

Article

Not peer-reviewed version

Correlation between hyperlipidemia-related diseases and thorax/thigh circumference ratio along with Body Condition Score in dogs

[Kyuhyung Choi](#)*

Posted Date: 28 August 2024

doi: 10.20944/preprints202408.1967.v1

Keywords: Thorax/thigh circumference ratio; Body condition score; Hyperlipidemia; Obesity; Patellar luxation



Preprints.org is a free multidiscipline platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Article

Correlation between Hyperlipidemia-Related Diseases and Thorax/Thigh Circumference Ratio along with Body Condition Score in Dogs

Kyuhyung Choi ^{1,2}

¹ Department of Veterinary Pathology, College of Veterinary Medicine, Seoul National University Seoul, Republic of Korea; cokonut@naver.com or kyudac@snu.ac.kr

² Bundang New York Animal Hospital, Bundang-Gu, Gyeonggi-do, Republic of Korea

Abstract: There are some limitations in using the Body Condition Score (BCS) for client education to prevent obesity, hyperlipidemia-related diseases, and orthopedic diseases in dogs because it is hard to quantify in detail. In small dogs, patellar luxation is a common orthopedic disease that is related to obesity and hind leg muscle. In this study, we evaluated the thorax/thigh circumference ratio as a prognostic evaluation index, along with the BCS, for assessing patellar dislocation and other hyperlipidemia-related diseases. I analyzed eleven client-owned dogs that visited Bundang New York Animal Hospital, South Korea. According to the results, triglycerides (TGs) showed a negative correlation with thorax/thigh value ($R = -0.585$, $p\text{-value} = 0.059$) and a strong positive correlation with thigh circumference ($R = 0.749$, $p\text{-value} = 0.008$). Total cholesterol (TC) showed a strong positive correlation with thigh circumference ($R = 0.776$, $p\text{-value} = 0.005$), whereas the thorax/thigh value showed a negative correlation with the medial patella luxation (MPL) grade with low significance ($R = -0.343$, $p\text{-value} = 0.302$). These data indicate that thigh circumference can be an excellent negative indicator for hyperlipidemia and thorax/thigh value shows a low correlation with medial patella luxation, which encompasses other factors including varus and trochlear groove, despite the limitations of this study due to the small sample size.

Keywords: thorax/thigh circumference ratio; body condition score; hyperlipidemia; obesity; patellar luxation

Introduction

The Body Condition Score was first introduced in dairy cows to evaluate their productivity (Wildman et al., 1982). It is traditionally used in the form of a five-grade or nine-grade scale, and a higher grade reflects more body fat. A score of three points on the five-grade system or five points on the nine-grade system is suitable for the healthy maintenance of cows. The BCS is also applied to other animals including small animals such as feline and canine species. The criteria of the BCS are visibility of rib, lumbar vertebrae, and pelvic bone and waist discernible in dogs, and an ideal state of body is 4 to 5 points on the nine-grade system (Dorsten & Cooper, 2004). As this is a somewhat subjective element, evaluation of the BCS can vary slightly depending on the person measuring it, and the scores are not subdivided in detail, so it is quite difficult to monitor subtle differences (Yam et al., 2017). Failure in monitoring subtle differences using the BCS can lead to obesity, hyperlipidemia (José Lahm Cardoso et al., 2016), and other endocrine diseases. Hyperlipidemia most commonly results in diabetes, hypothyroidism, and Cushing's syndrome in dogs (Xenoulis & Steiner, 2010) as well as humans (Liberopoulos & Elisaf, 2002; Yadav & Pitchumoni, 2003). To date, the correlation between hyperlipidemia and orthopedic diseases has not been clearly documented in dogs, and there are only a few studies on the effects of hyperlipidemia on knee tendons in rats (Grewal, 2013) (Oniki et al., 2005). However, the anatomy of dogs and rats is very different, so the results may not be applicable to dogs. In contrast, there are many studies on the correlation between obesity, BCS, and orthopedic diseases, and numerous studies have attempted to develop monitoring

indicators and prognostic evaluation biomarkers to assist in assessing the BCS (S. A. Kleine et al., 2019) (Leclerc et al., 2017) (S. Kleine et al., 2019) (Webb et al., 2020). In humans, abdominal fat is closely related to hypertension and the waist-to-hip ratio, which is positively correlated with cardiovascular disease in epidemiological research (Björntorp, 1992). Moreover, abdominal fat can increase insulin resistance, leading to a higher risk of diabetes mellitus (Després et al., 1989). Therefore, in order to manage abdominal fat effectively, various indicators such as waist-to-hip ratio and waist-to-chest ratio, along with Body Mass Index (BMI), have been developed (Fink et al., 2003). Additionally, although BMI-related abdominal fat is commonly associated with diabetes mellitus, hypertension, and cardiovascular diseases, hind leg muscle circumference has been shown to be a better indicator than BMI in respiratory diseases such as COPD (Marquis et al., 2002). In contrast, there are few biomarkers or indicators other than the BCS for monitoring obesity and related diseases even though their importance is increasing in veterinary medicine. Moreover, in veterinary medicine, there are breed differences even in the same species, so the same BCS does not always reflect the same body fat, especially in dogs. For example, Schnauzers are genetically prone to hyperlipidemia because VLDL and chylomicrons accumulate abnormally to a large degree in this species compared to other species (Xenoulis et al., 2007). Thus, Schnauzers may be more susceptible than other breeds to hyperlipidemia-related diseases such as pancreatitis, and it has been demonstrated that it may be related to mutation of the SPINK1 gene (Bishop et al., 2010).

Comprehensive monitoring of body fat in a detailed but simple way is key to managing health successfully in veterinary medicine as well as in human medicine. The significance and originality of this study lies in its development of an indicator that can be used alongside the BCS and body weight to diagnose hyperlipidemia and related diseases.

Materials and Methods

Blood samples were collected from randomly selected eleven client-owned dogs (Table 1) visiting Bundang New York Animal Hospital, South Korea. All blood samples were collected from the cephalic vein of the dogs in a fasted state without anesthesia or sedation and centrifuged at 14500 RPM for 1 minute, and the sera were directly analyzed using a DRI-CHEM NX500 (Fujifilm), a dry chemistry analyzer, immediately. The samples were measured directly without dilution at room temperature. The circumference of the thigh and thorax of the dogs was measured manually using a tape measure (Figure 1). JASP was used for data analysis and graph creation (<https://jasp-stats.org>).

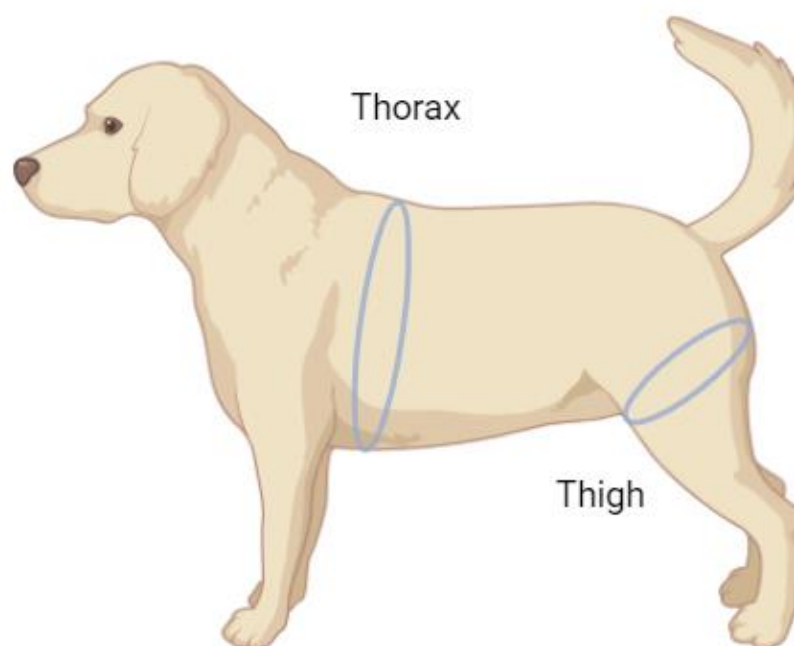


Figure 1. How to measure the thorax/thigh ratio: the thickest parts of the body and hindleg are the standard for measuring the thorax and thigh circumference, respectively.

Results

As expected, the BCS and thorax circumference showed a positive correlation ($R = 0.487$, p -value = 0.128), and the BCS and TC showed a significant strong positive correlation ($R = 0.683$, p -value = 0.021). The BCS and TG also showed a significant strong positive correlation, as expected ($R = 0.587$, p -value = 0.057). The BCS has been used as an indicator of obesity, and these data confirm that the BCS is indeed a valid standard.

The thorax/thigh value and MPL showed a negative correlation with low significance ($R = -0.343$, p -value = 0.302). The thorax/thigh value and TC showed a negative correlation ($R = -0.461$, p -value = 0.154). The thorax/thigh value and TG showed a negative correlation with low significance ($R = -0.316$, p -value = 0.344). The TG and thorax/thigh value showed a significant negative correlation ($R = -0.585$, p value 0.059). These data indicate that the thorax/thigh value has limited application at present but it shows potential, so further investigation involving a larger sample is needed.

Interestingly, TC and thigh (left side) circumference showed a positive correlation ($R = 0.561$, p -value = 0.073). TC and thigh (right side) circumference showed a significant strong positive correlation ($R = 0.776$, p -value = 0.005). TG and thigh (right side) circumference also showed a significant strong positive correlation ($R = 0.749$, p -value = 0.008). TG and thigh (left side) circumference also showed a significant strong positive correlation ($R = 0.711$, p -value = 0.014). As there are only a few studies that focused on the correlation between hyperlipidemia and thigh circumference in veterinary and human medicine, further investigation using a large sample would be beneficial to assess the utilization of thigh circumference as a prognostic indicator for hyperlipidemia.

Discussion

It has been revealed that although the BCS involves subjective elements, it is a reliable standard for diagnosing obesity, which is positively correlated with hyperlipidemia in dogs. To more easily monitor obesity and related diseases, the thorax/thigh circumference ratio was first introduced in this study. Although the thorax/thigh value is insignificantly correlated with medial patella luxation, which is multifactorial, the thorax/thigh value has a strong negative correlation with triglycerides. It can be explained that small thigh circumference may lead to increasing level of triglycerides in human (Jung et al., 2012) but further investigation of mechanism is needed. In fact, patellar dislocation commonly results from hindleg angular limb deformity and trochlear groove depth (Malghem & Maldague, 1989). Therefore, the thorax/thigh ratio can be a useful indicator for hypertriglyceridemia even though there are clear limitations when applied to orthopedic diseases such as patellar dislocation and hindleg limping. Additionally, as there are many studies on the correlation between hyperlipidemia and thigh circumference in humans, validating this correlation in the veterinary field, especially in small animals, can help monitor animal health at home more effectively.

However, hyperlipidemia may be related to underlying diseases such as gallbladder sludge (Table 1, case 4, Pomeranian) or genetic predisposition (for example, idiopathic familial hyperlipidemia in Schnauzers) rather than abdominal fat or body weight in dogs, so it is important to check the underlying disease and breed difference beforehand. In fact, in cases 4 and 6, hyperlipidemia was observed in dogs with larger thighs than other dogs of similar weight (Table 1). Hindleg lipid deposition changes with aging and may be related to metabolic changes (Neumann-Haefelin et al., 2003), implying that a large portion of the hindleg of cases 4 and 6 may consist of lipids. In addition to hindleg fat, abdominal fat is closely related to diabetes, hyperlipidemia, high blood pressure, and cardiovascular disease in humans, and there have been recent attempts to monitor abdominal fat by quantifying it with CT. The importance of abdominal fat in diseases has recently emerged in the veterinary field (Figure 2), but there are few studies that evaluated abdominal fat using CT in veterinary medicine (Nagao et al., 2019).

The results of this study are significant because hyperlipidemia and obesity can be easily monitored by simply measuring body and leg circumferences, along with the BCS and body weight, at a local hospital or at home. Although this study has limitations due to the small number of dogs, the thorax/thigh ratio and thigh circumference, along with the BCS, can be secondary indicators for hyperlipidemia, which can be used to improve obesity monitoring systems to provide proper diet and supplements to prevent or treat related diseases.

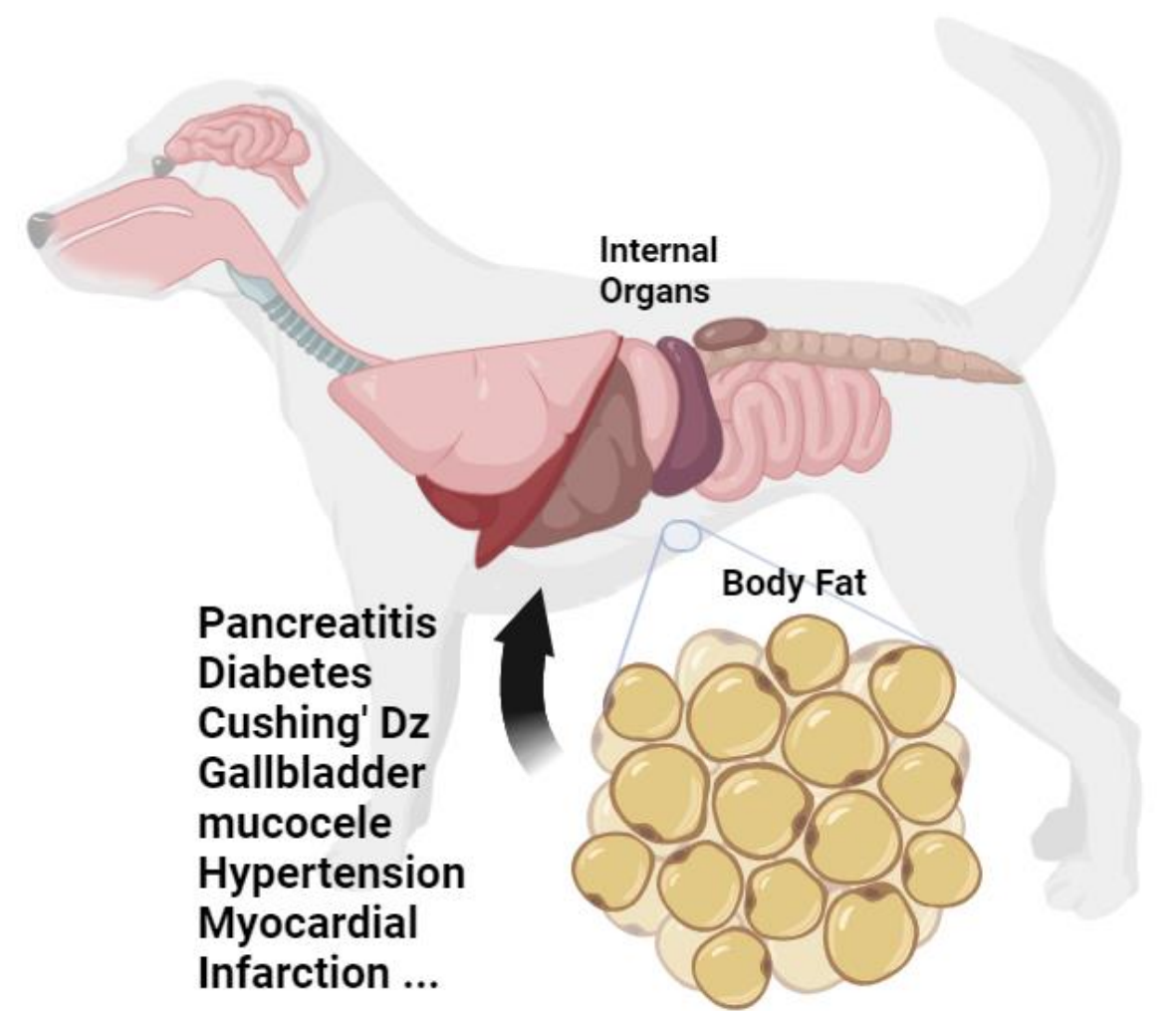


Figure 2. Arrow indicates the effect of visceral fat and abdominal fat on various underlying diseases.

Table 1.

#	Breed	Age	Sex	Body weight	BCS	Thigh circumference (L/R), cm	Thorax circumference, cm	Thorax/thigh ratio	Total Cholesterol (111~312)	Triglycerides (30~133)	Patella luxation grade (L/R)	Gait	Concurrent disease
1	Pug	17 y	CM	7.95 kg	6/9	19/19	45	2.37/2.37	229	104	2/2	N	
2	Pomera nian	3 y 6 m	CM	3.75 kg	5.5/9	13/16	36	2.76/2.25	287	101	0/0	N	
3	Bichon Frise	1 y 3 m	SF	2.73 kg	4/9	15/12	28	1.86/2.33	120	57	1.5/2	N	
4	Pomera nian	6 y 6 m	CM	3.4 kg	6/9	19/19	25	1.3/1.3	500	432	2/1	N	Gallbladder mucocele
5	Mix	1 y	SF	2.95 kg	4/9	14/14	26	1.86/1.86	162	45	2/1	LP	
6	Pomera nian	5 y	SF	3.9 kg	7.5/9	18/22	43	2.38/1.95	500	333	3.5/2.5	LP	

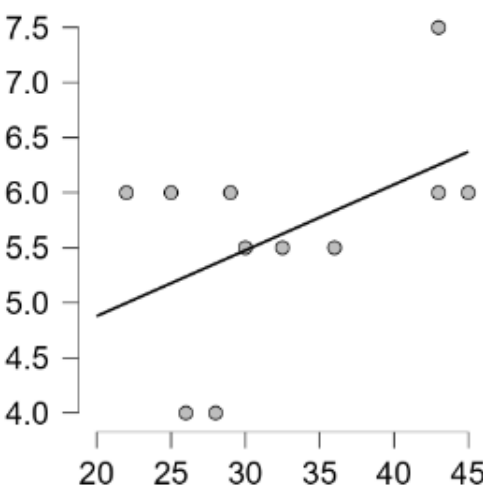
7	Pomera nian	3 y	SF	2.5 kg	6/9	15.5/16	22	1.46/1.375	293	111	3/2.5	N
8	Pomera nian	3 y 4 m	SF	4.85 kg	5.5/9	14/14	30	2.14/2.14	338	43	2.5/2.5	N
9	Bichon Frise	2 y 7 m	SF	3.6 kg	6/9	14/13	29	2.07/2.23	120	87	2/1.5	N
10	Maltese	6 y 6 m	CM	5.35 kg	6/9	16/17	43	2.68/2.52	305	95	2/1	N
11	Maltese	5 y 2 m	CM	5 kg	5.5/9	15.5/14.5	32.5	2.09/2.24	317	86	2.5/2.5	RP

(LP: left-sided pain, RP: right-sided pain).

Dataset 1

Pearson's Correlations ▼

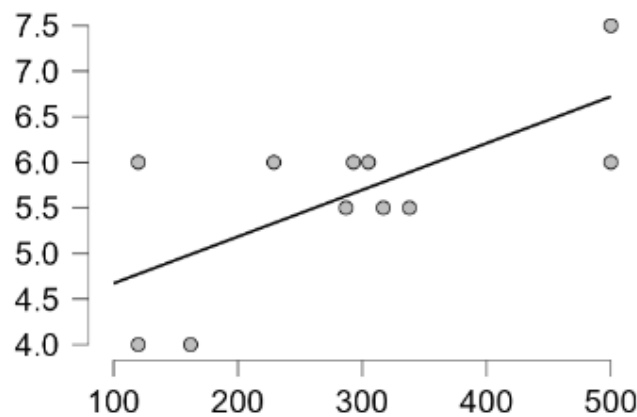
Variable		BCS	Thorax circumference
1. BCS	Pearson's r	—	
	p-value	—	
2. Thorax circumference	Pearson's r	0.487	—
	p-value	0.128	—



BCS and thorax circumference showed a positive correlation (R = 0.487, p-value = 0.128).

Pearson's Correlations ▼

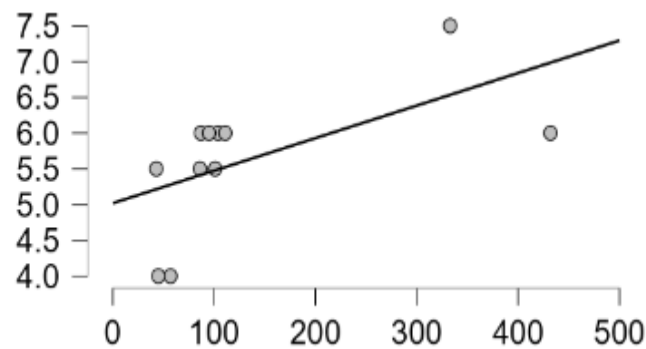
Variable		BCS	TC
1. BCS	Pearson's r	—	
	p-value	—	
2. TC	Pearson's r	0.683	—
	p-value	0.021	—



BCS and TC showed a significant strong positive correlation, as expected ($R = 0.683$, $p\text{-value} = 0.021$).

Pearson's Correlations ▼

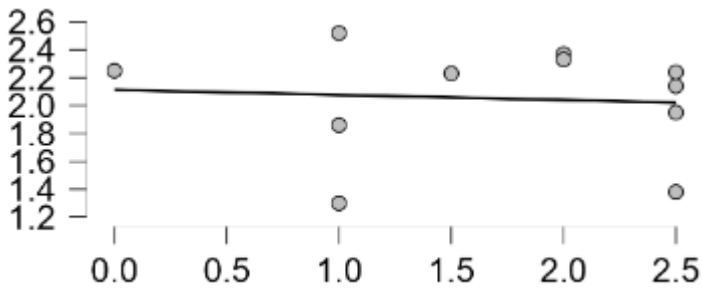
Variable		BCS	TG
1. BCS	Pearson's r	—	—
	p-value	—	—
2. TG	Pearson's r	0.587	—
	p-value	0.057	—



BCS and TG also showed a significant strong positive correlation, as expected ($R = 0.587$, $p\text{-value} = 0.057$).

Pearson's Correlations ▼

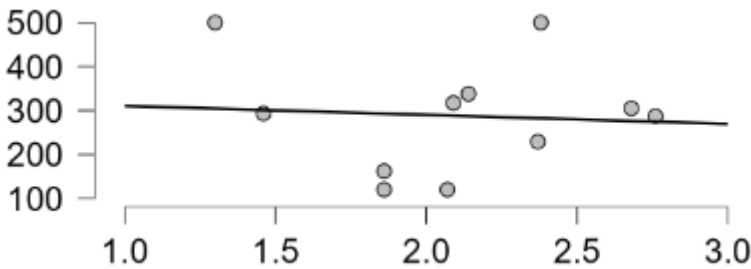
Variable		Thorax/Thigh (L)	MPL (L)
1. Thorax/Thigh (L)	Pearson's r	—	—
	p-value	—	—
2. MPL (L)	Pearson's r	-0.343	—
	p-value	0.302	—



Thorax/thigh value and MPL showed a negative correlation with low significance ($R = -0.343$, $p\text{-value} = 0.302$).

Pearson's Correlations ▼

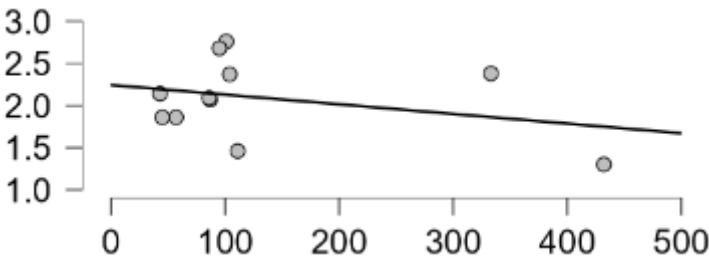
Variable		Thorax/Thigh (R)	TC
1. Thorax/Thigh (R)	Pearson's r	—	—
	p-value	—	—
2. TC	Pearson's r	-0.461	—
	p-value	0.154	—



Thorax/thigh value and TC showed a negative correlation ($R = -0.461$, $p\text{-value} = 0.154$).

Pearson's Correlations ▼

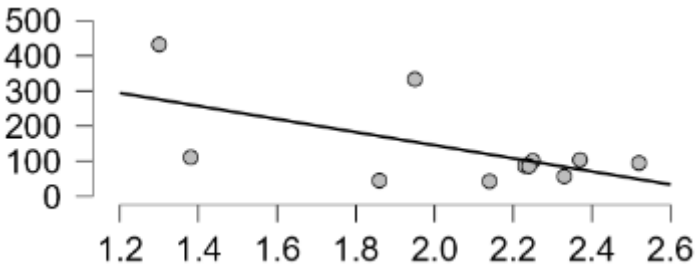
Variable		Thorax/Thigh (L)	TG
1. Thorax/Thigh (L)	Pearson's r	—	—
	p-value	—	—
2. TG	Pearson's r	-0.316	—
	p-value	0.344	—



Thorax/thigh value and TG showed a negative correlation with low significance (R = -0.316, p-value = 0.344).

Pearson's Correlations ▼

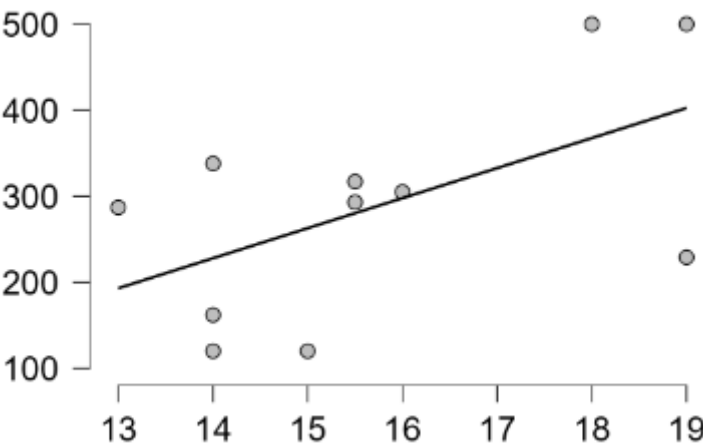
Variable		TG	Thorax/Thigh (R)
1. TG	Pearson's r	—	—
	p-value	—	—
2. Thorax/Thigh (R)	Pearson's r	-0.585	—
	p-value	0.059	—



TG and thorax/thigh value showed a significant negative correlation (R = -0.585, p-value = 0.059).

Pearson's Correlations ▼

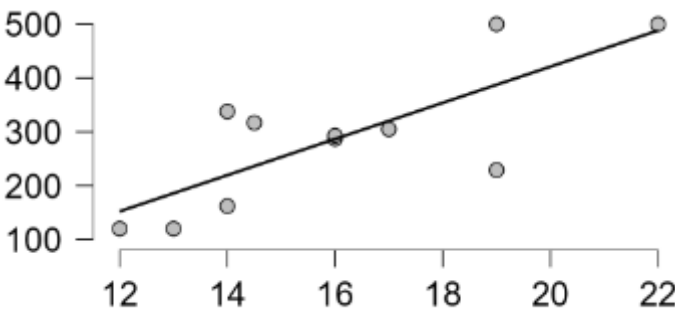
Variable		TC	Thigh (L)
1. TC	Pearson's r	—	—
	p-value	—	—
2. Thigh (L)	Pearson's r	0.561	—
	p-value	0.073	—



TC and thigh (left side) circumference showed a positive correlation ($R = 0.561$, $p\text{-value} = 0.073$).

Pearson's Correlations ▼

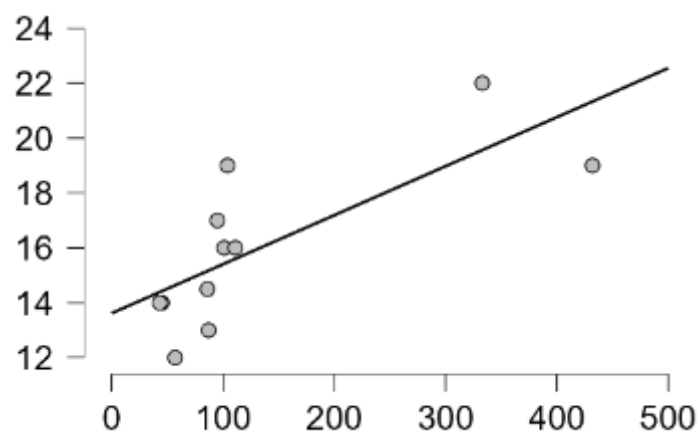
Variable		TC	Thigh (R)
1. TC	Pearson's r	—	
	p-value	—	
2. Thigh (R)	Pearson's r	0.776	—
	p-value	0.005	—



TC and thigh (right side) circumference showed a significant strong positive correlation ($R = 0.776$, $p\text{-value} = 0.005$).

Pearson's Correlations

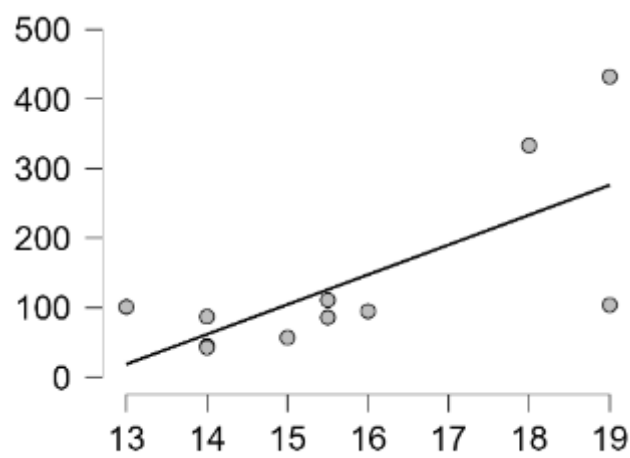
Variable		Thigh (R)	TG
1. Thigh (R)	Pearson's r	—	
	p-value	—	
2. TG	Pearson's r	0.749	—
	p-value	0.008	—



TG and thigh (right side) circumference showed a significant strong positive correlation ($R = 0.749$, $p\text{-value} = 0.008$).

Pearson's Correlations ▼

Variable		TG	Thigh (L)
1. TG	Pearson's r	—	
	p-value	—	
2. Thigh (L)	Pearson's r	0.711	—
	p-value	0.014	—



TG and thigh (left side) circumference showed a significant strong positive correlation ($R = 0.711$, $p\text{-value} = 0.014$).

Author Contributions: K.C. designed the concept of the study, collected and analyzed the data, and wrote the manuscript.

Institutional Review Board Statement: Data supporting this study are included within the article and/or supporting materials.

Data Availability Statement: Informed consent was waived (or exempted) by the IRB due to the retrospective design of this study. Prior to sample collection, all pet owners signed an informed consent form.

Abbreviations

Body Condition Score (BCS), Total Cholesterol (TC), Triglycerides (TG), Medial Patellar Luxation (MPL)

References

1. Bishop, M. A., Xenoulis, P. G., Levinski, M. D., Suchodolski, J. S., & Steiner, J. M. (2010). Identification of variants of the SPINK1 gene and their association with pancreatitis in Miniature Schnauzers. *American journal of veterinary research*, 71(5), 527-533.
2. Björntorp, P. (1992). Abdominal fat distribution and disease: an overview of epidemiological data. *Annals of medicine*, 24(1), 15-18.
3. Després, J.-P., Nadeau, A., Tremblay, A., Ferland, M., Moorjani, S., Lupien, P. J., Thériault, G., Pinault, S., & Bouchard, C. (1989). Role of deep abdominal fat in the association between regional adipose tissue distribution and glucose tolerance in obese women. *Diabetes*, 38(3), 304-309.
4. Dorsten, C. M., & Cooper, D. M. (2004). Use of body condition scoring to manage body weight in dogs. *Journal of the American Association for Laboratory Animal Science*, 43(3), 34-37.
5. Fink, B., Neave, N., & Manning, J. (2003). Second to fourth digit ratio, body mass index, waist-to-hip ratio, and waist-to-chest ratio: their relationships in heterosexual men and women. *Annals of human biology*, 30(6), 728-738.
6. Grewal, N. (2013). *The link between hypercholesterolemia and tendon pathology* University of British Columbia].
7. José Lahm Cardoso, M., Fagnani, R., Zaghi Cavalcante, C., de Souza Zanutto, M., Júnior, A. Z., Holsback da Silveira Fertonani, L., Calesso, J. R., Melussi, M., Pinheiro Costa, H., & Yudi Hashizume, E. (2016). Blood pressure, serum glucose, cholesterol, and triglycerides in dogs with different body scores. *Veterinary Medicine International*, 2016(1), 8675283.
8. Jung, K. J., Lee, G. J., & Jee, S. H. (2012). The association between thigh circumference and lipids profile in Korean population: The Korea Medical Institute Study. *Journal of Lipid and Atherosclerosis*, 1(2), 79-86.
9. Kleine, S., Sanderson, S., George, C., Roth, I., Gogal, R., Thaliath, M., & Budsberg, S. (2019). Correlation of synovial fluid leptin with body habitus in the healthy and osteoarthritic canine knee. *Osteoarthritis and Cartilage*, 27, S473-S474.
10. Kleine, S. A., Sanderson, S. L., George, C., Roth, I., Gogal, R. M., Thaliath, M. A., & Budsberg, S. C. (2019). Correlation of serum and synovial leptin concentrations with body condition scores in healthy and osteoarthritic dogs. *Veterinary Surgery*, 48(5), 780-785.
11. Leclerc, L., Thorin, C., Flanagan, J., Biourge, V., Serisier, S., & Nguyen, P. (2017). Higher neonatal growth rate and body condition score at 7 months are predictive factors of obesity in adult female Beagle dogs. *BMC veterinary research*, 13, 1-13.
12. Liberopoulos, E. N., & Elisaf, M. S. (2002). Dyslipidemia in patients with thyroid disorders. *HORMONES-ATHENS*, 1, 218-223.
13. Malghem, J., & Maldague, B. (1989). Depth insufficiency of the proximal trochlear groove on lateral radiographs of the knee: relation to patellar dislocation. *Radiology*, 170(2), 507-510.
14. Marquis, K., Debigaré, R., Lacasse, Y., LeBlanc, P., Jobin, J., Carrier, G., & Maltais, F. (2002). Midthigh muscle cross-sectional area is a better predictor of mortality than body mass index in patients with chronic obstructive pulmonary disease. *American journal of respiratory and critical care medicine*, 166(6), 809-813.
15. Nagao, I., Ohno, K., Nagahara, T., Yokoyama, N., Nakagawa, T., Fujiwara, R., Yamamoto, K., Goto-Koshino, Y., Tomiyasu, H., & Tsujimoto, H. (2019). Evaluation of visceral fat mass in dogs by computed tomography. *Journal of Veterinary Medical Science*, 81(11), 1552-1557.
16. Neumann-Haefelin, C., Kuhlmann, J., Belz, U., Kalisch, J., Quint, M., Gerl, M., Juretschke, H. P., & Herling, A. W. (2003). Determinants of intramyocellular lipid concentrations in rat hindleg muscle. *Magnetic Resonance in Medicine: An Official Journal of the International Society for Magnetic Resonance in Medicine*, 50(2), 242-248.
17. Oniki, Y., Kato, T., Irie, H., Mizuta, H., & Takagi, K. (2005). Diabetes with hyperlipidemia: a risk factor for developing joint contractures secondary to immobility in rat knee joints? *Journal of Orthopaedic Science*, 10, 221-226.
18. Webb, T. L., du Plessis, H., Christian, H., Raffan, E., Rohlf, V., & White, G. A. (2020). Understanding obesity among companion dogs: New measures of owner's beliefs and behaviour and associations with body condition scores. *Preventive veterinary medicine*, 180, 105029.
19. Wildman, E., Jones, G., Wagner, P., Boman, R., Troutt Jr, H., & Lesch, T. (1982). A dairy cow body condition scoring system and its relationship to selected production characteristics. *Journal of dairy science*, 65(3), 495-501.
20. Xenoulis, P. G., & Steiner, J. M. (2010). Lipid metabolism and hyperlipidemia in dogs. *The Veterinary Journal*, 183(1), 12-21.

21. Xenoulis, P. G., Suchodolski, J. S., Levinski, M. D., & Steiner, J. M. (2007). Investigation of hypertriglyceridemia in healthy Miniature Schnauzers. *Journal of veterinary internal medicine*, 21(6), 1224-1230.
22. Yadav, D., & Pitchumoni, C. (2003). Issues in hyperlipidemic pancreatitis. *J Clin Gastroenterol*, 36(1), 54-62.
23. Yam, P. S., Naughton, G., Butowski, C. F., & Root, A. L. (2017). Inaccurate assessment of canine body condition score, bodyweight, and pet food labels: a potential cause of inaccurate feeding. *Veterinary sciences*, 4(2), 30.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.