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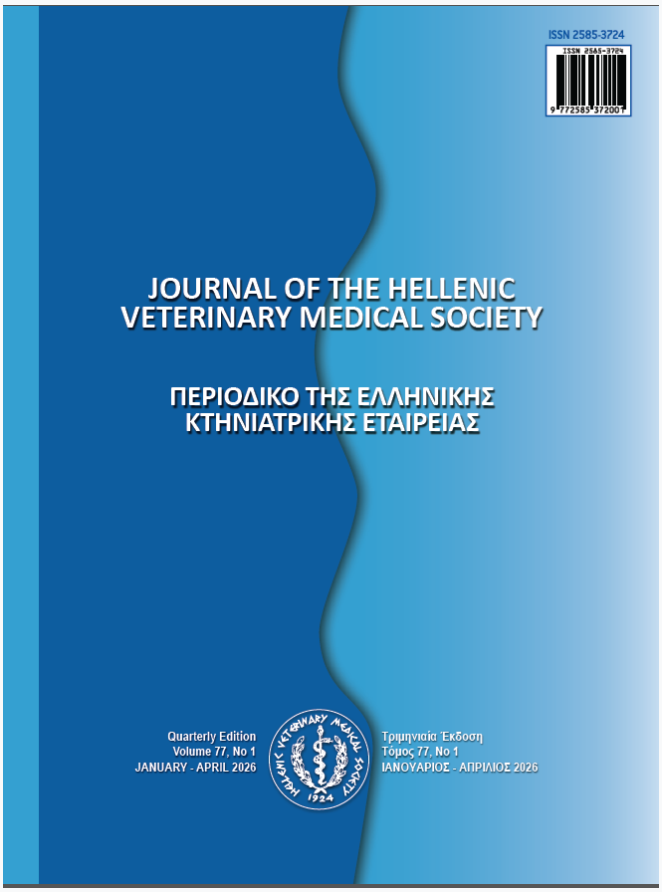

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M Çıkma, E Gülersoy

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Evaluation of Serum Biochemical Parameters, Visfatin, and C-Reactive Protein Concentrations in Obese Versus Non-Obese Cats

M. Çikma,[1] E. Gülersoy[1,*]

[1]Harran University, Veterinary Faculty, Department of Internal Medicine, Şanlıurfa, Türkiye

ABSTRACT: Obesity in cats is associated with chronic low-grade systemic inflammation, driven by an acute-phase response from adipose tissue. In addition to increasing disease risk, obesity also reduces lifespan. This study aimed, for the first time, to evaluate visfatin concentrations in clinically healthy obese and non-obese cats, assess its relationship with C-reactive protein (CRP) concentrations and selected biochemical parameters, and explore their utility as early biomarkers of obesity-related changes. A total of 194 cats presented for routine health checks and vaccinations were screened; after applying inclusion and exclusion criteria, 40 were assigned to the Obese group and 20 to the Control group. All cats underwent physical examination, complete blood count (CBC), serum biochemistry analysis, and measurements of serum CRP and visfatin concentrations. Body condition score (BCS) and body weight were significantly higher in the Obese group ($p<0.0001$). While CBC values remained within reference interval, monocyte ($p<0.027$) and red cell distribution width (RDW) ($p<0.0001$) levels were significantly increased in obese cats. Although serum biochemistry parameters were within reference interval, the Obese group had significantly higher blood urea nitrogen (BUN) ($p<0.012$) and total bilirubin (TBIL) ($p<0.0001$), and lower alanine transaminase (ALT) concentrations ($p<0.035$). Serum CRP ($p<0.0001$) and visfatin ($p<0.001$) concentrations were also markedly increased in obese cats. Diagnostic evaluation indicated that monocyte count, aspartate aminotransferase (AST), lactate dehydrogenase (LDH), and gamma glutamyl transferase (GGT) had acceptable value, RDW, BUN, and visfatin had excellent value, and CRP and TBIL demonstrated outstanding diagnostic utility for identifying subclinical inflammation. In conclusion, the findings highlight the persistence of chronic low-grade inflammation in obese cats, even in the absence of clinical signs. Routine monitoring of CRP and visfatin, along with dietary and behavioral interventions, may be crucial for early detection and management of obesity and its related comorbidities in at-risk cats.

Keyword: adipokine; biomarker; body condition scoring; cat; obesity

Correspondence author:
E. Gülersoy,
Harran University, Veterinary Faculty, Department of Internal Medicine,
Şanlıurfa, Türkiye
E-mail address: egulersoy@harran.edu.tr

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INTRODUCTION

Obesity is a complex, multifactorial, noncommunicable disease characterized by excessive adipose tissue accumulation due to caloric intake exceeding energy expenditure, which can ultimately impair health (WHO, 2021). A cat is considered obese when its total body weight exceeds its ideal body weight by more than 20% (Michel and Scherk, 2012). Obesity has been associated with various health problems, including metabolic disorders, osteoarthritis, and lower urinary tract disease (Prahl et al., 2007). In addition to increasing disease risk, obesity also reduces lifespan in cats (German, 2006). Therefore, routine health evaluations, monitoring of body weight changes, and assessment of body condition score (BCS) during clinical examinations are essential for the early detection and prevention of obesity (Laflamme, 2006).

Adipose tissue plays a key role in energy metabolism, which is regulated by neural, hormonal, and nutrient-related signals (Morton and Schwartz, 2011). Moreover, adipose tissue functions as an endocrine organ by producing various hormones and peptides known as adipokines, including adiponectin, interleukins (ILs), and proinflammatory cytokines such as tumor necrosis factor-alpha (TNF-α). An increase in adipose tissue leads to abnormal production and secretion of these adipokines, which can disrupt glucose homeostasis, metabolism, inflammation and immune responses, and cardiovascular function (Radin et al., 2009). Through the secretion of proinflammatory mediators, adipose tissue contributes to both mechanical and metabolic comorbidities (Wang and Nakayama, 2010). Visfatin has been identified as a novel adipocytokine associated with visceral fat accumulation in both humans and mice (Samal et al., 1994). Although its physiological role is not yet fully understood, initial studies suggested that visfatin exerts insulin-like effects by binding to insulin receptors and lowering plasma glucose concentrations. However, these insulin-mimetic properties have since been questioned (Fukuhara et al., 2005). Several studies have reported correlations between circulating visfatin concentrations and fasting glucose, insulin resistance, visceral fat, body mass index (BMI), and triacylglycerol concentrations (Pagano et al., 2006). C-reactive protein (CRP), a proinflammatory biomarker, is commonly used to differentiate between viral and bacterial infections, but increased concentrations can also be observed in conditions such as rheumatoid arthritis, various malignancies, trauma, and postoperative states (Prucha, 2015). Similar to CRP, visfatin exhibits proinflammatory properties. Studies in obese humans have shown that TNF-α is independently associated with visfatin concentrations, while CRP has been identified as a stronger predictor of basal visfatin concentrations (De Luis et al., 2008).

Given the similarities between feline and human obesity-related disorders, and the established roles of visfatin and CRP concentrations in inflammation and metabolic regulation, investigating these markers in obese cats may provide novel insights into the pathophysiological mechanisms of obesity. This study aims, for the first time, to evaluate visfatin concentrations in clinically-healthy obese cats, explore their associations with CRP concentrations and selected biochemical parameters, and assess their potential utility as biomarkers for early detection and management of obesity-related changes.

MATERIAL AND METHODS

This thesis study was approved by Harran University Animal Experiments Local Ethics Committee with session number 2024/003, decision number 01-12 on 16.05.2024.

Animals

A total of 194 cats, brought to the Harran University Veterinary Faculty Animal Hospital for preventive health checks and vaccinations, were evaluated between March 2023 and May 2024. Body weight and BCS were measured, while nutritional status, breed, age, and neutering status were recorded for all cats. Anamnesis information indicated that all cats had access to toys, such as scratching posts and balls, within the house. Laboratory analyses were conducted following physical examination of all cats that met the study's inclusion criteria.

Physical Examination

Following an acclimation period of approximately 15 minutes in the examination room, rectal body temperature, respiratory and heart rate (per minute), and gingival capillary refill time (CRT) were measured as part of the physical examination. Lung and heart auscultation, along with evaluation of palpable lymph nodes, were also performed. Additionally, systolic blood pressure (SBP) was measured using an inflatable cuff placed on the digital artery, with measurements repeated three times (MINDRAY uMEC12 Vet bedside monitor, China). Ultrasonographic (Mindray Z60, China), radiographic (Fujifilm FCR Prima, Japan), and orthopedic examinations

were conducted when necessary. BCS was assessed using a 9-point-scale, and body weights were measured on a digital scale.

Sampling

Blood samples were collected from cats deemed healthy based on physical examination and classified as obese or non-obese according to the 9-point-scale BCS. Venous blood samples (3-5 mL) were obtained via cephalic vein, ensuring minimal stress to the cats. Tubes with K_3EDTA (1-2 mL) were used for complete blood count (CBC), while tubes without anticoagulant (2-3 mL, with gel) were used for serum biochemistry analysis.

Laboratory Examinations

CBC, including measurements of white blood count (WBC), lymphocytes (Lym), monocytes (Mon), granulocytes (Gra), erythrocytes (RBC), mean cell volume (MCV), hematocrit (Hct), mean hemoglobin (MCH), mean hemoglobin concentration (MCHC), reticulocyte distribution width (RDW), and hemoglobin (Hb), was performed using an autoanalyzer (Sysmex pocH 100i, Japan) within 20 minutes of sample collection. Venous blood samples were allowed to clot at room temperature for 20-30 minutes and then centrifuged at 3000 rpm for 10 minutes. Serum was then separated, with a portion stored in sterile Eppendorf tubes at -20 °C for biomarker analysis and the remaining sample measured using an automatic biochemistry device (Seamaty SMT-120V, China) within 40 minutes. Serum biochemistry analysis included evaluation of blood urea nitrogen (BUN), creatinine (Crea), aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), lactate dehydrogenase (LDH), gamma glutamyl transferase (GGT), total bilirubin (TBIL) and glucose concentrations.

Inclusion/Exclusion criteria and Forming Subgroups

To assess the health status of the cats, additional examinations were performed on those whose physical examination, CBC, and serum biochemistry results were within reference interval. Specifically, fecal samples were collected directly from the rectum using sterile swabs for native microscopic examination (performed using a light microscope at ×100 magnification, Olympus, Japan) to detect motile protozoa such as *Giardia* spp. and *Tritrichomonas foetus*, as well as helminth eggs including *Toxocara* spp., *Ancylostoma* spp., and *Dipylidium* spp. Additionally, feline immunodeficiency virus (FIV) and feline leukemia virus (FeLV) were evaluated using a rapid diagnostic test kit (IDEXX SNAP FIV/FeLV Combo Test; IDEXX Laboratories). Radiographic and ultrasonographic examinations were performed using a 5–7.5 MHz microconvex probe, and when necessary, echocardiographic examinations were performed using a 7.5–10 MHz sector probe (Mindray Z60, China). Among the cats were considered to be healthy according to physical, laboratory, and imaging examinations, those with normal BCS were included in the Control group, while those with BCS >6 were classified as healthy obese and included in the Obese group.

Biomarkers Measurements

Serum visfatin and CRP concentrations were measured using commercial feline-specific ELISA kits (BT Lab Bioassay Technology Laboratory, China) following the manufacturer's instructions. The CRP standard curve range was 5-320 ng/ml, with a sensitivity of 2.59 ng/ml. Intra-assay CV was <8%, and inter-assay CV was <10%. The visfatin standard curve range was 0.1-6.4 ng/ml, with a sensitivity of 0.05 ng/ml. Intra-assay CV was <8%, and inter-assay CV was <10%.

Statistical Analyses

Statistical analyses were performed using SPSS 27.00 software. After normality analysis, data were presented as median (range) or mean ± SD, depending on the distribution, with the Mann-Whitney U or Kruskal-Wallis test applied. Receiver operating characteristic (ROC) analyses were conducted to evaluate the clinical performance of the investigated parameters in identifying subclinical inflammatory processes in obese cats. The area under the curve (AUC), standard error, p-value, cut-off value, sensitivity, and specificity were investigated. In ROC analysis, an AUC of 0.5 indicated no discrimination (i.e., no ability to diagnose patients with/without disease based on the test), AUCs of 0.7 to 0.8 were considered acceptable, 0.8 to 0.9 were considered excellent, and AUCs above 0.9 were considered very superior. Statistical significance was set at $p < 0.05$ for all tests.

RESULTS

Animals

In total, 40 of the 194 cats screened were included in the Obese group, and 20 in the Control group. The animals included in this study were randomly selected indoor cats of both sexes and various breeds, aged 1-9 years. All cats were fed a combination of

commercial dry and wet food 2-3 times a week and received routine vaccinations and antiparasitic treatments, as reported in the anamnesis. In the Obese group, 27 cats were male and 13 were female. The breeds in this group included 33 mixed-breed, 4 Scottish, 2 Siamese, and 1 British Shorthair. All cats in this group were neutered. In the Control group, 11 cats were male and 9 were female, all neutered. The majority of the Control group were mixed-breed (12), with 2 Scottish Fold, 2 British Longhair, 2 Exotic, 1 Persian, and 1 Tuxedo.

Inclusion/Exclusion Results

Of the 194 cats screened and deemed eligible for inclusion in the study, 134 were excluded based on specific findings. Thirty-four cats had increased thickness of the urinary bladder wall (wall thickness >0.2 cm) on ultrasonographic examination. Twenty-two cats showed arrhythmias during cardiac auscultation. Eighteen cats were found to be hypertensive (SBP >160 mmHg) during blood pressure measurement. Forty-eight cats displayed radiographic signs, such as a peribronchial pattern indicative of feline asthma, a flattened diaphragm, and increased distance between the caudal border of the heart and diaphragm. Twelve cats showed mild lameness on orthopedic examination. These cats were excluded from the study.

Physical Examination Findings

Although the parameters assessed during the physical examination were within reference interval, comparison between groups revealed that the body temperature of obese cats was significantly higher than that of healthy cats ($p<0.030$). BCS and body weight were also greater in the Obese group compared to the Control group ($p<0.0001$). No abnormalities were detected during cardiac auscultation; however, lung sounds were muffled in four of the 40 cats in the Obese group. Physical examination findings and 9-point BCS results are presented in Table 1.

CBC Findings

All CBC values were within reference interval. However, Mon and RDW levels were significantly higher in the Obese group compared to the Control group ($p<0.027$ and $p<0.0001$, respectively). CBC findings are presented in Table 2.

Serum Biochemistry Findings

Serum biochemistry analysis for all cats included in the study was within reference interval. However, intergroup comparisons revealed that BUN ($p<0.012$) and TBIL ($p<0.0001$) concentrations were higher, while ALT concentrations were lower ($p<0.035$) in the Obese group compared to the Control group.

Table 1. Physical Examination Findings

Parameters	Obese Group n:40 median (range)	Control Group n:20 median (range)	p value
Respiratory rate (breaths/min)	28 (21-32)	26.5 (24-30)	0.735
Heart rate (beats/min)	123.5 (120-138)	129 (122-133)	0.352
CRT (sec)	1.5 (1-2)	1 (1-2)	0.130
Body temperature (°C, rectal)	**39.05 (38.2-39.8)**	**38.35 (38.1-39.1)**	**0.030**
BCS (9-point scale) *	**7 (6-9)**	**4 (4-5)**	**0.0001**
Age (year)	4 (1-9)	6.5 (3-9)	0.153
Body weight (kg)	**7.75 (5-9)**	**3.65 (3-4.5)**	**0.0001**
SBP (mmHg)	137 (116-142)	122 (114-142)	0.214

CRT: Capillary refill time, BCS: Body condition score, SBP: Systolic blood pressure, kg: Kilogram, *(Teng et al., 2018).

Table 2. CBC findings

Parameters	Obese Group n:40 median (range)	Control Group n:20 median (range)	p value
WBC (K/µL)	11.12 (5.39-18.84)	10.86 (6.7-11.98)	0.264
Lym (K/µL)	4.14 (1.78-9.47)	5.02 (3.96-6.85)	0.286
Mon (K/µL)	**0.87 (0.17-2.44)**	**0.52 (0.2-0.99)**	**0.027**
Gra (K/µL)	6.39 (2.16-12.52)	4.23 (2.4-7.19)	0.127
RBC (M/µL)	10.42 (6.65-13.6)	10.14 (6.39-10.7)	0.288
MCV (fl)	40.8 (34.3-49.5)	39.1 (37.5-43)	0.274
Hct (%)	42 (25.1-52.7)	38.8 (27.4-41.1)	0.128
MCH (g/dL)	13.6 (11-15.2)	13.65 (12.1-16.1)	0.583
MCHC (g/dL)	32.85 (28.3-36.8)	33.9 (32.4-39.4)	0.117
RDW (%)	**16.8 (12.9-22.9)**	**14.25 (13.4-15.1)**	**0.0001**
Hb (g/dL)	13.85 (8.3-16.7)	12.7 (9.4-15.1)	0.201

WBC: White Blood Cell, Lym: Lymphocyte, Mon: Monocyte, Gra: Granulocyte, RBC: Red Blood Cell, MCV: Mean Cell Volume, Hct: Hematocrit, MCH: Mean Corpuscular Hemoglobin, MCHC: Mean Corpuscular Hemoglobin Concentration, RDW: Red Cell Distribution Width, Hb: Hemoglobin

The serum biochemistry analyses are presented in Table 3.

Visfatin and CRP Measurement Results

Serum CRP concentrations were significantly higher in obese cats compared to the control group ($p<0.0001$). Similarly, serum visfatin concentration in obese cats was significantly higher than in the non-obese cats ($p<0.001$). The results of visfatin and CRP concentrations are presented in Table 4.

ROC Analysis

As a result of ROC analysis of CBC parameters, Mon level (AUC = 0.708) was determined to have acceptable diagnostic value in identifying the subclinical inflammatory process in obese cats, while RDW (AUC = 0.862) was found to have excellent diagnostic value.

In defining the subclinical inflammatory process in obese cats, the serum biochemical parameter BUN (AUC = 0.854) demonstrated excellent diagnostic value, while AST (AUC = 0.725), LDH (AUC = 0.725), and GGT (AUC = 0.758) showed acceptable diagnostic value. Additionally, TBIL (T. Bil, AUC = 0.942) exhibited outstandings diagnostic value. The results of the ROC analysis for the serum biochemical parameters are presented in Table 6, with the corresponding ROC curves shown in Figure 2. Visfatin (AUC = 0.867) demonstrated excellent diagnostic value, while CRP (AUC = 0.925) showed outstanding diagnostic value in identifying subclinical inflammatory processes in obese cats. The results of the ROC analysis for these biomarkers are presented in Table 7, and the corresponding ROC curves are shown in Figure 3.

Spearman correlation analysis revealed a moderate positive correlation between body weight and BCS, as well as between visfatin and CRP. The results of the Spearman correlation analysis are presented in Table 8.

Table 3. Serum biochemistry findings

Parameters	Obese Group n:40 median (range)	Control Group n:20 median (range)	p value
BUN (mg/dL)	**18.9 (10.8-28)**	**10.2 (8.9-19.7)**	**0.012**
Crea (mg/dL)	0.9 (0.6-1.8)	0.94 (0.6-1.1)	0.638
AST (U/L)	42 (15-80)	30.5 (21-45)	0.104
ALT (U/L)	**34.5 (22-73)**	**46.5 (32-64)**	**0.035**
ALP (U/L)	35.5 (16-64)	35.5 (22-44)	0.642
LDH (U/L)	210.5 (101-324)	162 (105-301)	0.252
GGT (U/L)	7.5 (2-12)	5.5 (2-8)	0.059
TBIL (mg/dL)	**0.6 (0.25-0.9)**	**0.27 (0.18-0.38)**	**0.0001**
Glucose (mg/dL)	98 (80-120)	96 (77-105)	0.554

BUN: Blood urea nitrogen, Crea: Creatinine, AST: Aspartate aminotransferase, ALT: Alanine aminotransferase, ALP: Alkaline phosphatase, LDH: Lactate dehydrogenase, GGT: Gamma glutamyl transferase, TBIL: Total bilirubin

Table 4. Visfatin and CRP concentrations

Parameters	Obese Group n:40 median (range)	Control Group n:20 median (range)	p value
CRP (ng/mL)	92.45 (57.01-146.43)	54.32 (39.23-79.06)	0.0001
Visfatin (ng/mL)	1.75 (1.02-2.89)	1.15 (0.83-1.55)	0.001

CRP: C-reactive protein

DISCUSSION

Feline obesity is not merely a cosmetic concern; it significantly increases the risk of comorbidities such as diabetes mellitus (DM) and hepatic lipidosis (Biourge et al., 1994). Given that obesity induces a systemic low-grade inflammatory state, coupled with the rising global prevalence and the difficulty of reversing advanced obesity (e.g., reducing a 12 kg cat to 4.5 kg), it is evident that this condition warrants serious veterinary attention (German 2006, Wisse 2004). In this study, clinically healthy obese and non-obese cats, verified through physical and laboratory assessments, were evaluated within a defined period to detect subclinical inflammation or underlying metabolic disturbances based on serum visfatin and CRP concentrations. Although routine CBC and serum biochemistry parameters largely remained within reference ranges, both CRP and visfatin concentrations were significantly elevated in obese cats compared to their non-obese counterparts. A moderate positive correlation between visfatin and CRP further supports the presence of obesity-associated low-grade systemic inflammation, despite the absence of overt clinical signs. ROC analysis identified monocyte count, RDW, BUN, AST, LDH, GGT, TBIL, and serum levels of CRP and visfatin as potential biomarkers for detecting this subclinical inflammatory state.

Table 5. ROC analysis of CBC parameters

Parameter	AUC	Std. Error	Asymp. Sig.	Asymptotic 95% Confidence Interval		Cut-off	Sensitivity (%)	Specificity (%)
				Lower Bound	Upper Bound			
WBC	0.567	0.117	0.626	0.338	0.795	10.86	55	50
Lym	0.342	0.118	0.248	0.110	0.574	4.15	45	50
Mon	0.708	0.107	0.128	0.499	0.917	0.51	75	50
Gra	0.675	0.114	0.201	0.451	0.899	4.88	70	66.7
RBC	0.658	0.122	0.248	0.419	0.898	10.02	65	50
MCV	0.621	0.111	0.378	0.403	0.839	38.9	65	33.3
Hct	0.683	0.113	0.181	0.461	0.905	27.45	95	33.3
MCH	0.425	0.156	0.584	0.119	0.731	13.15	65	50
MCHC	0.292	0.113	0.128	0.069	0.514	32.55	60	16.7
RDW	0.862	0.072	0.008	0.721	1.000	14.35	90	66.7
Hb	0.629	0.118	0.346	0.398	0.860	12.5	70	50

WBC: Leukocyte, Lym: Lymphocyte, Mon: Monocyte, Gra: Granulocyte, RBC: Erythrocyte, MCV: Mean corpuscular volume, Hct: Hematocrit, MCH: Mean corpuscular hemoglobin, MCHC: Mean corpuscular hemoglobin concentration, RDW: Red cell distribution width, Hb: Hemoglobin

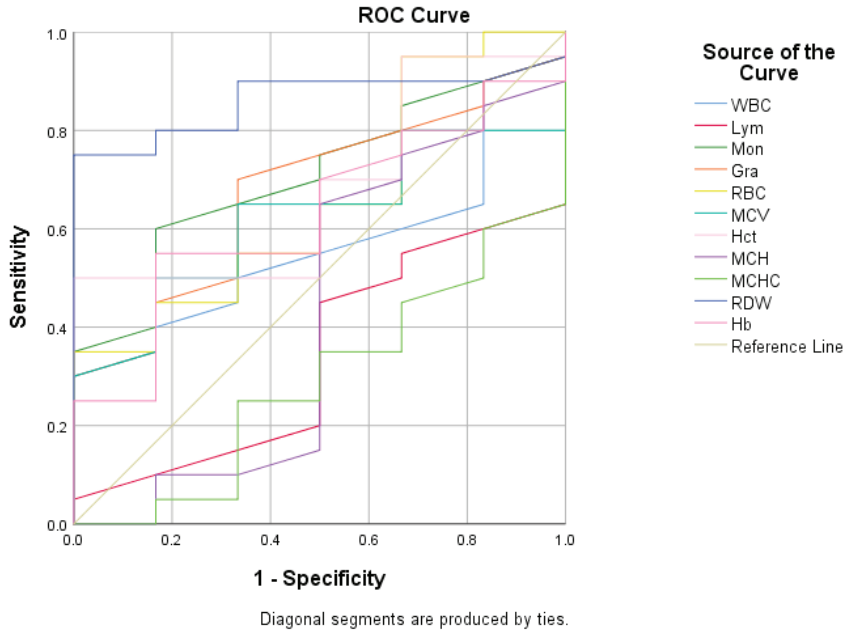

Figure 1. ROC curves of CBC parameters.

Obesity prevention in cats requires early identification of risk factors, particularly in young and middle-aged individuals. Neutering is a significant contributor due to hormonal changes that alter metabolism (Fettman et al., 1997; Martin et al., 2001), and when combined with unrestricted feeding, it substantially increases the risk of weight gain (Nguyen et al., 2004). Dry food, often fed to indoor cats, may contribute to overfeeding, as commercial guidelines—based on active, intact cats—can exceed actual energy needs by up to 30% (Hoenig and Ferguson, 2002). In this study, all obese cats were primarily fed dry food with inconsistent portion control, despite owners' attempts to regulate intake. In

Table 6. ROC analysis of serum biochemistry parameters

Parameter	AUC	Std. Error	Asymp. Sig.	Asymptotic 95% Confidence Interval		Cut-off	Sensitivity (%)	Specificity (%)
				Lower Bound	Upper Bound			
BUN	0.854	0.095	0.010	0.668	1.000	11.7	95	66.7
Creatinine	0.542	0.140	0.761	0.268	0.816	0.7	90	33.3
AST	0.725	0.103	0.100	0.524	0.926	24	85	33.3
ALT	0.196	0.096	0.026	0.008	0.384	43	20	50
ALP	0.538	0.120	0.784	0.303	0.772	28.5	70	33.3
LDH	0.725	0.128	0.100	0.473	0.977	147	90	50
GGT	0.758	0.103	0.059	0.556	0.961	5.5	80	50
TBIL	0.942	0.044	0.001	0.855	1.000	0.27	95	50

BUN: Blood urea nitrogen, Crea: Creatinine, AST: Aspartate aminotransferase, ALT: Alkaline aminotransferase, ALP: Alkaline phosphatase, LDH: Lactate dehydrogenase, GGT: Gamma glutamyl transferase, TBIL: Total bilirubin

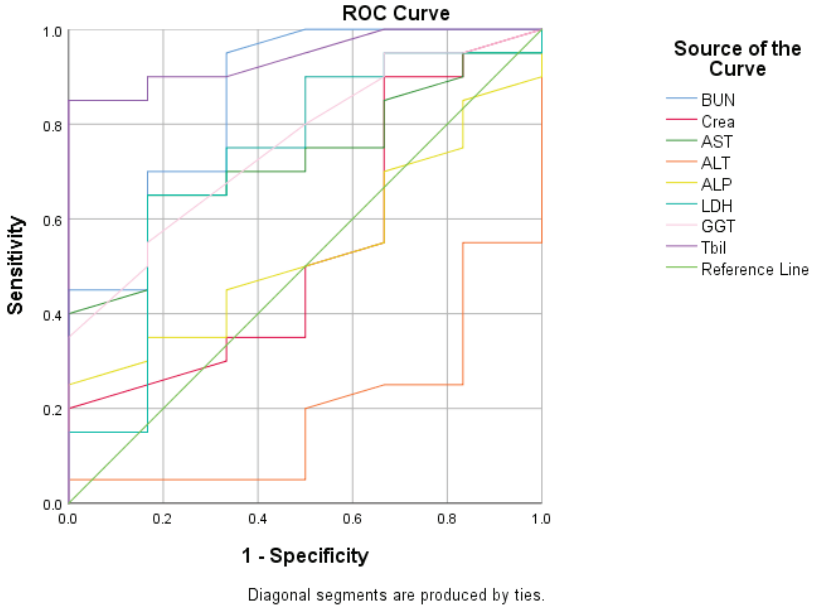

Figure 2. ROC curves of serum biochemistry parameters.

Table 7. ROC analysis results of CRP and visfatin concentrations

Parameter	AUC	Std. Error	Asymp. Sig.	Asymptotic 95% Confidence Interval		Cut-off	Sensitivity (%)	Specificity (%)
				Lower Bound	Upper Bound			
CRP	0.925	0.052	0.002	0.823	1.000	57.42	95	50
Visfatin	0.867	0.074	0.007	0.722	1.000	0.95	100	33.3

CRP: C-reactive protein, AUC: Area under curve, Std. error: Standard error

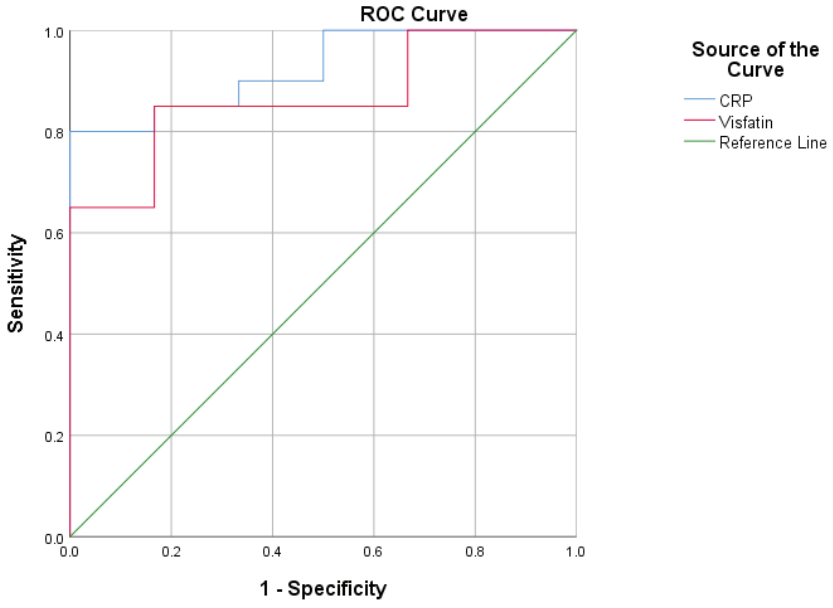

Figure 3. ROC curves of CRP and visfatin.

Table 8. Spearman correlation analysis of certain parameters

Parameter	BCS	Body weight	CRP	Visfatin	Glucose
BCS	1	0.638**	0.288	0.196	0.207
Body weight		1	0.427*	0.321	0.190
CRP			1	0.668**	0.267
Visfatin				1	-0.206
Glucose					1

BCS: Body condition score, **Correlation is significant at 0.01 level (2-tailed), *Correlation is significant at 0.05 level (2-tailed)

addition to dietary factors, sedentary lifestyles and limited environmental enrichment further exacerbate obesity risk. Regular physical activity supports muscle maintenance, cardiovascular health, mental stimulation, and metabolic rate (Patterson and Levin, 2008). While owners reported providing toys and enrichment items, anamnesis revealed minimal interactive play, suggesting that insufficient owner engagement and environmental stimulation may also play a significant role in the development of obesity (German et al., 2006).

Obesity is reported to be more prevalent in middle-aged (5 to 11 years old) and male cats, likely due to age-related declines in metabolic rate and physical activity (Courcier et al., 2012). Although no definitive genetic predispositions have been identified, some studies have reported a higher incidence of obesity in domestic shorthair, domestic longhair, domestic medium-hair, Manx, or mixed-breed cats (Lund, 2005). However, other studies have found no significant association between breed and obesity risk (Courcier et al., 2012). A more recent investigation involving 22 different breeds including Cornish Rex, Sphynx, Abyssinian, Devon Rex, Oriental Shorthair, Maine Coon, Ragdoll, Burmese, Norwegian Forest Cat, British Shorthair, and Persian suggested that obesity predisposition is more closely related to breed standards than to breed itself. Breeds described as chubby, stocky, square, broad-chested, or muscular were found to be more prone to obesity (Corbee, 2014). In the present study, the obese cats ranged from 1 to 9 years of age. Among them, 33 were mixed breed (tabby), 4 were Scottish Fold, 2 were Siamese, and 1 was British Shorthair. The non-obese control group also primarily consisted of mixed-breed cats (12 tabbies). Of the obese cats,

27 were male and 13 female; in the Control group, 11 were male and 9 female. All cats included in the study were neutered. These demographic characteristics (age, breed, sex, and neutering status) are consistent with previous findings regarding obesity risk (Lund, 2005; Courcier et al., 2012). Although control cats were matched to the obese group by age and breed, their normal body condition may reflect higher levels of owner-facilitated physical activity and more frequent owner-cat interactions.

The first step in identifying and managing obesity is its timely recognition. While severe obesity is often readily apparent, the veterinarian's objective is to detect early changes in body weight and condition to implement preventive dietary and exercise interventions (Laflamme, 1997). Accurate and consistent weighing is essential, preferably using a reliable small-animal scale such as a pediatric scale, and it is recommended to use the same device throughout monitoring to reduce variability. Nonetheless, discrepancies between different scales can occur. For this reason, the BCS system remains the most widely accepted and validated method for assessing excess adiposity (German et al., 2006; Laflamme, 1997; Burkholder, 2000). It is also a practical tool for estimating body fat percentage in clinical settings. The BCS not only provides tangible feedback to pet owners but, when used consistently and with familiarity, yields reproducible and meaningful results (Laflamme, 1997; Burkholder, 2000). In this study, body weights were measured using pediatric scales. The mean body weight of cats in the Obese group was significantly higher than that of the Control group ($p<0.0001$). According to the 9-point BCS system, the median score of the obese group was 7 (range: 6–9), while the control group had a median score of 4 (range: 4–5), also statistically significant ($p<0.0001$) (Table 1). These findings confirm the effectiveness of the 9-point BCS system, alongside precise body weight measurements, in accurately distinguishing obese cats from controls, underscoring its value as a reliable tool for assessing feline body condition.

Obesity has been associated with a chronic low-grade systemic inflammatory state, characterized by an acute phase response originating from adipose tissue. While substantial evidence supports the inflammatory nature of obesity, limited studies have examined its impact on hematological parameters and thrombotic risk. Thus, CBC may serve as a valuable tool for monitoring obesity and its related complications (Fantuzzi, 2005). In the present study, monocyte levels in obese cats were significantly higher than in non-obese control cats ($p = 0.027$; Table 2). Furthermore, ROC analysis was conducted to assess the diagnostic performance of CBC parameters in detecting obesity-related low-grade inflammation (Table 5, Figure 1). Monocyte levels demonstrated notable diagnostic utility, with an AUC of 0.708. While adipocytes dominate adipose tissue, macrophages constitute a significant resident cell population (Gregor and Hotamisligil, 2011). Although preadipocytes exhibit macrophage-like functions, adipose tissue macrophages primarily originate from circulating monocytes derived from the bone marrow (Weisberg et al., 2003). Chemokines such as leptin, monocyte chemoattractant protein-1 (MCP-1), and leukotriene B4 enhance monocyte infiltration by promoting adhesion and migration. The elevated monocyte counts observed in obese cats herein corroborate prior findings and likely signify the chronic low-grade inflammation and adipose tissue remodeling characteristic of obesity (Fantuzzi, 2005; Harman-Boehm et al., 2007).

Red cell distribution width (RDW), a measure of the variability in the size of circulating red blood cells, is part of the standard CBC and was traditionally considered to have limited clinical relevance. However, recent studies have demonstrated strong associations between increased RDW levels and both short- and long-term outcomes in various clinical conditions, including chronic heart failure, pulmonary embolism, and septic shock (Patel et al., 2010). Notably, increased RDW has been linked to inflammation and dietary patterns, two central features of insulin resistance in obesity (Förhécz et al., 2009). As such, RDW may serve as a useful marker for the chronic low-grade inflammation observed in obese individuals and may help identify patients at risk for metabolic complications. In the present study, RDW values were significantly higher in the Obese group compared to the Control group (Table 2). ROC analysis further demonstrated that RDW possesses excellent diagnostic value for distinguishing obese from non-obese individuals (Table 5). The increased RDW levels observed in conjunction with increased monocyte counts suggest the presence of a chronic low-grade inflammatory state, potentially related to insulin resistance in these cats. Due to the shorter lifespan of feline erythrocytes compared to other species, the turnover of aged red blood cells is more rapid. In obese cats, this turnover may be further accelerated, leading to increased production of young

erythrocytes, reflected by increased MCV and RDW (Lalor et al., 2014). Previous studies have shown that obesity induces a proinflammatory state, characterized by increased levels of inflammatory cytokines and alterations in leukocyte populations, including increased neutrophil and monocyte counts in obese children and dogs (Radakovich et al., 2017). However, aside from monocyte counts, other CBC parameters showed no significant differences between obese and control cats, which may be attributed to the subtle and low-grade nature of inflammation present in this population. Additionally, the lack of concurrent comorbidities likely contributed to the minimal hematological alterations observed, underscoring that early-stage obesity-associated inflammation can remain clinically silent and undetectable by routine blood counts (Gkrinia and Belančić, 2025).

Some animals may be at greater risk than others for developing metabolic, obesity-related secondary diseases; however, the clinical identification of overweight individuals at increased risk remains a significant challenge. The detection of abnormal clinical parameters has shown limited sensitivity for the early diagnosis of weight-related comorbidities. Previous studies have reported increased concentrations of BUN, creatinine, phosphorus, calcium, cholesterol, and ALP in overweight dogs, although findings have been inconsistent, suggesting these parameters are not reliable early indicators of obesity-related disorders (Hamper, 2016). In cats, obesity has been associated with increased triglyceride concentrations (Mori et al., 2012), and lipid metabolism alterations are commonly observed due to the intake of energy-dense diets rich in carbohydrates and fats (Hoenig et al., 2003). However, in cats fed commercial dry food, total cholesterol concentrations have not consistently correlated with obesity (Aguiar et al., 2018). Additionally, previous studies have reported higher HDL concentrations (Bauer, 1996; Hoenig et al., 2003) and lower GGT activity in obese cats (Saely et al., 2008). In the present study, biochemical analysis revealed that obese cats exhibited significantly higher concentrations of BUN and TBIL, along with lower ALT activity, compared to non-obese controls (Table 3). Comparative ROC analysis demonstrated that BUN had excellent diagnostic performance, while AST, LDH and GGT showed acceptable performance. Notably, TBIL had outstanding diagnostic value among the serum biochemical parameters analyzed (Table 6). Although all measured values remained within reference ranges, the observed elevation in BUN may reflect glycemic variability or early renal alterations. The decreased ALT concentrations could be associated with hepatic lipid accumulation or altered enzyme clearance mechanisms, while increased TBIL may indicate hepatic dysfunction or a chronic low-grade inflammatory state (Gülersoy et al., 2023; Huang et al., 2024).

The acute phase response is a crucial, nonspecific systemic reaction that occurs in response to disturbances affecting homeostasis, typically triggered by infection or tissue injury of various etiologies (Gruys et al., 1999). Key positive acute phase proteins, CRP, serum amyloid A (SAA), and haptoglobin (Hp), are primarily synthesized by hepatocytes following cytokine stimulation (Heinrich et al., 1998). Obesity is now widely recognized as a chronic low-grade proinflammatory condition, particularly involving visceral adipose tissue, and is commonly associated with comorbidities such as insulin resistance, dyslipidemia, and hypertension (Gregor and Hotamisligil, 2011). Obese individuals are more susceptible to recurrent infections, and increased serum CRP concentrations have been reported under such conditions (Jeemon et al., 2011; Shilpa et al., 2014). Numerous studies have demonstrated a strong and independent association between circulating CRP concentrations, largely induced by interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α) in obesity, and cardiovascular events (Allan et al., 2000). The imbalance of adipokines characteristic of obesity may further promote oxidative stress and endothelial dysfunction, including reduced adiponectin, increased leptin, and increased levels of proinflammatory and antifibrinolytic mediators (Van et al., 2006). In dogs, prolonged and more pronounced increases in circulating CRP and fibrinogen concentrations have been observed in obesity, potentially reflecting the inflammatory crosstalk between adipose tissue and lipid metabolism (Verschuur et al., 2001). In the present study, serum CRP concentrations in obese cats were nearly double those of non-obese controls. Moreover, ROC analysis revealed that CRP exhibited outstanding diagnostic accuracy for detecting low-grade subclinical inflammation in obese cats (AUC = 0.925) (Table 7). These findings support the hypothesis that adipokine dysregulation in obesity, marked by decreased adiponectin and elevated leptin levels, induces subtle structural and functional changes in tissues and organs that may not be reflected in routine serum biochemistry or CBC pa-

rameters. Concurrently, this dysregulation promotes IL-6–mediated inflammation, contributing to the observed elevation in CRP concentrations (Heinrich et al., 1998; Coppack, 2001; Van et al., 2006; Gkrinia and Belančić, 2025).

Visfatin was originally isolated from peripheral blood lymphocytes as a secreted growth factor that enhances the maturation of B cell precursors (Samal et al., 1994). More recently, it has been identified as a novel adipokine associated with visceral fat in both humans and mice. While the physiological role of visfatin is not fully understood (Fukuhara et al., 2005), it was initially reported to mimic insulin effects by binding to the insulin receptor and reducing plasma glucose concentrations. However, this finding was later retracted due to doubts regarding its insulin-mimicking effects (Fukuhara et al., 2007). Despite this, the discovery of visfatin has been considered potentially significant for improving our understanding of obesity pathogenesis. A number of studies have explored the role of visfatin in glucose metabolism and obesity-related conditions. Although the findings are not entirely consistent, several studies on obesity, Type 2 DM, metabolic syndrome, obesity-related low-grade inflammation, and cardiovascular disease have reported increased circulating visfatin concentrations in these conditions (Samal et al., 1994; Chang et al., 2011). Visfatin has been shown to possess proinflammatory properties, and a relationship between serum visfatin concentrations and systemic inflammation in obesity has been observed. For instance, one study found a positive correlation between visfatin, CRP, and TNF-α in obese individuals, emphasizing visfatin's role in systemic inflammation associated with obesity. Moreover, it has been reported that increased visfatin concentrations in conditions of hyperinsulinemia and/or insulin resistance stimulate the production of proinflammatory cytokines, which, in turn, further exacerbate insulin resistance (Moschen et al., 2007). In the present study, serum visfatin concentrations were higher in obese cats compared to non-obese cats (Table 4). The comparative ROC analysis revealed that serum visfatin concentrations had excellent diagnostic value (AUC = 0.867) for determining chronic low-grade inflammation in obese cats (Table 7). Additionally, Spearman correlation analysis showed a moderate positive correlation between visfatin and CRP (Table 8). These results align with previous studies demonstrating that elevated serum visfatin concentrations act as key mediators in obesity-related pathophysiology by promoting proinflammatory cytokine production and impairing insulin signaling pathways (Yin et al., 2019). Visfatin, primarily secreted by adipose tissue macrophages, contributes to a chronic low-grade inflammatory state, which exacerbates insulin resistance and metabolic dysregulation commonly observed in obese individuals (Chang et al., 2011; Yin et al., 2019).

CONCLUSION

This study underscores the presence of chronic low-grade inflammation in obese cats, even without overt clinical signs. All affected cats were fed commercial dry food, which may exceed the caloric needs of sedentary indoor cats, especially when combined with insufficient physical activity and owner interaction. The demographic profile, primarily male, mixed-breed cats, aligns with known predispositions to obesity. While the 9-point-scale BCS system remains a useful clinical tool, repeated application may improve accuracy in assessing body fat. Although CBC yielded limited diagnostic value, serum biochemistry revealed alterations associated with metabolic dysfunction, including increased BUN, decreased ALT, and increased TBIL concentrations. Elevated CRP and visfatin concentrations further reflected the proinflammatory state in obesity, with both markers showing strong potential for identifying subclinical inflammation and insulin resistance. In conclusion, early recognition of inflammation through routine monitoring of CRP and visfatin, combined with dietary and behavioral interventions, may be essential for effective obesity management and prevention of related comorbidities in at-risk cats.

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