PAW MORPHOMETRIC AND FOOT IMPRINT IN PREDICTING FELINE WEIGHT

By

AINURUL IMAN BINTI JASNI

A RESEARCH PAPER SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF VETERINARY MEDICINE

FACULTY OF VETERINARY MEDICINE

UNIVERSITI MALAYSIA KELANTAN

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ABSTRACT

An abstract of research paper presented to the Faculty of Veterinary Medicine, Universiti Malaysia Kelantan, in partial requirement of the course DVT 55204 – Research Project.

This study investigates the relationship between paw morphometric indices and body weight in domestic felines, with implications for forensic, veterinary, and conservation applications. Among the variables examined, RightTotalLength and RightTotalWidth exhibited statistically significant positive correlations with body weight ($r = 0.449$ and $r = 0.364$, respectively), indicating that larger paw dimensions are moderately associated with heavier cats. However, measurements such as LeftPadLength and LeftPadWidth showed no significant predictive value. A regression model explained 31.8% of the variability in body weight, highlighting RightTotalLength as a key predictor ($p = 0.032$), although additional variables such as age, sex, or breed may further improve accuracy.

Comparison with prior studies underscores the potential of paw morphometrics in non-invasive body metric estimation, mirroring applications in wildlife species like tigers and black bears. Despite its strengths—such as the use of simple, non-invasive data collection methods—the study was limited by its small sample size ($n = 38$) and lack of additional morphometric variables, which could enhance predictive power.

Future research should involve larger, more diverse feline populations and advanced techniques like the Footprint Identification Technique (FIT) to improve model robustness. Practical applications include quick weight estimation tools for veterinary and conservation use, as well as forensic models for identifying felines from pawprints at crime scenes. The findings contribute valuable insights into feline morphology, supporting interdisciplinary applications in health, welfare, and forensic science.

ABSTRAK

Kajian ini menyelidiki hubungan antara indeks morfometrik tapak kaki dan berat badan dalam kucing domestik, dengan implikasi untuk forensik, perubatan veterinar, dan pemuliharaan. Antara pemboleh ubah yang dikaji, RightTotalLength dan RightTotalWidth menunjukkan korelasi positif yang signifikan secara statistik dengan berat badan (r = 0.449 dan r = 0.364, masing-masing), menunjukkan bahawa dimensi tapak kaki yang lebih besar berkait secara sederhana dengan kucing yang lebih berat. Waau bagaimanapun, ukuran seperti LeftPadLength dan LeftPadWidth tidak menunjukkan nilai ramalan yang signifikan. Model regresi menjelaskan 31.8% variasi berat badan, dengan RightTotalLength dikenal pasti sebagai pemboleh ubah peramal utama (p = 0.032), walaupun pemboleh ubah tambahan seperti umur, jantina, atau baka mungkin dapat meningkatkan ketepatan.

Perbandingan dengan kajian terdahulu menekankan potensi morfometrik tapak kaki dalam anggaran ukuran badan secara tidak invasif, mencerminkan aplikasi pada spesies hidupan liar seperti harimau dan beruang hitam. Walaupun mempunyai kekuatan seperti penggunaan kaedah pengumpulan data yang mudah dan tidak invasif, kajian ini terhad oleh saiz sampel yang kecil (n = 38) dan kekurangan pemboleh ubah morfometrik tambahan yang boleh meningkatkan daya ramalan.

Kajian masa depan disarankan melibatkan populasi kucing yang lebih besar dan lebih pelbagai serta menggunakan teknik canggih seperti Footprint Identification Technique (FIT) untuk meningkatkan keteguhan model. Aplikasi praktikal termasuk alat anggaran berat badan yang pantas untuk kegunaan veterinar dan pemuliharaan, serta model forensik untuk mengenal pasti kucing berdasarkan jejak tapak kaki di tempat kejadian jenayah. Penemuan ini menyumbang kepada pemahaman mendalam tentang morfologi kucing, menyokong aplikasi merentas disiplin dalam kesihatan, kebajikan, dan sains forensik.

CERTIFICATION

This is to certify that we have read this research paper entitled **'Paw Morphometric and Foot Imprint in Predicting Feline Weight'** by **Ainurul Iman Binti Jasni**, and in our opinion, it is satisfactory in terms of scope, quality, and presentation as partial fulfillment of the requirements for the course DVT 55204 – Research Project.

____

Dr. Abubakar Danmaigoro

DVM., M.Sc. (UDUSOK), PhD Veterinary Anatomy & Histology (UPM)

Senior Lecturer

Faculty of Veterinary Medicine

Universiti Malaysia Kelantan

(Supervisor)

____

Dr. Mohammed Dauda Goni

DVM (UNIMAID), M.Sc. in Public Health (UPM),

PhD in Public Health and Epidemiology (USM)

Senior Lecturer

Faculty of Veterinary Medicine

Universiti Malaysia Kelantan

(Co-supervisor)

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious, the Most Merciful.

First and foremost, all praise and gratitude are due to Allah (SWT) for granting me the strength, patience, and guidance to complete this project paper. Without His blessings, this achievement would not have been possible.

I would like to express my deepest appreciation to Dr. Abubakar Danmaigoro and Dr. Mohammed Dauda Goni for their invaluable guidance, advice, and mentorship throughout this journey.

A heartfelt thanks to Siti Nur Amany Ayuni Binti Shahrul Nizan, whose unwavering support and assistance were instrumental in achieving this milestone. I am also profoundly grateful to my friends, Nurulnajiha binti Ahmad Jame,Wong Chin Hui, and Amir for their encouragement and companionship.

To my beloved family, thank you for your unconditional love, prayers, and support, which have been my greatest source of strength. I also extend my gratitude to the lab assistants of FPV UMK for their technical assistance and cooperation and Neofelis, whose inspiration and contributions were greatly valued.

Thank you to everyone who played a role in making this project a reality. May Allah bless all of you for your kindness and support.

DEDICATED TO MY SUPPORTIVE PARENT AND FAMILY

JASNI MOHD NOOR & SUFIAH RAHUMAT

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LIST OF ABBREVIATIONS

CW	Cat weight
LTL	Left Total Length
LTW	Left Total Width
LPL	Left Pad Length
LPW	Left Pad Width
RTL	Right Total Length
RTW	Right Total Width
RPL	Right Pad Length
RPW	Right Pad Width

CHAPTER 1

1.0 INTRODUCTION

1.1 BACKGROUND

Paw morphometrics which includes the size and shape of paw pads, claws, and digits, plays a fundamental role in a cat's locomotion, balance, tactile perception, and forensic assessment of the species (McGreevy et al., 2008; Bradshaw et al., 2012). Previous research has highlighted the importance of paw features in facilitating various behaviors, such as climbing, grasping, and prey capture (Lascelles & Thomson, 2004; Courcier et al., 2010). However, there is paucity of scientific knowledge on the relationship between paw morphometrics and overall body weight in domestic and wild felids.

Body weight is a critical indicator of feline health and fitness, with obesity being a prevalent issue in domestic cat populations worldwide that links to various health problems ((Rowe et al., 2022; German, 2016). Understanding how paw morphology correlates with body weight can provide valuable insights into musculoskeletal health, locomotor efficiency, and metabolic regulation in felines (Hunter & Barrett, 2007; Sunquist & Sunquist, 2002). Furthermore, such knowledge may have practical applications in Veterinary medicine, conservation biology, and forensic medicine.

The domestic cat (*Felis catus*) has long been a subject of fascination and study due to its unique morphological features, behavioral adaptations, and close companionship with humans. Among the various aspects of feline biology, the relationship between paw morphometrics and body weight stands out as crucial in forensic assessment yet a relatively little information is scientific domain. Understanding this correlation holds significant implications for feline health, welfare, and evolutionary ecology.

The present study aims to address this knowledge gap by investigating the correlation between paw morphometrics and body weight in felines. By examining a diverse population of domestic and stray cats in both urban and rural settings, we seek to elucidate the relationship between paw size, shape, and body weight of the cats. Insights from this study can inform veterinarians, breeding programmers, and conservation efforts aimed at promoting the health, welfare, and ecological sustainability of feline populations.

1.2 RESEARCH PROBLEM STATEMENT

Forensic investigations may occur in fields or outdoor settings with restricted access to specialized equipment for weighing carcasses. However, limited attention has been paid to the relationship between paw morphometrics and overall body weight in domestic felids. There is no reliable and accurate model to estimate weight based on the paw size and morphometrics of felines for the purposes of modeling and predictive forensic investigation in domestic felids.

1.3 RESEARCH QUESTIONS

1. Can paw morphometric indices estimate the body weight of felines?
2. Is it significant to use paw morphometrics indices to estimate the body weight of feline?

3. Is there any correlation between the body weight of a feline with the morphometric indices of the paw?

1.4 RESEARCH HYPOTHESIS

Null hypothesis: There is no significant correlation between paw morphometrics indices and body weight in felines.

Alternative hypothesis: There is a significant positive correlation between paw morphometrics indices and body weight in felines

1.5 RESEARCH OBJECTIVES

- To assess the body weight and paw morphometric indices of cats
- To determine the relationship between feline body weight and paw morphometric indices in cats.
- To evaluate the reliability of the predictive model between feline paw morphometric and body weight.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 FOOT IMPRINT AND FELINE WEIGHT

In forensic science, examination of the paw morphology is used to determine the species of animals in the wild. Animal paw imprints are categorized according to the number of toes that show in a paw print and include the following groups: two toes, four toes, five toes, and four front toes with five hind toes (Stern & Lamm, 2011). The pugmarks of male and female tigers differed markedly in terms of pad length and pad area compared to other measures (Singh et al., 2014).

Feline considered under the family of Felidae in the order Carnivora which includes wild cats such as the jaguar (*Panthera onca*), the cheetah (*Acinonyxjubatus*), and the lion (*Panthera leo)*, and domestic cats (*Felis catus*). Felids possess short- to medium-length limbs and utilize digitigrade locomotion. With their retractable claws, most felids can climb trees and catch prey (Lamberski 2015). When landing, the central pad of the felid's forepaws is the first to contact the ground, providing initial support. The innate feeding behavior of cats requires hunting (prey seeking, stalking, and chasing) and scavenging (Landsberg et al., 2011), resembling their ancestral African wildcat (Rodan & Heath, 2015).

Felids are carnivorous and their body size and environment impact their diets (Dev et al., 2020). The most common gait transition seen in felids is trotting to galloping. Transition duration and speed are heavily dependent on body size (Dev et al., 2020). The existing research estimates the absolute number of Puma to monitor the population using the footprint, trial count, and hunter harvest (Alibhai et al., 2017). For the endangered Amur tiger relocation, the distribution numbers recorded using the footprint (Alibhai et al., 2023). Indirect signs (such as footprints, scat, nests, etc.) might be the most cost-effective and efficient detection method for many species. Animal footprints have been the foundation for population indices and estimators as they are met in the wild more often than the animals themselves. The animal does not have to be seen, trapped, or touched during footprint surveys, also known as track surveys (Alibhai et al., 2017).

Mammal species frequently leave behind footprints that are enough to identify the sex and individuals who left them (Alibhai et al., 2023). There have been numerous documented attempts to use footprints in various contexts. These include the use of footprints as a straightforward index of abundance for occupancy analysis (Karanth et al., 2010; Karanth et al., 2011); simple measurements taken directly from footprints in the field for tiger *Panthera tigris* and brown bear *Ursus arctos* visual pattern recognition and unsupervised neural nets in Snow leopard, *Panthera uncia* (Alibhai et al., 2023).

2.2 ASSESSING FELINE WEIGHT VIA PAW DATA

A study by Hayward et al. (2002), uses the traditional method in the Russian Far East, in identifying individual Amur tigers from their tracks in the snow based on measurements of the palmar pad width of the front paw, which varies with age and sex. It is reported to be easy, fast, specific, and affordable. The classic technique used in Amur Tiger monitoring in China and Russia distinguishes between subadult males and adult females (Hayward et al., 2002).

The recent software Footprint Identification Technique (FIT) features an extraction window in JMP software for the extraction of variables from the footprint photographed. This software was adopted in the works of Alibhai et al., (2023).

Further research was carried out to recreate natural settings by adding natural, sifted snow to the enclosure areas, stacked to a depth of 2-3 cm. This was done because there was an unusual absence of snowfall throughout the sample time. They trained animals to walk on the surface by rewarding them with food. Then they moved them to a safe enclosure and collected paw prints (Alibhai et al., 2023). The photographs were taken with a compact digital camera directly overhead, with the footprint, ruler, and label card centered within the frame (Gu et al., 2014).

2.3 EVALUATING FELINE WEIGHT THROUGH PAW MORPHOMETRICS

The only footprints collected were the back ones because, while walking normally, the hind feet usually register more than the front feet, leaving less complete front imprints (Sharma et al. 2005). They created the system to solely employ left-hind footprints to simplify field gathering and reduce the need for footprint collecting. According to Riordan (1998), Right-hind prints had a slightly higher misclassification rate than left-hind prints. On the other hand, Indian scientists sampled tracks with around five separate imprints of the left and right hind foot, whereas Russian researchers measured only the usual width of the front pad for Amur tigers. Other studies have demonstrated that increasing the sample size and including additional variables—such as toe dimensions, stride length, or angle measurements—could enhance the accuracy of models predicting body weight in Sharma et al., (2005b) study shown in Figure 2.3.1.

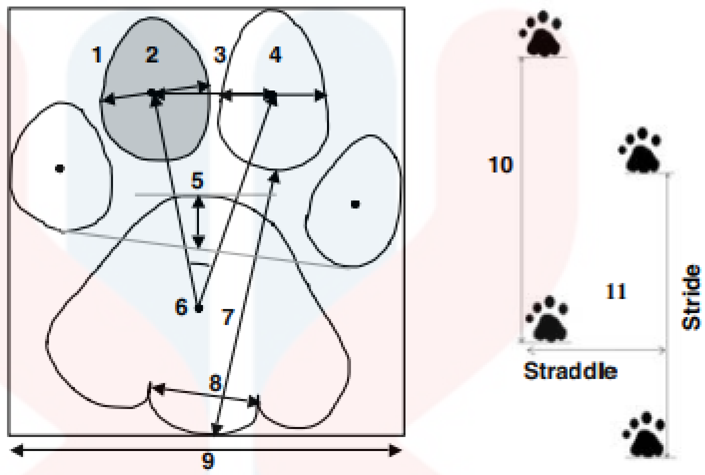

Figure 2.3.1. The measurement of paw morphometrics from a study by Sharma et al. (2005b)

Because of this, the forepaw is significantly larger than the rear paw in both sexes and if the pugmark is traced in a linear frame, the frame typically has a squarish form. But when the pugmarks on the hind paws are traced, the male's fit in a distinctly squarish frame whereas the female's fit in a comparatively rectangular frame. (Panwar, 1979) The paw is a supple organ that adapts to the surface that it can rest on. On slippery surfaces, it can spread out and appear larger, while on hard surfaces covered in a thin layer of sand or grit, it can appear smaller and more compact. But even in these circumstances, each pugmark has its unique qualities, and the differences mostly in size can always be understood in relation to their natural environment (Panwar, 1979).

Furthermore, radio and GPS collars have been known to injure or even kill a number of species, such as the black rhino, mule deer, kit foxes, and African wild dogs (Alibhai et al., 2017). The animals may be at less risk from the outside by employing the manual measurement approach. This study suggests that the relationship between body weight and paw morphometrics could aid in the creation of a veterinary tool for musculoskeletal diagnosis, rehabilitation program design, and weight management intervention. It can be used as gait analysis and biomechanics, Moreover, it can be used as a health indicator to assess the cat's health status and thus may be used for medication dosing. The correlation between paw morphometrics and body weight can be further studied with age, sex, and breed variables using more precise parameters for each digit of the paw.

CHAPTER 3

3.0 METHODOLOGY

3.1 ETHICAL CONSIDERATIONS

When using felines in a study methodology, animal welfare must be taken into account from an ethical standpoint. It is necessary to use gentle handling and non-invasive ways to reduce anxiety and discomfort during the data collection processes. In the interim holding area, the cats must thus be given the proper housing, food, and care. Cats with owner must obtain permission before any information about their pets is published to protect their confidentiality.

Moreover, during the study procedure, any felines must not be discriminated against based on the breed, age or health status of the cat. Each of the participants must be treated with respect regardless of their characteristics. Based on Figure 3.1, the ink pad used in this study has toxicological effects when administered at levels exceeding 5000 mg/kg. We ensured that our usage did not exceed this threshold to avoid potential toxicity.

TOXICOLOGICAL INFORMATION

Information on toxicological effects

Acute toxicity	:	LD/LC50 values that are relevant for classification [1,2,3-Propanetriol]		
		Oral-rat	LD50	>5,000mg/kg
		Dermal-rabbit	LD50	>5,000mg/kg
Carcinogenicity	:	Not listed by IARC, EPA, EU, NTP.		

Figure 3.1. Shows the toxicological information of the ink pad used

Sources: Safety Data Sheet according to Safe Work Australia Document "Model Code of Practice : Preparation of Safety Data Sheets for Hazardous Chemicals," n.d.

3.2 SAMPLE COLLECTION AND PREPARATION

3.2.1 STUDY AREA

The study will be conducted in the districts of Kota Bharu, Kelantan, Malaysia

3.2.2 STUDY DESIGN

A cross-sectional study will be conducted by collecting data on paw morphometric and body weight measurements taken on a sample of felines which is gathered at one point in time. It facilitates determining the correlation between paw morphology and body weight in different subjects in a population density. It can offer insightful information on the correlation between these variables and is rather easy to accomplish.

3.2.3 STUDY POPULATION

One common formula for determining sample size is the Cochran formula:

Given that the study of the correlation between paw morphometrics and body weight in felines in Kota Bharu, Kelantan, and assuming does not have any prior information about the population's characteristics, a conservative estimate of p=0.5 to ensure maximum variability in the population. For example, if on a 95% confidence level (Z=1.96) and a margin of error of E=0.05, the calculation would be:

n=1.962·0.5·(1−0.5)/0.05^2

n=3.8416·0.250.002/0.0025

n=0.9604/0.0025

n=384.16

Rounding up to the nearest whole number, the sample size of approximately 385 cats for this study. The sample size will be around only 10% because it's a pilot test of 38 cats.

3.2.4 SELECTION CRITERIA

Any cat regardless of their age, sex, and breed to determine the correlation.

3.2.5 INCLUSION CRITERIA

The feline must have limbs and complete paw digits without pathologic lesions.

3.2.6 EXCLUSION CRITERIA

Cats with polydactylous digits are not allowed to participate in this study. Therefore, the paw's condition needs to be normal. Since pododermatitis may affect the measurement of paw size, cats with this condition need to be avoided.

3.2.7 DATA COLLECTION AND ANALYSIS

Simple random sampling was used to select the cats. Each cat was weighed using a digital scale before obtaining paw impressions. Pawprints were captured using watercolor or ink pads, with the cats encouraged to walk across paper surfaces. Food was provided as an incentive to facilitate proper impressions. If the pawprints were not clear, handlers manually obtained impressions. Measurements of the pawprints, including total length, total width, pad width, and paw length, were taken using a Vernier caliper. Only hindlimb pawprints were measured, as they were more accessible and less prone to overlapping with forelimb prints, following the methodology suggested by Alibhai et al. (2023).

Data collection tools included a Vernier caliper for measuring pawprint dimensions (mm) and a digital weight scale for recording body weight. Data were organized in spreadsheet software like Microsoft Excel and analyzed using statistical tools such as SPSS to evaluate the preliminary relationship between paw morphometrics and feline body weight. The findings from this pilot study were intended to guide future research with larger sample sizes and more comprehensive methodologies.

Each cat was assigned a unique identification number to facilitate tracking and analysis. Descriptive statistics, such as mean (standard deviation) or median (interquartile range), were calculated for paw morphometric measurements and body weight using SPSS software. An appropriate statistical method was used to assess the correlation between paw morphometrics and body weight. Then, the correlation coefficient such as Pearson's correlation coefficient or Spearman rank correlation coefficient. Regression analysis can be used using linear regression depending on the nature of the data that helps to model the relationship between paw morphometrics and body weight.

CHAPTER 4

4.1 RESULT

A total of 38 samples were collected from the Kota Bharu district. The samples were strays cats within the study area. The descriptive statistics shown in Table 4.1 is a summary of measurements for the left and right hindlimbs across 38 samples. For the left hindlimb, the total length has a mean of 26.26 ± 4.71 mm and the total width averages 24.51 ± 4.82 mm. The left pad length and width have means of 12.45 ± 2.09 mm and 15.36 ± 1.47 mm, respectively. For the right hindlimb, the total length averages 27.20 mm with a standard deviation of 2.58 mm, while the total width averages 25.35 mm with a standard deviation of 3.31 mm. The pad length and width for the right side have means of 12.77 mm and 15.64 mm, with standard deviations of 1.64 mm and 1.33 mm, respectively. The data suggests slightly higher averages for the right hindlimb in most measurements, reflecting potential asymmetry or natural variation within the sample. Overall, the results suggest that total length and width are more closely linked to body weight than pad measurements as shown in table 4.1 below

Table 4.1. The descriptive statistics of summary from paw morphometric of 38 samples

Paw Morphometrics Variables N=38	Mean ± Standard Deviation (mm)
Left Total Length	26.26 ± 4.71
Left Total Width	24.51 ± 4.82
Left Pad Length	12.46 ± 2.09
Left Pad Width	15.36 ± 1.47
Righ Total Length	27.20 ± 2.58
Right Total Width	25.36 ± 3.32
Right Pad Length	12.77 ± 1.64
Right Pad Width	15.64 ± 1.33

4.1.1 RIGHT PAW MORPHOMETRICS VARIABLES

Some points deviate from the central cluster of data, particularly at the higher or lower ends of RightTotalLength. Thus, terms as outlier. However, a weak positive correlation between RightTotalLength and Catweight, and might be weaken statistical significance as in Figure 4.2.

There may be points in the top-right corner that suggest a decrease in Catweight with increased RightTotalWidth in Figure 4.3. These outlier points might generate a false impression of a negative trend that is not consistent with the rest of the data. Modifying for these outliers could render the relationship appear less strong, possibly supporting the insignificance observed in the regression analysis.

The examination of the correlation between RightPadLength and CatWeight illustrated in Figure 4.4 displays a wide range of data points, including several values at both the upper and lower extremeties. The lack of a definitive trend among these variables further suggests that RightPadLength does not show a significant correlation with CatWeight. This absence of connection seems authentic rather than affected by outliers, since their effect on this relationship is minimal. In general, RightPadLength is not a dependable indicator of CatWeight within this dataset.

The relationship between RightPadWidth and CatWeight in Figure 4.5 appears to be unreliable due to the presence of isolated points on the right side of the plot, which may act as outliers. These outliers could create a misleading impression of greater variance or spread in the data. If these outliers were removed or adjusted for, the correlation between RightPadWidth and CatWeight is strong suggeting that RightPadWidth has little effect on CatWeight. Therefore, based on the current analysis, RightPadWidth is a reliable predictor of CatWeight.

The relationship between RightPadWidth and CatWeight in Figure 4.5 The correlation between RightPadWidth and CatWeight would likely weaken further, reinforcing the conclusion that RightPadWidth has little to no effect on CatWeight. Therefore, based on the current analysis, RightPadWidth does not appear to be a reliable predictor of CatWeight.

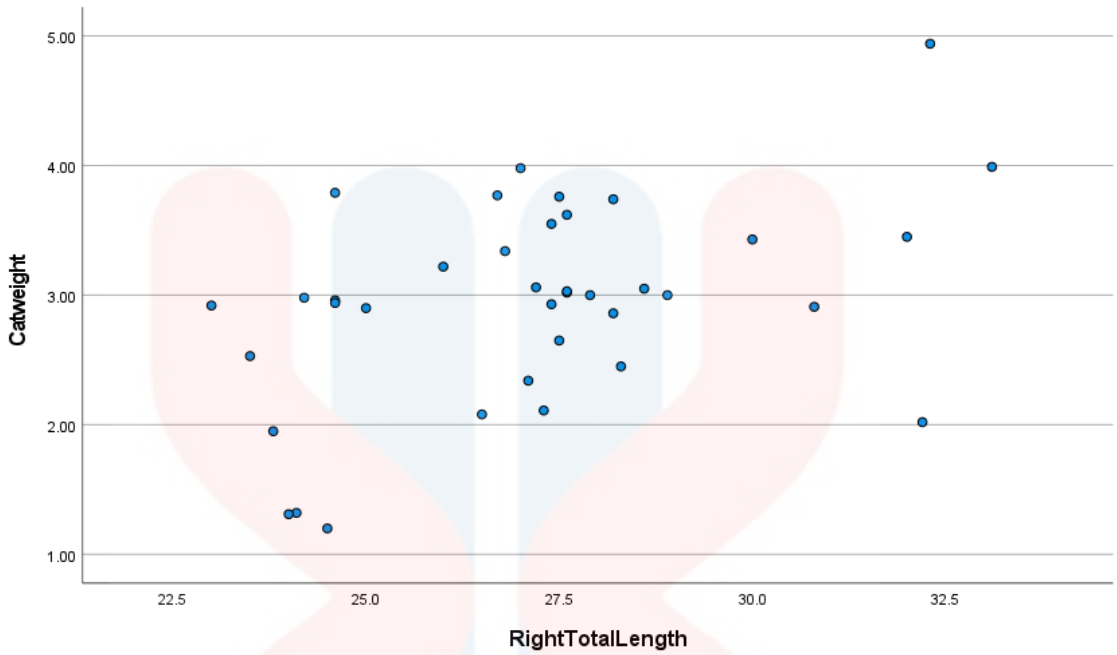

Figure 4.2. Scatter plot of Right Total Length

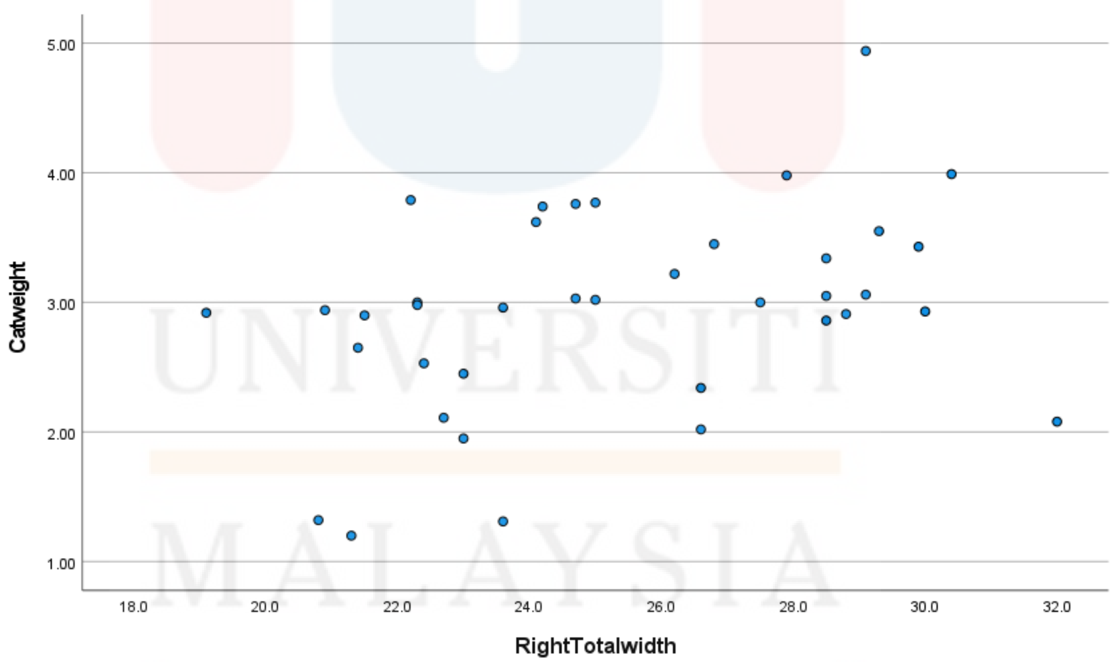

Figure 4.3. Scatter plot of Right Total Width

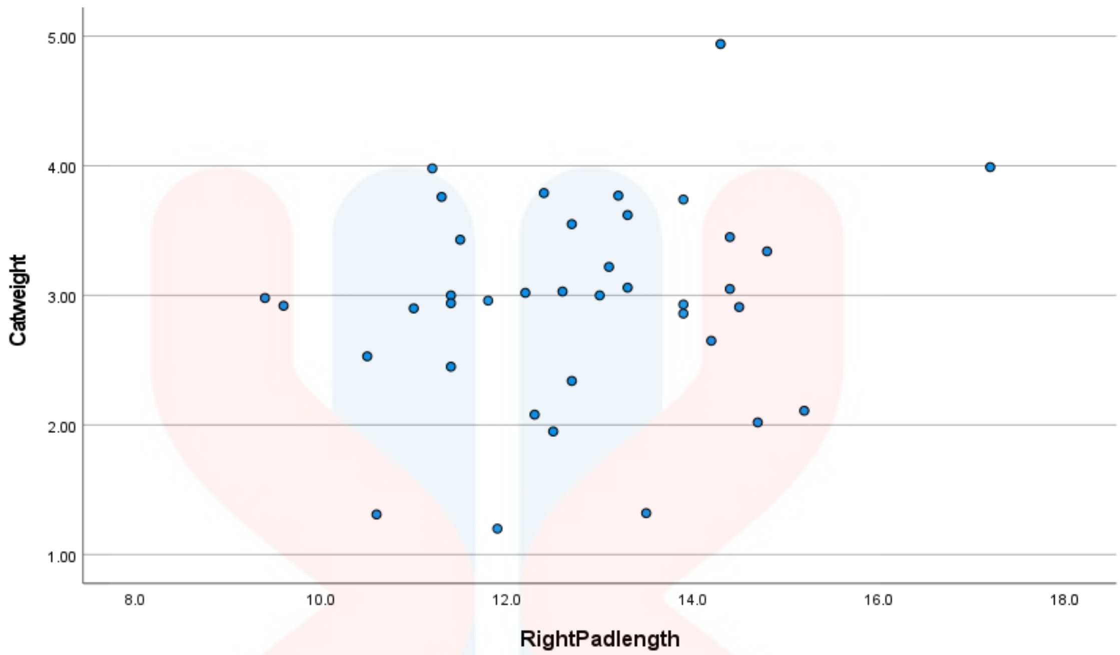

Figure 4.4. Scatter plot of Right Pad Length

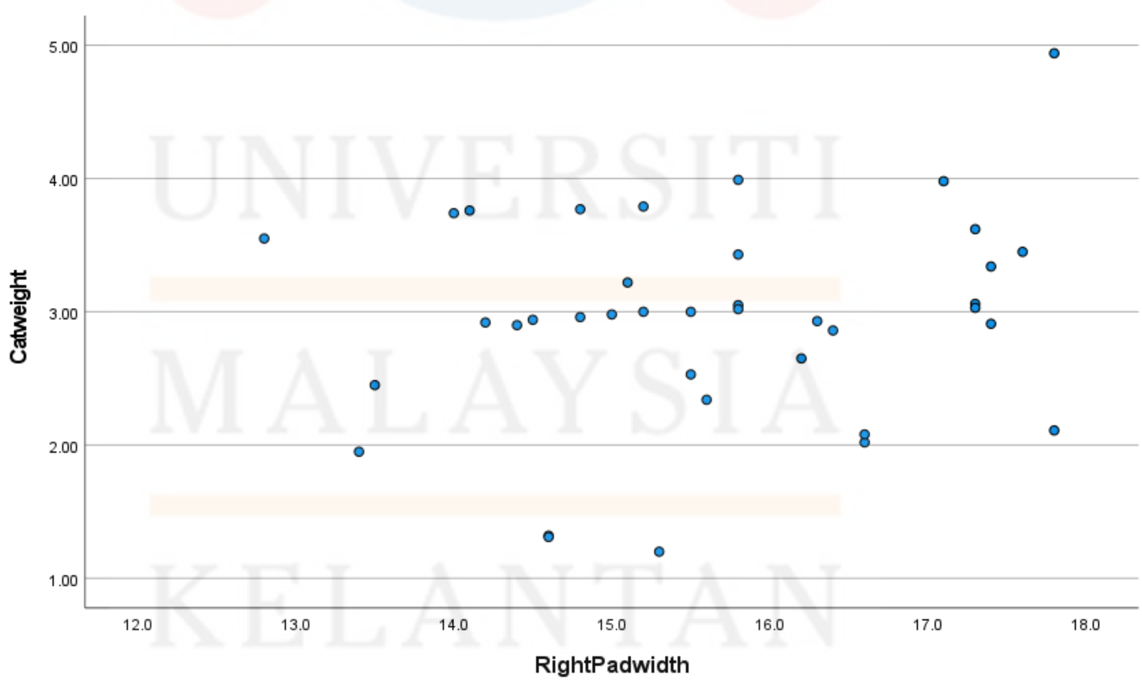

Figure 4.5. Scatter plot of Right Pad Width

4.1.2 LEFT PAW MORPHOMETRICS VARIABLES

There is a weak positive correlation between LeftTotalLength and CatWeight, where an increase in LeftTotalLength tends to coincide with an increase in CatWeight shown in Figure 4.6. However, the correlation is not strong, as the data points are widely spread out and do not follow a clear linear trend. Most data points are clustered around LeftTotalLength values between 20 and 30 and CatWeight values between 2 and 3.5, suggesting that the majority of observations fall within these ranges. A few outliers, with LeftTotalLength around 40 and higher CatWeight values close to 5, deviate from the main cluster, possibly representing exceptional cases that do not fit the general trend. This plot implies a weak relationship between the two variables, and the wide spread of data points suggests that other factors may influence CatWeight, or the correlation may simply not be strong. The presence of outliers further supports the notion that the relationship is inconsistent across all data points.

Figure 4.7 shows a minor positive correlation, indicating that Catweight may likely grow as LeftTotalWidth does. However, this trend is not strong, as the points are scattered with considerable spread. The points are somewhat clustered in the middle range of LeftTotalWidth (around 15 to 30), but there are some outliers.There are a few data points with low LeftTotalWidth and low Catweight and one with high LeftTotalWidth and high Catweight. A few points stand out, like the one with high LeftTotalWidth around 35–40 and another with high Catweight around 4.0. From visual inspection, the correlation does not seem very strong; it appears moderate at best. According to the previous correlation Table 2, there is a weak and non-significant association between LeftTotalWidth and Catweight of 0.199.

The data points for LeftPadlength and Catweight shown by Figure 4.8 are scattered without a clear linear trend, indicating no strong or consistent relationship between the two variables. A cluster of points is observed around a LeftPadlength of 12 to 14, but within this range, Catweight values vary widely, from below 2.0 to around 4.0. This spread suggests that variations in LeftPadlength do not reliably predict Catweight. A few data points with higher LeftPadlength values (above 16) and low or high Catweight values could be considered potential outliers, but they do not significantly alter the overall pattern of scattered points.

This lack of a visible trend is consistent with the regression analysis, where LeftPadlength was not statistically significant ($p = 0.263$), suggesting it has little to no effect on Catweight. The potential outliers do not appear to strongly influence the general pattern, and adjusting for them would likely not change the interpretation, as the data already shows no clear association. Overall, the plot supports the conclusion that LeftPadlength is not a significant predictor of Catweight. Changes in LeftPadlength do not correspond to changes in Catweight, indicating that this variable has minimal predictive value in this context.

There doesn’t seem to be a clear linear relationship between LeftPadwidth and Catweight in Figure 4.9. The data points are scattered, suggesting a weak strong correlation between these two variables. Most data points are clustered between 14 to 16 (LeftPadwidth) and 3 to 4 (Catweight). There’s an outlier around 18 for LeftPadwidth and 4 for Catweight, which is noticeably separated from the rest of the data. There is considerable variation in Catweight values across the LeftPadwidth range, with weights between 2.0 to 4.0 for most data points. However, the distribution appears more spread out at certain values, especially towards the right. In summary, while most of the data points are concentrated in a particular range, a few outliers are present, and there isn’t a clear pattern or strong relationship between the two variables.

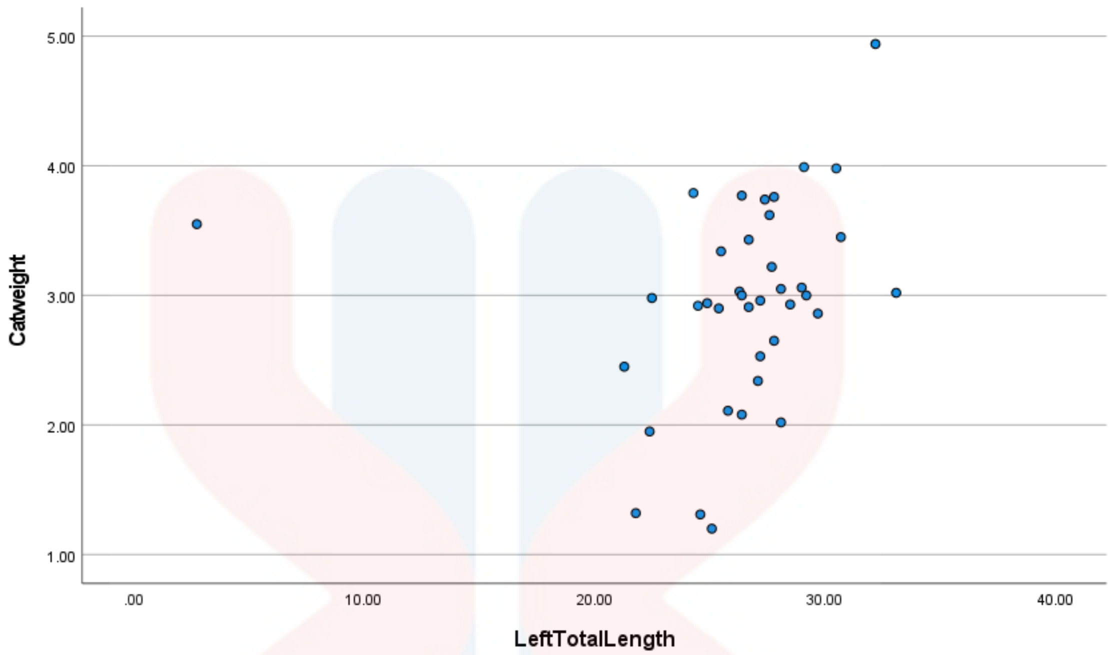

Figure 4.6. Scatter plot of Left Total Length

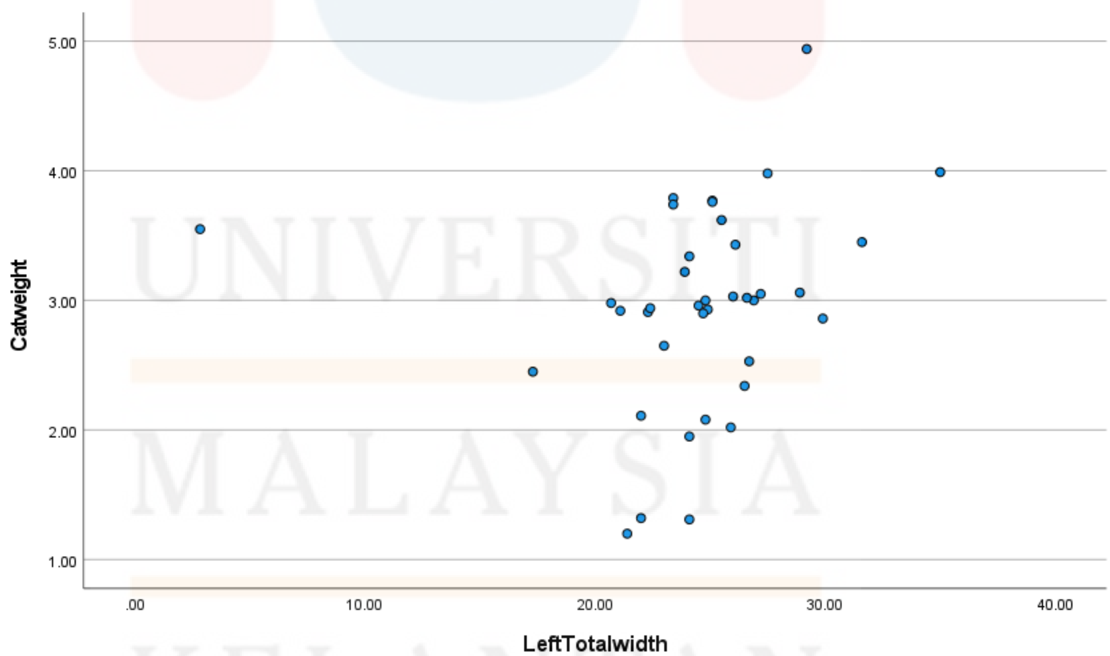

Figure 4.7. Scatter plot of Left Total Width

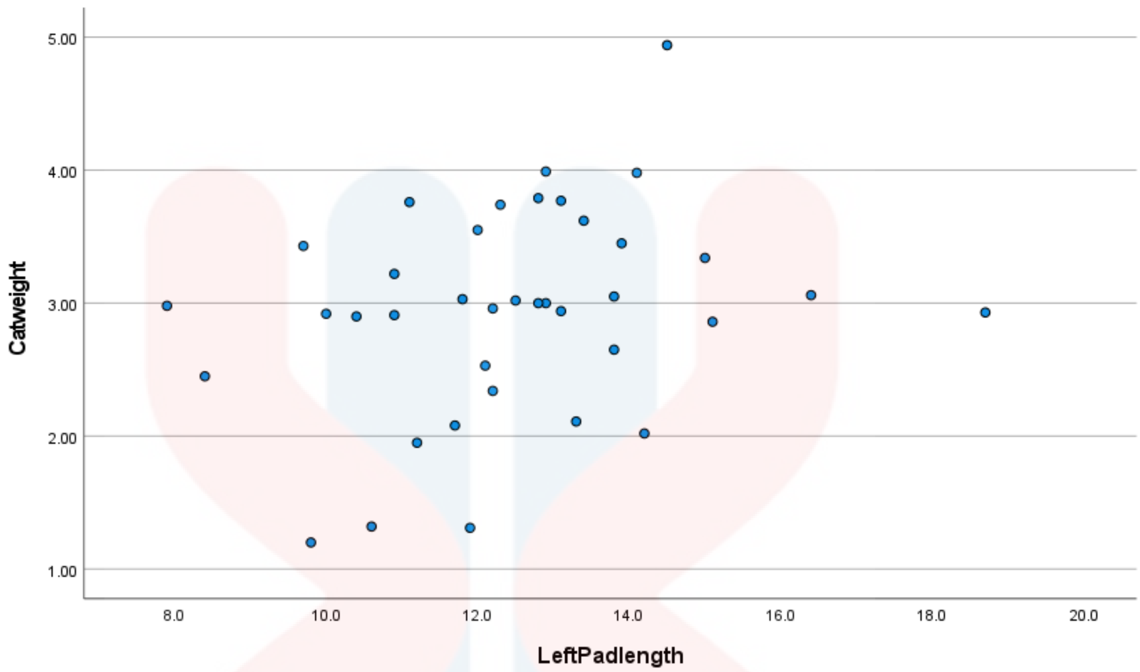

Figure 4.8. Scatter plot of Left Pad Length

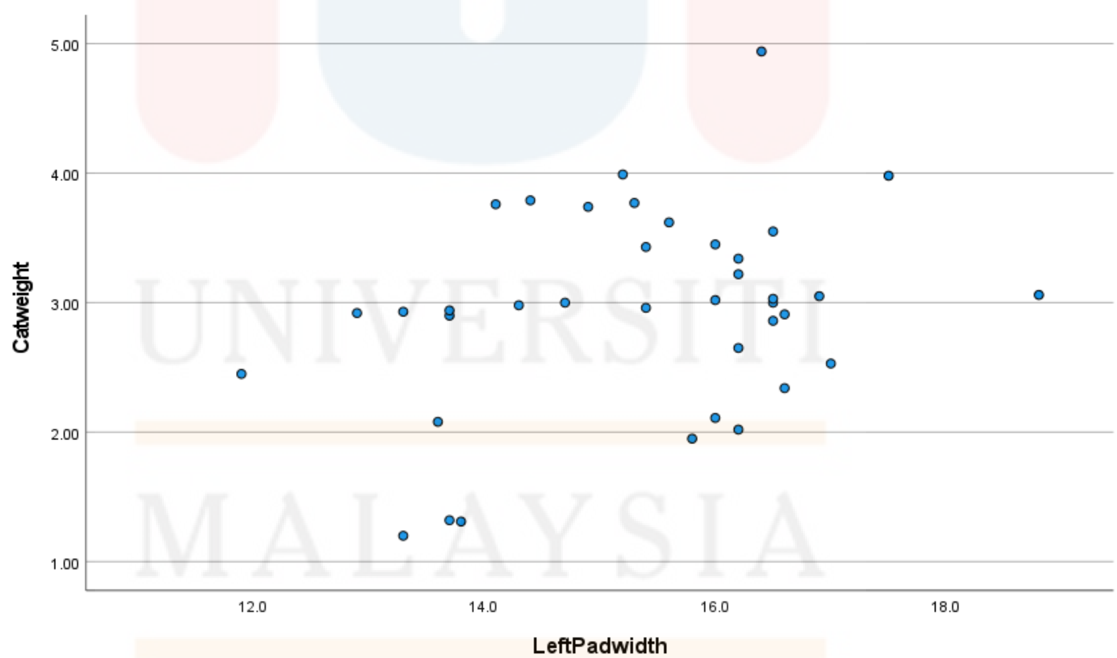

Figure 4.9. Scatter plot of Left Pad Width

4.1.3 CORRELATIONS BETWEEN CAT BODY WEIGHT AND PAW MORPHOMETRICS

RightTotalLength has a Pearson correlation of 0.449 with "Catweight" and a significance level of 0.005, indicating a moderately strong and statistically significant positive correlation based on Table 4.2. RightTotalWidth has a correlation of 0.364 with "Catweight" and a significance level of 0.025, also suggesting a moderate positive relationship that is statistically significant. Other variables such as "LeftTotalLength," "LeftTotalWidth," "LeftPadLength," "LeftPadWidth," "RightPadWidth," and "RightPadLength" exhibit weak correlations with "Catweight" (values closer to zero), and their significance levels are greater than 0.05, indicating that these correlations are not statistically significant. The statistically significant positive correlations indicate that when "Catweight" increases so do "RightTotalLength" and "RightTotalWidth". The absence of significant association for other metrics shows that changes in "Catweight" are not closely related to those factors.

Table 4.2. The correlations from paw morphometric of 38 samples

Correlations										
		CW	**LTL**	**LTW**	**LPL**	**LPW**	**RTL**	**RTW**	**RPL**	**RPW**
CW	**Pearson Correlation**	1	0.185	0.199	0.271	0.304	0.449**	0.364*	0.191	0.188
	Sig. (2-tailed)		0.267	0.231	0.100	0.064	0.005	0.25	0.250	0.257
	N	38	38	38	38	38	38	38	38	38

**Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at 0.05 level (2-tailed)

4.1.4 MULTIPLE REGRESSION

The regression model shows an R value of 0.564, signifying a moderate positive relationship between the predictors and the dependent variable, Catweight. The R Square (R^2) value of 0.318 indicates that around 31.8% of the variation in Catweight can be accounted for by the independent variables presented in the model in Table 2. The Adjusted R Square of 0.130 is lower, suggesting that some predictors might not be significantly influencing the model. The ANOVA Table 4 presents an F-statistic of 1.691 that assesses the overall model's fit, with a p-value of 0.143, exceeding the 0.05 significance level. This indicates that the model overall lacks statistical significance, and the independent variables do not successfully predict Catweight.

In terms of individual predictors, the Unstandardized Coefficients (B) represent the expected change in Catweight for a one-unit increase in each predictor, while the Standardized Coefficients (Beta) show the relative importance of each predictor. Among the predictors, only RightTotalLength is statistically significant with a p-value of 0.032, suggesting a positive relationship with Catweight. This indicates that as RightTotalLength increases, Catweight also tends to increase. The positive B value of 0.182 for RightTotalLength further supports this positive relationship. Other predictors do not show statistical significance, meaning they do not significantly contribute to predicting Catweight.

4.2 DISCUSSION

The study revealed that certain paw morphometric indices, such as RightTotalLength and RightTotalWidth, exhibit a statistically significant positive correlation with feline body weight, as indicated by the Pearson correlation coefficients of 0.449 and 0.364, respectively. These results suggest that larger paw dimensions are moderately associated with heavier cats. This finding aligns with existing literature that emphasizes the importance of morphological traits in estimating body metrics (McGreevy et al., 2008; Stella et al., 2009). The significant correlation found with RightTotalLength suggests that veterinarians could use this measurement as a quick assessment tool for estimating a cat's weight, particularly when direct weighing is impractical.

However, other variables, such as LeftPadLength and LeftPadWidth, did not show a significant correlation, indicating limited predictive value. This suggests these measurements do not provide reliable predictive value for estimating body weight. The presence of outliers in several plots also suggests that certain data points could skew interpretations of relationships, particularly in RightTotalWidth where a misleading negative trend was observed among outliers. However, their limited impact on the regression model suggests that these anomalies do not substantially affect the overall trends observed. Future studies could explore these outliers further to determine whether they represent distinct subpopulations or measurement artifacts.

The regression model explained 31.8% of the variability in body weight through these paw morphometric indices, with RightTotalLength emerging as a significant predictor (p =

0.032). This suggests that while paw dimensions provide insights into feline weight, additional factors may influence the outcomes.

Sharma et al. (2005) highlighted the effectiveness of using paw imprints to differentiate individual tigers and estimate size. Similar methodologies have been applied to species like black bears, emphasizing the broader applicability of this approach where it uses chest girth, and body length (Bartareau, 2016). This discrepancy may stem from the biological variability in cats, where factors such as muscle mass, fat distribution, and overall body condition affect weight independently of paw size (McGreevy et al., 2008; Buffington, 2002; German, 2006). Such findings highlight the complexity of relying solely on paw dimensions as predictors of body weight. This variability also raises the need to consider other morphological and physiological factors in future research to develop more accurate predictive models.

In wildlife management, paw morphometrics can serve as a non-invasive tool for monitoring populations where capturing animals is impractical or harmful. Thus this approach could be extended to wild felids for population health assessments. Under forensic application, the relationship between paw morphometrics and weight offers a new model for identifying animals in forensic investigations, particularly in crime scenes involving felines.

The data collection for this study is non-invasive where only simple tools used like ink pads and caliper minimize stress on the animals and make the method accessible. The development of a reliable model to estimate body weight from paw morphometrics could provide critical insights during forensic assessments, especially in contexts where direct measurements are not feasible (Bradshaw et al., 2012). Thus, the methodology is easy to implement in shelter, clinics and conservation settings.

The study was limited to a pilot sample of 38 cats, which may not reflect the complete variation in feline populations. Other studies have demonstrated that increasing the sample size and including additional variables—such as toe dimensions, stride length, or angle measurements—could enhance the accuracy of models predicting body weight in Sharma et al., (2005b). These additional morphometrics might provide better insights. The regression model explained only 31.8% of the weight variability, indicating the need for additional variables like age, sex, or breed.

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATIONS

In the future, this study might be improved by performing research with larger numbers of samples across diverse feline populations to improve the model's robustness. Advanced technique should be implemented to improve the accuracy of weight prediction such as the Footprint Identification Technique (FIT). The study should refer to longitudinal studies that examine the changes in paw morphometric and weight over time by considering the feline growth pattern and aging.

Veterinarians and academics might utilise these data to create relatively easy weight estimate tools for clinical and conservation applications. The technology might be used in forensic investigations to identify felines using pawprints found at crime scenes.

This study concludes that cat paw morphometrics has the potential to be a predictive method for body weight assessment. Among the studied characteristics, some indices, such as RightTotalLength, showed high predictive potential, implying a practical application in veterinary and zoological domains. However, not all morphometric variables showed strong correlations, indicating that further research is needed to refine and validate these findings across diverse populations. In general, the research offers significant understanding of feline morphometry and its possible application in determining weight.

APPENDIX

Figure 1. The cats collected was placed in carrier and cage

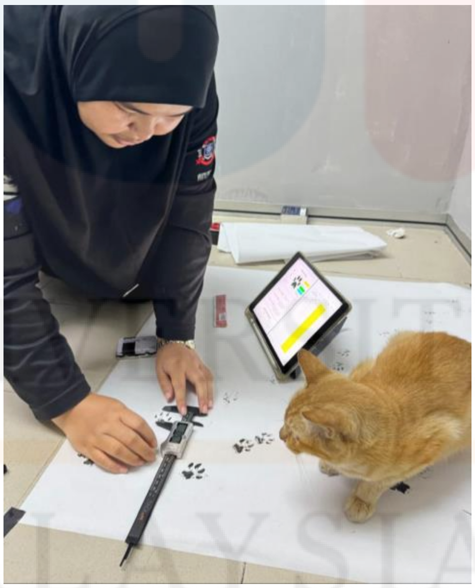

Figure 2. The Measurement of Paw Morphometrics from the imprint

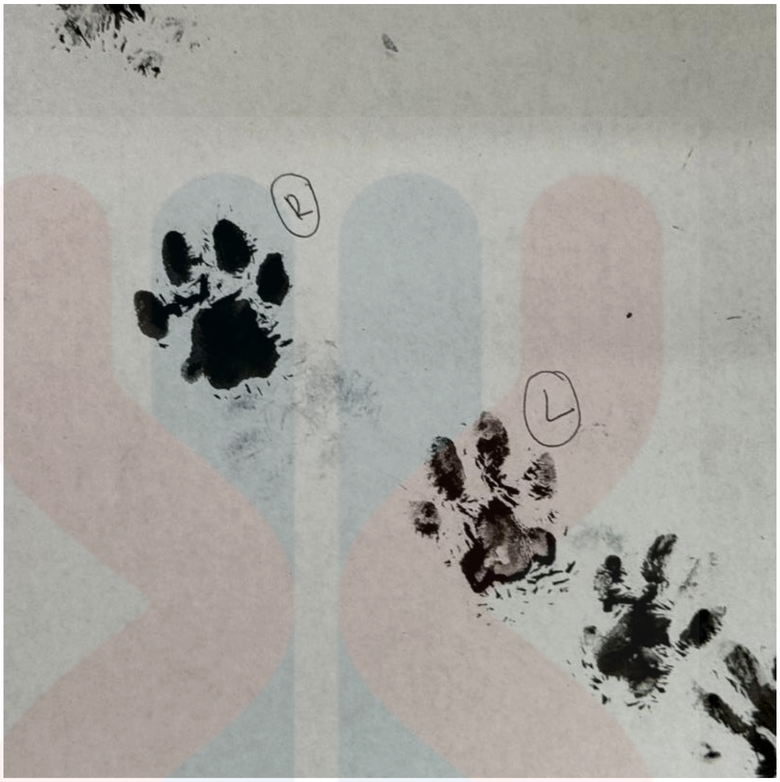

Figure 3. The Imprint of left and right hindlimb was labeled

Figure 4. The Paw Imprint measurement for Paw Morphometric indices Using Digital Vernier Caliper

Table 1. Correlation Analysis Between Body Weight and Paw Morphometrics

Correlations

		Catweight	LeftTotalLength	LeftTotalwidth	LeftPadlength	LeftPadwidth	RightTotalLength	RightPadwidth	RightPadlength	RightTotalwidth
Catweight	Pearson Correlation	1	.185	.199	.271	.304	.449**	.188	.191	.364*
	Sig. (2-tailed)		.267	.231	.100	.064	.005	.257	.250	.025
	N	38	38	38	38	38	38	38	38	38
LeftTotalLength	Pearson Correlation	.185	1	.896**	.360*	.218	.313	.588**	.205	.116
	Sig. (2-tailed)	.267		<.001	.026	.189	.056	<.001	.217	.487
	N	38	38	38	38	38	38	38	38	38
LeftTotalwidth	Pearson Correlation	.199	.896**	1	.375*	.277	.363*	.546**	.307	.229
	Sig. (2-tailed)	.231	<.001		.020	.092	.025	<.001	.061	.166
	N	38	38	38	38	38	38	38	38	38
LeftPadlength	Pearson Correlation	.271	.360*	.375*	1	.452**	.327*	.533**	.545**	.450**
	Sig. (2-tailed)	.100	.026	.020		.004	.045	<.001	<.001	.005
	N	38	38	38	38	38	38	38	38	38
LeftPadwidth	Pearson Correlation	.304	.218	.277	.452**	1	.335*	.512**	.357*	.394*
	Sig. (2-tailed)	.064	.189	.092	.004		.040	.001	.028	.014
	N	38	38	38	38	38	38	38	38	38
RightTotalLength	Pearson Correlation	.449**	.313	.363*	.327*	.335*	1	.489**	.682**	.640**
	Sig. (2-tailed)	.005	.056	.025	.045	.040		.002	<.001	<.001
	N	38	38	38	38	38	38	38	38	38
RightPadwidth	Pearson Correlation	.188	.588**	.546**	.533**	.512**	.489**	1	.485**	.427**
	Sig. (2-tailed)	.257	<.001	<.001	<.001	.001	.002		.002	.007
	N	38	38	38	38	38	38	38	38	38
RightPadlength	Pearson Correlation	.191	.205	.307	.545**	.357*	.682**	.485**	1	.498**
	Sig. (2-tailed)	.250	.217	.061	<.001	.028	<.001	.002		.001
	N	38	38	38	38	38	38	38	38	38
RightTotalwidth	Pearson Correlation	.364*	.116	.229	.450**	.394*	.640**	.427**	.498**	1
	Sig. (2-tailed)	.025	.487	.166	.005	.014	<.001	.007	.001	
	N	38	38	38	38	38	38	38	38	38

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 2. Model Summary showing the R value and R square

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.564[a]	.318	.130	.73468

a. Predictors: (Constant), LeftTotalwidth, RightTotalwidth, LeftPadwidth, RightPadlength, LeftPadlength, RightPadwidth, RightTotalLength, LeftTotalLength

Table 3. Comparison of Body Weight and Paw Morphometrics Using Analysis of Variance (ANOVA)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.300	8	.913	1.691	.143[b]
	Residual	15.653	29	.540		
	Total	22.953	37			

a. Dependent Variable: Catweight

b. Predictors: (Constant), LeftTotalwidth, RightTotalwidth, LeftPadwidth, RightPadlength, LeftPadlength, RightPadwidth, RightTotalLength, LeftTotalLength

Table 4. Coefficients Analysis Between Body Weight and Paw Morphometrics

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-1.174	1.712		-.686	.498	-4.676	2.328
	LeftTotalLength	.015	.068	.092	.225	.824	-.125	.155
	LeftPadlength	.094	.083	.251	1.142	.263	-.075	.264
	RightPadwidth	-.138	.144	-.234	-.959	.345	-.433	.157
	RightPadlength	-.167	.120	-.349	-1.387	.176	-.414	.079
	RightTotalwidth	.014	.054	.061	.266	.792	-.097	.126
	RightTotalLength	.182	.081	.594	2.251	.032	.017	.347
	LeftPadwidth	.107	.102	.200	1.050	.302	-.101	.315
	LeftTotalwidth	-.005	.061	-.028	-.074	.941	-.130	.121

a. Dependent Variable: Catweight

REFERENCES

Alibhai, S. K., Gu, J., Jewell, Z. C., Morgan, J., Liu, D., & Jiang, G. (2023). 'I know the tiger by his paw': A non-invasive footprint identification technique for monitoring individual Amur tigers (Panthera tigris altaica) in snow. Ecological Informatics, 73, 101947. https://doi.org/10.1016/j.ecoinf.2022.101947

Alibhai, S., Jewell, Z., & Evans, J. (2017). The challenge of monitoring elusive large carnivores: An accurate and cost-effective tool to identify and sex pumas (Puma concolor) from footprints. PloS One, 12(3), e0172065. https://doi.org/10.1371/journal.pone.0172065

Ashburner, J., & Ridgway, G. (2015). Tensor-Based Morphometry. In Elsevier eBooks (pp. 383–394). https://doi.org/10.1016/b978-0-12-397025-1.00309-2

Bartareau, T. M. (2016). Estimating the Live Body Weight of American Black Bears in Florida. *Journal of Fish and Wildlife Management*, *8*(1), 234–239. https://doi.org/10.3996/012016-jfwm-003

Boyd J. S., Paterson C., Schnorr M. and Schnorr B. (2001). A colour atlas of clinical anatomy of the dog and cat, 2nd ed. London, UK: Harcourt Publishers.

Bradshaw, J. W., Casey, R. A., & Brown, S. L. (2012). The Behaviour of the Domestic Cat. CABI.

Buffington, C. A. T. (2002). External and internal influences on obesity in cats. *Journal of the American Veterinary Medical Association*, *220*(7), 994-1002.

Chi, K. J., & Roth, V. L. (2010). Scaling and mechanics of carnivoran footpads reveal the principles of footpad design. Journal of the Royal Society Interface, 7(49), 1145–1155. https://doi.org/10.1098/rsif.2009.0556

Courcier, E. A., Thomson, R. M., Mellor, D. J., Yam, P. S., & Mellor, D. J. (2010). An epidemiological study of environmental factors associated with canine obesity. Journal of Small Animal Practice, 51(7), 362-367.

Dev, B., Tran, L., Jacob, S., & Granatosky, M. C. (2020). Feline Locomotion. In Springer eBooks (pp. 1–8). https://doi.org/10.1007/978-3-319-47829-6_1766-1

German, A. J. (2006). The growing problem of obesity in dogs and cats. *Journal of Nutrition*, *136*(7), 1940S-1946S.

Gu, J., Alibhai, S. K., Jewell, Z. C., Jiang, G., & Ma, J. (2014). Sex determination of Amur tigers (Panthera tigris altaica) from footprints in snow. Wildlife Society Bulletin, 38(3), 495–502. https://doi.org/10.1002/wsb.432

Hayward, G. D., Miquelle, D. G., Smirnov, E. N., & Chris Nations. (2002). Monitoring Amur Tiger Populations: Characteristics of Track Surveys in Snow. Wildlife Society Bulletin (1973-2006), 30(4), 1150–1159. http://www.jstor.org/stable/3784284

Hemmer, H. (1990). Domestication: The Decline of Environmental Appreciation. Cambridge University Press.

Isparta, S., Töre-Yargın, G., Wagner, S. C., Mundorf, A., Kul, B. C., Da Graça Pereira, G., Güntürkün, O., Ocklenburg, S., Freund, N., & Demirbas, Y. S. (2024). Measuring paw preferences in dogs, cats and rats: Design requirements and innovations in methodology. Laterality, 1–37. https://doi.org/10.1080/1357650x.2024.2341459

Karanth, K.U, Funston, & P.;Sanderson. (2010). Chapter Title: Many ways of Skinning a cat: Tools and techniques for studying wild felids. In Biology and Conservation of Wild Felids (p. Biol. Conservat. Wild Felids, 7 (2010), pp. 197–216).

Karanth, K. U., Gopalaswamy, A. M., Kumar, N. S., Vaidyanathan, S., Nichols, J. D., & MacKenzie, D. I. (2011). Monitoring carnivore populations at the landscape scale: occupancy modelling of tigers from sign surveys. Journal of Applied Ecology, 48(4), 1048–1056. https://doi.org/10.1111/j.1365-2664.2011.02002.x

Lascelles, B. D., & Thomson, M. (2004). Association of chronic pain and arthritis with performance in mobility, agility, and temperament in retired racing greyhounds. Journal of Veterinary Behavior, 3(3), 99-100.

McGreevy, P., Grassi, T. D., & Harman, A. M. (2008). A strong correlation exists between the distribution of retinal ganglion cells and nose length in the dog. Brain, Behavior and Evolution, 70(3), 218-226.

McGreevy, P. D., Thomson, P. C., Pride, C., Fawcett, A., Grassi, T., & Jones, B. (2008). Canine morphology and size estimation: Implications for welfare and breeding. *Animal Genetics*, *39*(5), 505–514.

Panwar HS. (1979). A note on tiger census technique based on pugmark tracings (Vols. 1063–1068–1068). Astronomical Society of the Pacific. Tigerpaper FAO;

Pontier, D., & Natoli, E. (1996). Male reproductive success in the domestic cat (Felis catus L.): a case history. Behavioral Ecology, 7(2), 194-201.

Riordan, P. 1998. Unsupervised recognition of individual tigers and snow leopards from their footprints. Animal Conservation 1:253–262.

Rowe, E. (2015). Canine and feline obesity: A growing epidemic. Veterinary Clinics of North America: Small Animal Practice, 45(5), 901-915. https://doi.org/10.1016/j.cvsm.2015.04.003

Safety Data Sheet according to Safe Work Australia document "Model Code of Practice : Preparation of safety data sheets for hazardous chemicals." (n.d.). Retrieved December 5, 2024, from https://www.accobrands.com.au/pdf/artline-stamp-pad-ink-esa-2n.pdf

Singh, R., Qureshi, Q., Sankar, K., Krausman, P. R., Joshi, B. D., & Goyal, S. P. (2014). Distinguishing sex of free-ranging tigers using pugmark measurements. Italian Journal of *Zoology/the Italian Journal of Zoology*, *81*(2), 304–309. https://doi.org/10.1080/11250003.2014.910276

Scarlett, J. M., Donoghue, S., Saidla, J., & Wills, J. (2002). Overweight cats: prevalence and risk factors. International Journal of Obesity, 26(4), 590-594.

Sharma, S., Y. Jhala, and V. B. Sawarkar. 2005. Identification of individual tigers (Panthera tigris) from their pugmarks. Journal of Zoology 267:9.

Stern, A. W., & Lamm, C. G. (2011). Utilization of Paw Prints for Species Identification in the Canidae Family. Journal of Forensic Sciences, 56(4), 1041–1043. https://doi.org/10.1111/j.1556-4029.2011.01768.x

Sunquist, M., & Sunquist, F. (2002). Wild Cats of the World. University of Chicago Press.