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Research Article

Alterations of lipid profile in overweight and obese dogs

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ABSTRACT

The purpose of the study was to determine the alterations of lipid profile in overweight and obese dogs. Obesity is defined as abnormal or excessive fat accumulation in the body. It is a chronic health problem for both human and animals. Dogs with restricted movements and fed high-energy diets are particularly at a high risk. In the study, 30 dogs of different ages, breeds and genders were used. Dogs were divided into 3 groups equally as ideal weight, overweight and obese according to the body condition score (BCS) chart. Serum samples were collected from all dogs and used to analyze lipid profile parameters using a biochemistry analyzer. In the study, significant increases were detected in total cholesterol (total-C, $p<0.01$), very low density lipoprotein (VLDL, $p<0.05$) and low density lipoprotein (LDL, $p<0.05$) in obese dogs compared to those of both ideal weight and overweight dogs. According to the cut-off values, the analyzed lipid profile parameters were found to increase in some dogs in both groups. However, the numbers of dogs with increases in lipid profile parameters were higher in obese dogs than in overweight dogs. Very strong positive correlations were also detected between some of lipid profile parameters. In conclusion, it has been revealed that there are significant alterations in lipid profile parameters in obese dogs. The levels of these changes are thought to be related to the severity of obesity in dogs. Presence of strong correlations between lipid profile parameters indicated that total-C, HDL, VLDL, LDL, total-C/LDL and Tg values can be used to evaluate severity of overweight and obesity in dogs.

INTRODUCTION

Obesity is a chronic health problem characterized by excessive fat accumulation in the body. It usually results from an imbalance between energy intake and use. This imbalance may develop due to many reasons such as age, gender, reproductive status, inactivity, nutrition, lifestyle, neutering, hypothyroidism, insulinoma, hyperadrenocorticism and corticosteriod use (Buishand and Kirpensteijn, 2023; Byers et al., 2011; Preet et al., 2021; Robertson, 2003; Ronja and Kölle, 2021). In dogs, an increase of 10-20% in ideal body weight is considered as overweight, while an increase above 30% is considered as obesity (Preet et al., 2021). Obesity rate in dogs has been increasing noticeably in recent years (Preet et al., 2021; Weir, 2024). Studies conducted in different countries revealed that approximately 22-66.1% of dogs are obese (Loftus and Wakshlag, 2015; Munoz-Prieto et al., 2018; Preet et al., 2021; Ronja and Kölle, 2021). It is well-known that obesity in dogs negatively affects the quality and duration of life (Preet et al., 2021; Shmalberg, 2013). High rates of cancer, diabetes mellitus (DM), heart diseases, hypertension, osteoarthritis, joint diseases, hormonal imbalances, skin diseases and urinary tract stones has been reported in obese dogs (Preet et al., 2021; Ramos and Castillo, 2020; Ronja and Kölle, 2021). It was found that 40 percent of obese dogs had at least one of the diseases such as diabetes, hypothyroidism and hyperadrenocorticism (Oh, 2011; Preet et al., 2021).

A number of metabolic changes have been shown to occur in obese dogs due to obesity. Increases in blood insulin, glucose, triglyceride, volatile fatty acids, cortisol, fructosamine, total cholesterol, leptin, glycogan-like protein-1 (GLP-1) levels and a decreases in high density lipoprotein (HDL) values have been reported in these dogs (De Marchi et al., 2020; Gonzlez-Villar and Perez-Bravo, 2022; Kennerman, 2006; Mori et al., 2013; Ramos and Castillo, 2020; Verkest et al., 2011). Type 2 DM due to insulin resistance has also been reported in obese dogs (Ramos and Castillo, 2020; Verkest et al., 2011; Zoran, 2010). However, the results of the studies in haematological and biochemical parameters of overweight or obese dogs were controversial. In some studies, increases in alkaline phosphatase (ALP), total protein, albumin, thyroxin, phosphorus, glucose, cortisol, insulin, insulin-like growth factor-1, LDL, leptin and type II cartilage, total-C and Tg values were obtained in overweight or obese dogs (De Marchi et al., 2020; Rafaj et al., 2016; Ramos and Castillo, 2020; Ricci et al., 2007; Usui et al., 2015). While decreases in creatinine, serum urea nitrogen (BUN) and C-reactive protein (CRP) were determined in obese dogs (Rafaj et al., 2016; Yamka et al., 2006). However, in some other studies, no changes were obtained in hema-

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tological and biochemical parameters including glucose, total protein, albumin, globulin, urea, bilirubin, ALT, AST ALP and GGT in overweight or obese dogs (Rafaj et al., 2016; Ricci et al., 2007). Lipid profile parameters have not been adequately investigated in overweight and obese dogs. Thus, the aim of the study was to investigate alterations in lipid profiles of overweight and obese dogs.

MATERIALS and METHODS

Animals and evaluation of obesity

A total of 30 owned dogs were used in the study to determine lipid profile parameters. Age, sex and breed characteristics were not considered in the selection of dogs. Body condition score in dogs was determined using the World Small Animal Veterinary Association (WSAVA), VCA Animal Hospitals Body Condition Scoring (BCS) system and existing studies (Chun et al., 2019; Williams and Buzhardt, 2022). Thus, the BCS in dogs was scored on a scale of 1-9 and dogs were equally divided into three groups: overweight, obese and ideal weight according to the BCS system. Ideal weight was considered for dogs with a BCS score of 4-5/9 and these animals were used as the ideal weight group (n=10). Animals with a BCS score of 6/9 were considered as the overweight group (n=10), and dogs with a BCS score of 7-9/9 were considered as the obese group (n=10). Animals with any systemic disease and undergoing surgery within 6 weeks were not included in the study.

Blood samples

Fasting (8-12 hours) peripheral blood samples were collected from each animal into plain tubes and then used to prepare serum samples by centrifuging at 4000 RMP for 20 minutes. Collected serum samples were then kept at -80°C until used to determine lipid profile parameters.

Biochemical analysis

In the study, total cholesterol (Total C), high density lipoprotein (HDL), very low density lipoprotein (VLDL) and triglyceride (Tg) levels in serum samples were measured by using a biochemistry device (Roche cobas integra 400 Plus, USA). Low density lipoprotein (LDL) concentrations in the serum samples were calculated with the following formula as described Ramos and Castillo (2020); LDLP= total cholesterol–(HDLP+Tg/5). Additionally, Total C/LDL and HDL/LDL were also calculated for each dogs.

Statistical analysis

The normality of the distributions of the data was analyzed with the Kolmogorov-Smirnov test. Statistical differences between the parameters obtained from the ideal weight group, overweight and obese groups were determined by One Way Anova (posthoc Duncan). In the presence of high variances in parameters, a nonparametric Kruskal Wallis H test was used to determine statistical significance between these groups. Furthermore, to determine the correlation between the data, the parameters with normal distribution were analyzed with Pearson's correlation coefficient (r), and the parameters with non-normal distribution were analyzed with Spearsman's rho. In correlation tests, negative (-) or positive (+) correlation values (r) were accepted as very weak (-,+ 0-0.19) weak (-,+ 0.2-0.39), moderate (-,+ 0.4-0.59), strong (-,+ 0.6-0.79) and very strong (-,+ 0.8-1.00) as described by Meghanathan (2016). All the values were expressed as mean and standard deviations of the mean (mean±SD), median, minimum maximum (min-max). The level of the significance was accepted as $p<0.05$.

In the study, the cut-off value for each parameter in overweight and obese dogs was determined by Reciver Operating Characteristic (ROC) analysis. The cut-off value of each parameter was used to determine individual increases or decreases within groups. Values higher or lower than the cut-off value were considered as an increase or decrease in the parameter of that animal.

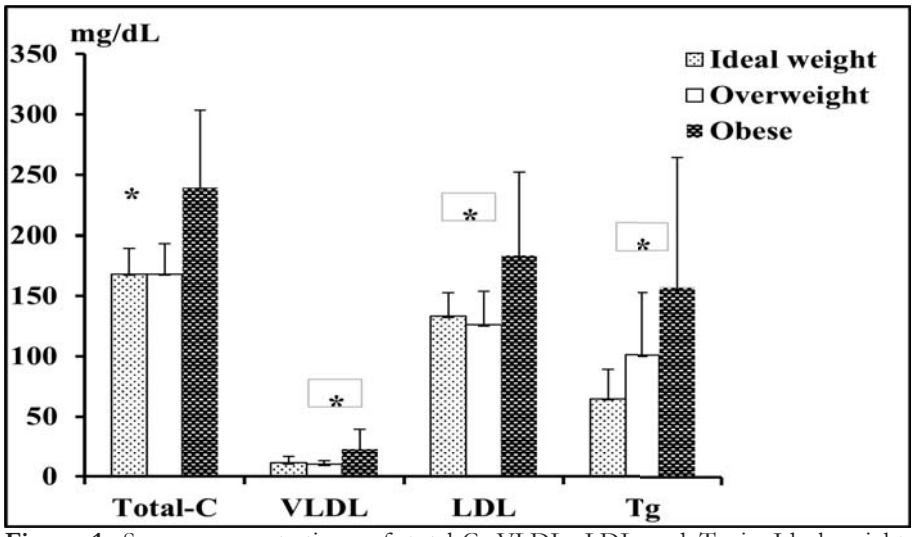

Figure 1. Serum concentrations of total-C, VLDL, LDL and Tg in Ideal weight, Overweight and obese dogs (mean±SD). Total-C: Total cholesterol, VLDL: Very low density lipoprotein, LDL: Low density lipoprotein, Tg: triglyceride. *: $p<0.05$, **:$p<0.01$.

Table 1. Lipid profile of ideal weight, overweight and obese dogs (mean±SD).

Parameters	Ideal weight (n=10)	Overweight (n=10)	Obese (n=10)	Median (min-max)
Total-C (mg/dL)	168.22±21.32[b]	168.1±25.34[b]	239.33±64.06[a]	184.5 (132-391)
HDL (mg/dL)	111.37±9.86[a]	109±10.08[a]	127±27.96[a]	114.5 (88-190)
VLDL (mg/dL)	11.37±5.28[b]	10.1±2.84[b]	22.91±16.61[a]	11.5 (5-69)
LDL (mg/dL)	133.3±19.35[b]	126.06±27.63[b]	183.53±68.41[a]	139.2 (85.6-333.8)
Total-C/LDL	1.26±0.05[a]	1.34±0.15[a]	1.33±0.21[a]	1.28 (1.16-1.79)
HDL/LDL	0.84±0.07[ab]	0.87±0.19[a]	0.71±0.12[b]	0.79 (0.48-1.27)
Tg (mg/dL)	64.75±24.35[b]	101.2±51.75[ab]	157±107.51[a]	92 (32-380)

Total-C: Total cholesterol. HDL: High density lipoprotein. VLDL: Very low density lipoprotein. LDL: Low density lipoprotein. Tg: triglyceride. Different letters above the columns indicate significant difference between the groups. The significant level was accepted as $p<0.05$

As a result of ROC analysis, parameters were given as area under curve (AUC), sensitivity% (sns), specificity% (sps) and cut-off value.

SPSS software computer programme (version 27.0 for Windows, SPSS Inc, Chicago) was used to perform all the statistical analyses.

RESULTS

In the present study, the lipid profile was examined, and obesity related lipid metabolism changes were revealed. Significant increases were detected in total-C ($p<0.01$), VLDL ($p<0.05$), LDL ($p<0.05$) and Tg ($p<0.05$) values of obese dogs compared to those of ideal weigt group (Figure 1, Table 1). Additionally, serum concentrations of total-C ($p<0.01$),

Table 2. Cut-off values of the lipid profile parameters for overweight and obese dogs.

	AUC (Area)	Cut-off (95 confidence intervals%) (lower-upper bound)	p value	sensitivity%-specificity%
Total-C (mg/dL)	0.298	177.5 (0.114-0.483)	0.096	40.9-50
HDL (mg/dL)	0.452	113.5 (0.235-0.669)	0.69	45.5-50
VLDL (mg/dL)	0.344	11.5 (0.121-0.566)	0.197	50-50
LDL (mg/dL)	0.392	139.2 (0.192-0.592)	0.373	50-50
Total-C/LDL	0.409	1.26 (0.2-0.618)	0.453	40-62.5
HDL/LDL	0.556	0.81 (0.465-0.848)	0.97	63.6-37.5
Tg (mg/dL)	0.190	83.5 (0.029-0.351)	0.01	27.3-75

Total-C: Total cholesterol, HDL: High density lipoprotein, VLDL: Very low density lipoprotein, LDL: Low density lipoprotein, Tg: triglyceride.

Table 3. Cut-off values of the lipid profile parameters for overweight and obese dogs.

Parameters	Cut-off	Overweight (n=10)	Obese (n=10)
Total-C (mg/dL)	177.5	4(40%)	9(90%)
HDL (mg/dL)	113.5	5(50%)	7(70%)
VLDL (mg/dL)	11.5	3(30%)	8(80%)
LDL (mg/dL)	139.2	3(30%)	8(80%)
Total-C/LDL	1.26	7(70%)	5(50%)
HDL/LDL	0.81	6(60%)	2(20%)
Tg (mg/dL)	83.5	6(60%)	9(90%)

Total-C: Total cholesterol, HDL: High density lipoprotein, VLDL: Very low density lipoprotein, LDL: Low density lipoprotein, Tg: triglyceride.

VLDL ($p<0.05$) and LDL ($p<0.01$) were found to be significantly high in obese dogs compared to that of overweight dogs. The ratio of HDL/LDL in obese dogs were lower than that of overweight dogs ($p<0.05$, Table 1).

In the study, cut-off values were calculated for each parameter and used to determine the number of dogs showing an increase or decrease in these parameters (Table 2). The number and percentages of dogs with increases in parameters according to the calculated cut-off values are given in Table 3. In obese group, increase in total-C, HDL, VLDL, LDL and Tg values were obtained in 9(90%), 7(70%), 8(80%), 8(80%) and 9(90%) dogs, respectively. The numbers of obese dogs showing increases in these parameters were higher than overweight dogs. However, the numbers of obese dogs with increased in total-C/HDL and HDL/LDL were less than in overweight dogs (Table 3).

In the study, correlations between the parameters of the groups were analyzed and the results were given in table 4. In the obese group, very strong positive correlations were detected between total-C and HDL ($p<0.01$), VLDL ($p<0.01$), LDL ($p<0.01$). Furthermore, very strong positive correlations were also detected between HDL and VLDL ($p<0.01$), LDL ($p<0.01$), and between VLDL and LDL ($p<0.01$). Additionally, a very strong positive correlation was obtained between total-C/LDL and Tg in obese group (Table 4).

Table 4. Cut-off values of the lipid profile parameters for overweight and obese dogs.

Groups		Total-C	HDL	VLDL	LDL	Total-C / LDL	HDL/LDL	Tg
[2]Overweight	**Total-C**	1	0.570	0.697*	0.936**	-0.548	-0.785**	-0.162
	HDL		1	0.565	0.598	-0.449	-0.224	-0.396
	VLDL			1	0.663*	-0.531	-0.454	-0.297
	LDL				1	-0.803**	-0.889**	0.147
	Total-C/ LDL					1	0.811**	0.890**
	HDL/LDL						1	0.496
	Tg							1
[1]Obese	**Total-C**	1	0.834**	0.997**	0.958**	-0.279	-0.511	-0.286
	HDL		1	0.854**	0.840**	-0.473	-0.255	-0.445
	VLDL			1	0.926**	-0.474	-0.614*	-0.433
	LDL				1	-0.520	-0.605*	-0.546
	Total-C/ LDL					1	0.582*	0.946**
	HDL/LDL						1	0.468
	Tg							1

Total-C: Total cholesterol, HDL: High density lipoprotein, VLDL: Very low density lipoprotein, LDL: Low density lipoprotein, Tg: trygliceride. The significant level was accepted as $p<0.05$. 1: Spearsman's rho correlation test, *: $p<0.05$, **:$p<0.01$. 2: Pearson's correlation test: *: $p<0.05$, **:$p<0.01$.

DISCUSSION

Obesity emerges as a chronic problem in animals that are kept in home , movement is restricted, neutered and fed incorrectly (Preet et al., 2021; Robertson, 2003; Tunca, 2019). It is reported to be an increasing problem in dogs and the incidence rate is shown to be over 40-60% in dogs (Preet et al., 2021; Weir, 2024).

In studies conducted on obese and overweight dogs, conflicting results were obtained regarding lipid profile values (Kennerman, 2006; Rafaj et al., 2016; Usai et al., 2015). Rafaj et al. (2016) found that triglyceride concentrations were high only in overweight dogs, while no statistical difference was found in total cholesterol levels between overweight, obese and ideal weight dogs). In another study conducted by Kennerman (2006), an increase in total-C, LDL and Tg values, and decrease in HDL values were obtaned in obese dogs. Furthermore, Usui et al. (2015) reported that VLDL, Tg and Total-C values were higher in both overweight and obese dogs than in ideal weight dogs, LDL did not change, and HDL values increased only in obese dogs. However, in this study, no statistical differences were detected between overweight and obese dogs in lipid profile parameters. It has been suggested that the duration of obesity, severity of obesity, fasting time for sampling and age of the animals affected the lipid profile parameters in both overweight and obese dogs (Usai et al., 2015). In the present study, serum concentrations of total-C, VLDL, LDL and triglyceride values were significantly high in obese dogs compared to both overweight and ideal weight dogs. However, these values of overweight dogs were not statistically different from the ideal weight group. Although some of the results we obtained in the study were similar to the results obtained by Usai et al. (2015) and Kennerman (2006). On the other hand, the results of the current study are not compatible with the results obtained by Rafej et al. (2016). Although we tried to limit the fasting period to 8-12 hours in our study, there were differences in the ages and obesity periods of the animals used in the study. Therefore, possible reasons for this may be differences in the duration of obesity, duration of fasting, and age of the animals used in this study, as explained by Usui et al. (2015). According to the cut-off values, alterations in lipid profile were found to occur in some of dogs in both groups, but changes in these parameters were obtained in higher numbers of obese dogs than in overweight dogs, which may be related to the degree of obesity. Presence of strong correlations between lipid profile parameters indicated that total-C, HDL, VLDL, LDL, total-C/LDL and Tg values can be used to evaluate severity of obesity in dogs.

CONCLUSION

Changes in the lipid profile parameters do not occur in each obese or overweight dog. The levels of these changes are thought to be related to the severity of obesity in dogs. Strong and very strong correlations between parameters were determined in high number and in more parameters in obese dogs than in overweight dogs. It suggests that total-C, HDL, VLDL, LDL, total-C/LDL and Tg values can be used to evaluate severity of obesity in dogs. It is also conclusive that obesity is characterized as increases in total-C, VLDL, LDL and Tg concentrations in dogs.

DECLARATIONS

Ethics Approval

This study was approved by the Animal Ethics Committee (AEC), Burdur Mehmet Akif University, Türkiye (No:929/2022).

Conflict of Interest

Authors do not have any conflict of interests fort his study.

Consent for Publication

Consent on publication was confirmed with approval from the Republic of Türkiye Ministry of Agriculture and Forestry, Directorate of Burdur Provincial (No: E-69877819-325.04.02-5917267).

Author contribution

Idea, concept and design: HİG, EES

Data Collection and analysis: HİG, EES

Drafting of the manuscript: HİG, EES

Critical review: HİG, EES

Data Availability

Not applicable.

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