Screening of Blood Glucose Concentration in Domestic Cat (*Felis Catus*) Based on Body Condition Score, Breed, and Sex Using Portable Blood Glucose Meter

Lutfiah Annisa Billa[1]*, Nusdianto Triakoso[2], Kadek Rachmawati[3], Wiwik Misaco Yuniarti[2], Eduardus Bimo Aksono[3], Ira Sari Yudaniayanti[2]
[1]Student, [2]Veterinary Clinic Division, [3]Basic Veterinary Medicine Division,
Faculty of Veterinary Medicine, Universitas Airlangga
Corresponding author: blutfiah46@gmail.com

ABSTRACT

Type 2 diabetes mellitus (T2DM) is a common endocrine disease in domestic cats. Breed, sex, being overweight to an extent of obesity are predisposing factors for developing T2DM. One of the most common laboratory analyses conducted to confirm this disease is blood glucose concentrations. The aim of this research is to determine blood glucose concentration in domestic cats based on BCS, breed, and sex using a portable blood glucose meter. Research samples were obtained by taking blood samples from the marginal ear vein of 131 domestic cats that matched the sample's criteria, took at 2-hours post prandial, and drip onto the Sinocare strip. The results showed that the average blood glucose concentration was in the normal range, with a total of ideal (BCS ≥3/5) domestic cats (n=43) was 75.74 mg/dL, overweight (BCS ≥4/5) domestic cats (n=44) was 78.23 mg/dL, obese (BCS ≥5/5) domestic cats (n=44) was 89.66 mg/dL, male (n=51) was 80.57 mg/dL, female (n=80) was 81.69 mg/dL, Mixed Breed (n= 119) was 81.03 mg/dL, Angora (n=5) was 84.20 mg/dL, Persian (n=6) was 81.50 mg/dL and Ragdoll (n=1) was 92 mg/dL. Pearson correlation showed BCS (r=0.403; p= 0.000) had a moderate, positive, and significant correlation with blood glucose concentration in domestic cats. Meanwhile, the results of Kendall's Tau correlation showed that breed (p=0.740) and sex (p=0.555) had insignificant correlation with blood glucose concentration in domestic cats.

Keywords: body condition score, breed, sex, domestic cat, blood glucose concentration

Received: 09-01-2023 **Revised:** 19-03-2023 **Accepted:** 28-04-2023

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a common endocrine disease in domestic cats. Several studies have been identified that genetic and environmental factors play role in developing T2DM in domestic cats. Study conducted by McCann et al., (2007) showed that Burmese has been shown to be at a higher risk of developing T2DM. Reinforced by Öhlund et al., (2015) that found a significant association between Burmese, Russian Blue, Norwegian Forest, and Abyssinian breeds with having a higher risk of T2DM than the other cats. Beside breed, T2DM in domestic cat also has several predisposing factors as T2DM in people, including sex, increasing age, physical inactivity, and being overweight to an extent of obesity (O'neill et al., 2016).

Male has been identified as a risk factor for the development of T2DM in domestic cat (Slingerland et al., 2009). According to Appleton et al., (2001), male domestic cat of any weight had higher basal insulin concentrations and lower insulin sensitivity than female domestic cat, suggesting that males may be naturally more insulin resistant. Insulin sensitivity decreases, and

insulin concentrations increase in male domestic cats as they gain weight can leading to T2DM.

Being overweight or obese increases the chances of developing T2DM. Overweight defined as a condition where the levels of body fat exceed than what is considered optimal percent of body fat, while, obesity defined as being overweight to an extent that may affect individual's health (Sandøe et al., 2015). Body condition score (BCS) is the standard method of semi- quantitatively assessing degree of fat composition in domestic cat which uses a numerical scale to indicate the amount of fat in an animal's body by visually assessing the animal's body shape and palpating external skeletal landmarks (ribs, lumbar vertebrae, and pelvic bones including the abdominal tuck existence) to determine how much fat is around them (Chun et al., 2019). The most common BCS systems are 5-point scale. Scale 3 out of 5 (BCS ≥ 3/5) is the desire body condition (ideal), while an animal with a BCS of ≥ 1/5 means the animal is emaciated (thin) and an animal with a BCS of ≥ 5/5 is obese (Colville and Bassert, 2015).

Unfortunately, according to Wall et al., (2019), most of the owners are fundamentally inaccurate how they perceive their domestic cat's body condition and will not consult in their veterinarian for the weight problems of their domestic cats because they don't feel the necessity to bring it in to the animal hospital without any apparent symptom of disease. The visual normalization of overweight and obesity in domestic cats often promoted as cute, cuddly, and fluffy by the public might change an owner perception of what normal domestic cat body condition is when it is actually overweight or obese.

In overweight and obese individuals, the adipose mass tissue is increased. With increasing adiposity, fat cells become enlarged and less responsive to insulin that it becomes insulin resistance (Sabban et al., 2018). Insulin resistance is a condition where the cells in muscles, fat, and liver don't respond well to insulin and can't easily take up glucose from blood. As a result, β-cell produces insulin in sufficient quantities to maintain blood glucose concentrations at normal concentrations, but insulin can't work optimally absorbing glucose because it is disturbed. With insulin deficiency of lack of insulin receptivity, cells become deprived of glucose and glucose remains in the bloodstream resulting in high blood glucose concentrations (Wexler et al., 2018).

Therefore, early diagnosis and treatment of T2DM is important. One of the most common laboratory analyses conducted in order to confirm this disease in domestic cats is blood glucose concentrations. However, in many cases, stress hyperglycemia is a complicating factor interpreting blood glucose concentration in domestic cats. Rzymski and Poniedzialek (2013) reported that a visit to veterinary clinic can result in stress induced hyperglycemia in domestic cats, manifested by abnormal concentrations of glucose in blood. To anticipate this, Reeve-Johnson (2017) study indicates that home blood glucose monitoring using portable blood glucose meter is recommended to avoid the effects of stress hyperglycemia. Unlike venipuncture which involves more restraint and stress, portable blood glucose meters use only a drop of blood from the marginal ear vein nick technique.

METHOD

This research was conducted using an observational analytic method with a cross-sectional approach. The sampling technique used non-probability

purposive sampling technique. Research samples were obtained by taking blood samples from the marginal ear vein of 131 domestic cats based on BCS (ideal, overweight, and obese), breed, and sex (male and female) that matched the sample's criteria, took at 2- hours post prandial, and used a portable blood glucose meter with the brand Sinocare. The data in this study arranged in a table of mean and standard deviation. BCS breed, and sex of domestic cats were independent variables while blood glucose concentration was the dependent variable. To test the relationship between BCS, breed, and sex of domestic cats with blood glucose levels, a correlation test was performed. For the data with normal distribution, Pearson correlation was used and for data with not normal distribution, Kendall-Tau correlation was used.

RESULT AND DISCUSSION

Based on Table 1. The research results as a whole illustrate that from 131 domestic cats, the mean blood glucose concentration was still in the normal range, specifically 81.25 mg/dL. According to Gottlieb and Rand (2018), the blood glucose range in a healthy domestic cat is 58-117 mg/dL. Bruyette (2020) reinforced that if blood glucose concentrations are consistently above normal but below what is considered diabetes (> 117 to <180 mg/dL), it is associated with an increased risk of developing diabetes and considered prediabetes in domestic cats. Persistent hyperglycemia 180 mg/dL should be considered diabetes, but will only be accompanied by clinical signs after exceeding the renal threshold of 250-290 mg/dL. It can be seen that the minimum value of blood glucose concentration base on Table 1. in all domestic cats was 32 mg/dL, which is happened in obese domestic cat ((BCS ≥ 5/5). This indicates the domestic cat is suffering from hypoglycemia. According to Matthew and Thoppil (2018), In individuals who do not have diabetes, hypoglycemia is rare, but when it occurs, there are several major causes of hypoglycemia such as, pharmacological, alcoholism, critical illness, counter-regulatory hormone deficiency, and non-islet cell tumors. So, further investigation is needed to find out why the domestic cat suffering from hypoglycemia.

Table 1. Value of blood glucose concentration during research subjects

Variable (mg/dL)	Blood Glucose Concentration
N	131
Min	32
Max	186
Mean	81.25
SD	18.81

Meanwhile, the maximum value of blood glucose concentration in all domestic cats was 186 mg/dL, which is happened in obese domestic cat (BCS ≥ 5/5). Clinically, if an individual is obese, leptin levels in the body will increase. The hormone leptin is linked to the obesity gene. Leptin will inhibit the uptake of glucose causing glucose remains in the blood causing a condition called hyperglycemia. Other than that, the excess fat in obese individual causes adipose mass tissue increased which make the cell less responsive to the insulin. The loss of insulin sensitivity is due to a partitioning of fatty acids away from the adipose tissue to the muscle resulting in higher amounts of intramyocellular and extramyocellular fat. However, despite the insulin resistance in the peripheral tissues, hepatic insulin sensitivity is maintained in overweight and obese individuals, in

Table 2. Descriptive statistics of blood glucose concentration based on BCS, breed, and sex

Variable	N	Min (mg/dL)	Max (mg/dL)	Mean (mg/dL)	Significance value (p)	Correlation Coefficient (r)
BCS						
Ideal (BCS≥ 3/5)	43	43	105	75.74	0.000	0.403
Overweight (BCS ≥ 4/5)	44	41	109	78.23		
Obese (BCS≥ 5/5)	44	32	186	89.66		
Breed						
Mixed Breed	119	32	186	81.03	0.740	0.024
Angora	5	67	99	84.20		
Persian	6	64	107	81.50		
Ragdoll	1	92	92	92		
Sex						
Male	51	32	186	80.57	0.555	0.043
Female	80	41	118	81.69		

The correlation between BCS and blood glucose concentration was tested with Pearson correlation test, meanwhile, to see the correlation between breed and sex with blood glucose concentration, Kendall's Tau correlation test was used.

both the fasted and postprandial state. These increased blood glucose concentration concentrations are due to the failure of insulin action on the target tissue or insufficient production of insulin, or failure of both actions finally it causes hyperglycemia (Hoenig, 2014).

The results on Table 2. showed that the average blood glucose concentration of domestic cats in the obese category was higher than the average description of the blood glucose concentration in domestic cats with ideal and overweight BCS. Analysis of the Pearson correlation showed the significance (p) value for the relationship between body condition score and glucose concentration was 0.000 ($p < 0.05$), which means there is a correlation between BCS and blood glucose concentration. The Pearson correlations coefficient obtained was 0.403, so it can be interpreted that the strength of correlation between BCS and glucose concentration is moderate correlated and the direction of the relationship is unidirectional because the correlation value is positive. Which means, the greater the body condition score, the greater the blood glucose concentration.

These results align with the research conducted by Verbrugghe et al., (2009), stating that domestic cats have increased glucose, higher fasting plasma glucose concentrations, impaired glucose tolerance, and higher insulin resistance obese domestic cats. This is also corroborated by Strage et al., (2021) research, which showed significantly higher glucose concentrations in overweight domestic

cats than ideal domestic cats. Although the results in this study are equally significant with previous studies, there are still differences from this study, namely the level of correlation coeffieciet is smaller because it used a more diverse sample and the sample has more other risk factors. The differences between these studies were influenced by differences in sample diversity and there were several other possibilities such as blood sampling methods and bias in data processing. Age, initial history of sex, and physical examination may also be associated with changes in blood glucose concentrations. Past medical problems can reveal clinical signs of an underlying problem which will manifest as changes in blood glucose. Exposure to drugs or toxins known to be associated with changes in blood glucose should also be identified.

The average blood glucose concentration in domestic cats with Mixed breeds, Angora, Persian, and Ragdoll as a whole was still in the normal range (Table 2.). Kendall's Tau correlation analysis showed a value of 0.740, which p value > 0.05 means there was no correlation between breeds and blood glucose concentration. A shortcoming of this study is the lack of breed variety. Several studies have shown that Burmese cats are at high risk of developing T2DM. Öhlund et al., (2015) study found a significant association that the Burmese, Russian Blue, Norwegian Forest, and Abyssinian breeds having a higher risk of T2DM than the other cats. Kluger et al., (2009) study has shown a proportion of Australian Burmese cats to have fasting hypertriglyceridemia and an exaggerated postprandial triglyceride response after an oral fat tolerance test. The reason the Burmese cat has an increased risk of developing DM is still unknown, but dyslipidemia reflecting an inborn error of lipid metabolism has been described in the breed. However, research supporting these results is still limited.

Referring to Table 2. it can be seen that the average blood glucose concentration in males and females as a whole was still in the normal range. Kendall's Tau correlation analysis shows a value of 0.555, meaning there was no correlation between sex and blood glucose concentration. This result is in line with the research of McCann et al., (2007) which stated that there was no significant difference in blood glucose concentrations in male and female domestic cats, both are at apparent equal risk for developing T2DM. Reinforced by O'neill et al., (2016) study that indicates sex was not significantly associated with DM. However, this study had limitations.

Several studies have identified male domestic cats having a higher risk of developing T2DM in domestic cats. Male domestic cats are predisposed to obesity (Teng et al., 2017) which increased the risk of having T2DM and male domestic cats of any weight had higher basal insulin concentrations and lower insulin sensitivity than female domestic cats, suggesting that males may be naturally more insulin resistant. Insulin sensitivity decreases, and insulin concentrations increase in male domestic cats as they gain weight (Hoenig et al., 2007).

However, this study had limitations. The fact that the proportion of comparison of each sample variable was not balanced could cause bias. Other limitations of this study include lack of information about environmental risk factors such as diet, physical activity, age, and other factors that were unavailable in the database, but could influence the blood glucose concentration.

CONCLUSION

The blood glucose concentration average was still in the normal range with a total of ideal (BCS ≥3/5) domestic cats (n=43) was 75.74 mg/dL, overweight (BCS ≥4/5) domestic cats (n=44) was 78.23 mg/dL, obese (BCS ≥5/5) domestic cats (n=44) was 89.66 mg/dL, males (n=51) was 80.57 mg/dL, females (n=80) was 81.69 mg/dL, Mixed Breed (n= 119) was 81.03 mg/dL, Angora (n=5) was 84.20 mg/dL, Persian (n=6) was 81.50 mg/dL and Ragdoll (n=1) was 92 mg/dL.

The results of the Pearson correlation showed BCS (r=0.403; p=0.000) had a moderate, positive, and significant correlation with blood glucose concentration in domestic cats. The Kendall's Tau correlation test showed that breed (p=0.740) and sex (p=0.555) had insignificant correlation with blood glucose concentration in domestic cats.

REFERENCES

Appleton, D. J., Rand, J. S., and Sunvold, G. D. 2001. Insulin sensitivity decreases with obesity, and lean cats with low insulin sensitivity are at greatest risk of glucose intolerance with weight gain. Journal of Feline Medicine & Surgery, 3(4), 211-228.

Barrera, C., Gatica, A., and Morgan, C. (2012). Obese visceral adipose tissue grafted in lean mice can alter glucose homeostasis and energy efficiency. Journal of biological regulators and homeostatic agents, 26(3), 411-417.

Bruyette, D. (ed). 2020. Clinical Small Animal Internal Medicine. John Wiley & Sons.

Chun, J. L., Bang, H. T., Ji, S. Y., Jeong, J. Y., Kim, M., Kim, B., Lee, S. D., Lee, Y. K., Reddy, K. E., and Kim, K. H. 2019. A simple method to evaluate body condition score to maintain the optimal body weight in dogs. Journal of Animal Science and Technology, 61(6), 366.

Colville, T. P., and Bassert, J. M. 2015. Laboratory Manual for Clinical Anatomy and Physiology for Veterinary Technicians-E-Book. Elsevier Health Sciences

Hoenig, M., Thomaseth, K., Waldron, M., and Ferguson, D. C. 2007. Fatty acid turnover, substrate oxidation, and heat production in lean and obese cats during the euglycemic hyperinsulinemia clamp. Domestic animal endocrinology, 32(4), 329-338.

Hoenig, M. 2014. Carbohydrate metabolism and pathogenesis of diabetes mellitus in dogs and cats. Progress in molecular biology and translational science, 121, 377-412.

Mathew, P., & Thoppil, D. (2018). Hypoglycemia.

Kluger, E. K., Hardman, C., Govendir, M., Baral, R. M., Sullivan, D. R., Snow, D., and Malik, R. 2009. Triglyceride response following an oral fat tolerance test in Burmese cats, other pedigree cats and domestic crossbred cats.

Gottlieb, S., and Rand, J. 2018. Managing feline diabetes: current perspectives. Veterinary Medicine: Research and Reports, 9, 33.

McCann, T. M., Simpson, K. E., Shaw, D. J., Butt, J. A., and Gunn-Moore, D. A. 2007. Feline diabetes mellitus in the UK: the prevalence within an insured cat population and a questionnaire- based putative risk factor analysis. Journal of Feline Medicine and Surgery, 9(4), 289-299.

Öhlund, M., Fall, T., Ström Holst, B., Hansson-Hamlin, H., Bonnett, B., and Egenvall, A. 2015. Incidence of

diabetes mellitus in insured Swedish cats in relation to age, breed and sex. Journal of veterinary internal medicine, 29(5), 1342-1347.

O'neill, D. G., Gostelow, R., Orme, C., Church, D. B., Niessen, S. J. M., Verheyen, K., and Brodbelt, D. C. (2016). Epidemiology of diabetes mellitus among 193,435 cats attending primary-care veterinary practices in England. Journal of Veterinary Internal Medicine, 30(4), 964-972.

Reeve-Johnson, M. 2017. Screening for prediabetes in senior cats and metabolomic characteristics of obesity and Burmese cats.

Rzymski, P., and Poniedzialek, B. 2013. Blood glucose level as an insufficient indicator of feline diabetes mellitus: a case report. Veterinarni Medicina, 58(7), 385-387.

Sabban, E. N. C., Puchulu, F. M., and Cusi, K. (eds.). 2018. Dermatology and diabetes. Springer.

Sandøe, P., Corr, S., and Palmer, C. 2015. Companion animal ethics. John Wiley & Sons.

Slingerland, L. I., Fazilova, V. V., Plantinga, E.A., Kooistra, H. S., and Beynen, A. C. 2009. Indoor confinement and physical inactivity rather than the proportion of dry food are risk factors in the development of feline type 2 diabetes mellitus. The Veterinary Journal, 179(2), 247-253.

Strage, E. M., Ley, C. J., Forkman, J., Öhlund,

M., Stadig, S., Bergh, A., and Ley, C. (2021). Homeostasis model assessment, serum insulin and their relation to body fat in cats. BMC Veterinary Research, 17(1), 1-10.

Teng, K. T., McGreevy, P. D., Toribio, J. A. L., Raubenheimer, D., Kendall, K., and Dhand, N. K. 2017. Risk factors for underweight and overweight in cats in metropolitan Sydney, Australia. Preventive veterinary medicine, 144, 102-111

Verbrugghe, A., Hesta, M., Gommeren, K., Daminet, S., Wuyts, B., Buyse, J., and Janssens, G. P. 2009. Oligofructose and inulin modulate glucose and amino acid metabolism through propionate production in normal- weight and obese cats. British Journal of Nutrition, 102(5), 694-702.

Wall, M., Cave, N. J., and Vallee, E. 2019. Owner and cat-related risk factors for feline overweight or obesity. Frontiers in veterinary science, 6, 266.

Wexler, D. J., Powe, C. E., Barbour, L. A., Buchanan, T., Coustan, D. R., Corcoy, R., Damm, P., Dunne, D., Feig, D. S., Ferrara, A., Harper, L. M., Landon, M. B., Meltzer, S. J., Metzger, B. E., Roeder,

H., Rowan, J. A., Sacks, D. A., Simmons, D., Umans, J. G., and Catalano, P. M. 2018. Research Gaps in Gestational Diabetes Mellitus: Executive Summary of an National Institute of Diabetes and Digestive and Kidney Workshop. Obstetrics and gynecology, 132(2), 496..

***