs in the IS and the OW groups were found to be 136.1 ± 21.6 mmHg and 146.8 ± 21.2 mmHg respectively, showing no statistical difference between the values of the two groups ($p > 0.05$). Obesity in humans causes a series of cardiovascular changes and also increases in blood pressure (Silva, Domingos, & Caramaschi, 2018). In cats, hypertension associated with obesity is still not well described in the literature. Some authors have reported high blood pressure in animals with excess weight; however, further studies are needed for concrete evidence (Chandler, 2016; Freitas et al., 2018). Moreover, the increase in SBP can be triggered by certain situations, such as stress to different environments or situations associated with other processes that increase blood pressure or it can occur in an idiopathic way (Acierno

et al., 2018). Therefore, the importance of measuring SBP is worth emphasizing to carry out the early diagnosis of hypertension, since chronic increases in SBP can cause lesions in some target tissues, such as the kidney, eye, brain, and heart (Acierno et al., 2018).

In this study, the mean SBP measurement revealed that five (62.5%) of the animals in the IS group remained normotensive (SBP < 140 mmHg) and three (37.5%) had SBP > 140 mmHg. In contrast, in the OW group, seven (31.8%) remained normotensive and 15 (68.2%) had a SBP > 140 mmHg. Freitas et al. (2018) verified the increase in blood pressure in obese and OW cats. It was suggested that OW cats might have increased blood pressure, so it is important to develop new studies to promote a peaceful environment during the measurement, and more than two measurements should be performed on different days to confirm the presence of hypertension (Acierno et al., 2018).

Blood evaluations

There was no change in the blood count between the IS and the OW groups. Biochemical analyses (Table 5) showed the levels of creatinine, urea, AP, ALT, GGT, and triglycerides similar to that of reference in both groups. There was a slight non-significant increase in glucose level in the IS group (145 mg/dL) compared with that in the OW group (123 mg/dL). The increase in blood glucose level could be explained by transient hyperglycemia caused due to stress on blood collection or the possible lack of fasting prior to collection, as food intake in the last hours could influence the increase in glucose levels (Bonagura & Twedt, 2008; Reeve-Johnson et al., 2017, Behrend, Holford, Lathan, Rucinsky, Schulman, 2018; Costa & Borin-Crivellenti, 2019). Therefore, the cats in this study remained normoglycemic in both groups.

Table 5
The biochemical findings of the felines of the ideal score and overweight groups

Analyzed variables	IS ($\bar{x}$; ±SD)	OW ($\bar{x}$; ±SD)	Reference value
Creatinine (mg/dL)	0.9 ± 0.2	1 ± 0.3	0.7-1.8
Urea (g/dL)	33 ± 24.1	28.5 ± 10.7	23-63
Alkaline phosphatase (UI/L)	81.1 ± 16.9	85.6 ± 63.4	25-93
ALT (UI/L)	58 ± 20.0	36 ± 18.3	6-83
GGT (UI/L)	5 ± 1.8	4 ± 2.2	0-8
Glucose (mg/dL)	145.7 ± 21.5	123.4 ± 29.8	73-151.3
Triglycerides (mg/dL)	51.1 ± 21.3	75.6 ± 35.3	10-114
Cholesterol (mg/dL) *p = 0.0116	99.5 ± 14.2	134.6 ± 32.6	95-130

The data is presented as mean ± SD. *p < 0.05. Reference values (Kaneko et al., 2008). IS = ideal score; OW = overweight; SD = standard deviation.

Furthermore, compared to the IS group significant hypercholesterolemia (p = 0.0116) was observed in 11 (50%) animals of the OW group (6 overweight and 5 obese cats). Increased levels of triglycerides, cholesterol, and their fractions are reported in OW animals (Clark & Hoenig, 2016). In a study by Mori et al. (2012), significant hypercholesterolemia was found in 9/36 OW animals. However, the studies by Freitas et al. (2018) and Aguiar et al. (2018) did not find hyperlipidemia in 27 and 21 OW cats, respectively. In this study, an increase in total cholesterol levels in the OW group did not show any incidence of metabolic syndrome, which is characterized by alterations of at least two of the parameters, such as hyperglycemia, hyperlipidemia, increased ALT, and a decrease in adiponectin (Mori et al., 2012).

From this study, it was possible to guide and provide necessary information to the tutors, aiming at the five pillars of a healthy environment, to minimize the risk factors. It can further provide a more attractive environment for felines to promote quality of life, contribute to reducing the weight of the felines undergoing treatment, and prevent the onset of comorbidities resulting from feline obesity (Ellis et al., 2013).

Conclusion

This study concluded that the main laboratory alteration found in obese cats was hypercholesterolemia, which is of great importance to evaluate this parameter. It was observed that a low degree of physical activity could cause excess weight gain. Therefore, it was found that the guardians of cats at the ideal weight underestimated the BCS, which could contribute to the supply of excess food and consequently, obesity. Thus, it was sought to guide and raise the awareness of the tutors to promote the correct nutritional and environmental management and thus provide welfare and quality of life to animals.

Acknowledgments

We thank Capes for granting the scholarship to CNPq (308152 / 2019-0), thus contributing to the development of research.

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