Theriogenology 190 (2022) 32–37

Contents lists available at ScienceDirect

Theriogenology

journal homepage: www.theriojournal.com

Birth weight in the feline species: Description and factors of variation in a large population of purebred kittens

Amélie Mugnier [a,*], Thibault Cane [a], Virginie Gaillard [b], Aurélien Grellet [a], Sylvie Chastant [a]

[a] NeoCare, Université de Toulouse, ENVT, Toulouse, France
[b] Royal Canin, 650 Avenue de la Petite Camargue, Aimargues, France

A R T I C L E I N F O

Article history:
Received 13 May 2022
Received in revised form
13 July 2022
Accepted 13 July 2022
Available online 19 July 2022

Keywords:
Kitten
Birth weight
Breed
Litter size

A B S T R A C T

Birth weight is one of the earliest health parameters with short (neonatal period) and long term (adulthood) implications for an individual. The present work was conducted on the domestic cat, with the objective of determining factors affecting kitten birth weight. Data voluntarily shared by 139 French breeders allowed building a large dataset of purebred kittens (n = 3,547) from 15 breeds. A linear mixed model with queen and cattery as random terms was used to investigate variation factors of kitten birth weight such as breed, litter size, season of birth, age of the queen, presence of stillborn in the litter, sex of the kitten. The most important factor was breed which explained 25% of the variation in birth weight observed in the study population. The five other parameters were also significant but explained only a small additional part of the variance (less than 3% each). Analyses showed that kitten birth weight increased with the age of the queen, was higher in males than females and in litters without stillbirth than in litters with at least one stillborn. In addition, lower birth weights were recorded in summer and autumn compared to other seasons, and birth weight values decreased as the number of kittens in the litter increased. In order to group feline breeds according to their average birth weights and litter sizes, a K-means algorithm was used to identify three clusters among the 15 breeds represented (Group 1: small litter sizes/low birth weights; Group 2: large litter sizes/intermediate birth weights; Group 3: large litter sizes/high birth weights). This study, based on a large dataset established at the national scale, provides reference values of feline birth weights for breeders and veterinarians. The next step could be to explore the relationship between birth weight and neonatal mortality to help identify neonates requiring specific care.

1. Introduction

Extreme birth weight, whether low or high, is identified as a major risk factor for perinatal and postnatal mortality in a large variety of species [1–4]. In addition to its impact on short-term morbidity and mortality, known for several decades, birth weight now appears to be related to health in adulthood [5–7]. As evidence of intrauterine growth, birth weight is the earliest indicator of newborn health in both the short and long terms. Thus, precise knowledge of normal birth weight values and the identification of influencing factors (foetal, maternal and environmental) are essential. Whereas such studies have been widely conducted in species such as pig, bovine and rabbit [8–11], there are few publications on birth weight in the feline species, despite the increasing number of purebred cats (from 15,842 registered pedigrees in France in 2003 to 52,395 in 2020 [12]). A search with the keywords “birth weight” and “kitten” in PubMed returned less than ten coherent results versus about 700 results when associated with “piglet”.

Available data estimate a normal kitten's birth weight at 100 ± 10 g (mean ± standard deviation, SD) [13,14] with adult body weights ranging from 3 to 10 kg depending on the breed [15]. In dogs, significant differences in birth weight were found not only between breeds but also between breeds with the same adult body weight [1]. The cat is characterised by less variation in size than the dog but the results obtained in the canine species suggest that feline birth weight should still be studied by breed.

The objectives of the present study were to describe birth

* Corresponding author.
E-mail address: amelie.mugnier@envt.fr (A. Mugnier).

https://doi.org/10.1016/j.theriogenology.2022.07.008

weight values in a large population of purebred kittens at the country scale and to explore birth weight variation factors.

2. Materials and methods

2.1. Study population

This study was based on data collected through a questionnaire administered to French purebred cat breeders from 2016 to 2020. It was distributed through articles in breeders' journals, using direct mailings and Facebook® messages during feline exhibitions and *via* various cat breed associations. The completion of the questionnaire was voluntary. Recorded data included information about the litter (date of birth, breed, litter size and the presence of stillborn in the litter), queen (identity and age at queening) and kittens (sex and birth weight). The birth weight was the first weight measured on site by the breeders (immediately or a few hours after birth) using their own scales. The information collected was transferred anonymously into an Excel table (Microsoft Corporation, Redmond, Washington, USA) for analysis with the breeders' approbation.

2.2. Data management and analysis

All statistical analyses were performed using R software version 4.1.2 [16].

Varieties of the same feline breed were grouped for the analyses: Abyssinian and Somali, Exotic and Persian, Russian Blue and Nebelung (short and long-haired version of each). Finally, Orientals were grouped with Mandarins (long-haired version), Siamese (colorpoint version) and Balinese (long-haired colorpoint version) [17,18]. The dataset used for the analysis excluded data from kittens born before 2000, from stillborn neonates and from kittens with no birth weight value provided. All rows containing missing values on the parameters of interest (see below) were also excluded. Finally, we only selected kittens belonging to a breed with more than 50 individuals following the sorting steps described previously.

After a description of the population studied, a linear mixed regression model was applied to identify potential relationships between the response variable (birth weight) and the various candidate explanatory variables: breed, sex, season of queening (meteorological seasons), presence of stillborn in the litter, litter size and age of queen. Cattery and queen were introduced as random terms to deal with the non-independence of kittens belonging to the same cattery and born from the same mother. Due to right-skewed distribution, the variable "Age of queen at delivery" was log-transformed. The model was built using the lmer function of lme4 package [19]. The normal probability plot of residuals and the plot of residuals *versus* predicted values were generated to check whether the assumptions of normality and homogeneity of variance had been fulfilled. The least square means of the factors were obtained from this mixed model and pairwise comparisons were performed using Tukey's Honest Significant Difference method. A value of $P < 0.05$ was considered statistically significant and statistical uncertainty was assessed by calculating 95% confidence intervals (95CI).

Finally, breeds were clustered based on their average birth weight and their average litter size using K-means cluster analysis. Data were standardized because the two variables had different scales and values (formula: $y \leftarrow (x - \text{mean}) \div \text{standard deviation}$). Euclidean distance was used as a distance metric. The suitable cluster number was determined using silhouette analysis [20]. Litter size and birth weight averages by cluster were compared using a one-way ANOVA followed by pairwise comparisons with Bonferroni correction.

3. Results

3.1. Population characteristics

Data from a total of 3,547 live-born kittens from 15 breeds contributed to the analyses (Table 1). In total, 932 litters born between 2016 and 2020 in 139 French catteries were included. The top-ten breeds owned in France were represented in the dataset [21]. The number of kittens included per breed ranged from 55 for Scottish/Highland to 582 for Maine Coon (median = 179). The global mean litter size was 4.2 (SD: 1.7) kittens and 82% of litters had no stillbirths. The mother's age at parturition ranged from 0.6 to 10.6 years (mean: 2.9; SD: 1.8 years). Sex ratio was calculated as 1.1 (1,894 males vs 1,653 females); 69% of the kittens included were born in spring or summer (2,453/3,547). Fig. 1 shows the birth weight distribution of the population studied, with values ranging from 41 g (a Persian/Exotic kitten) to 182 g (a Norwegian Forest Cat kitten; Fig. 1) with a mean at 101.9 g (SD: 18.8, Appendix A).

3.2. Factors influencing kitten birth weight

The results of the multivariable model revealed that all the factors considered had significant effects on kitten birth weight (Table 2). The fixed effects explained 33% of the variation in the birth weight observed in the study population and the full model (i.e., including random terms) explained 68% of this variation.

The most important parameter was breed which explained 25% of the variation in birth weight (partial $R^2 = 24.8$, 95CI: 21.5–30.2). Thus, significant differences between breeds were observed ($P < 0.001$) and Fig. 2 shows the least square means per breed and the results of pairwise comparisons.

The other five parameters (sex, litter size, season of birth, presence of stillborn in the litter and age of the queen) each also explained only a small part of the variation in birth weight (less than 3%). The least square means of the birth weight of male and female kittens were 98.8 g (95CI: 96.9–100.8) and 93.8 g (95CI: 91.9–95.8) respectively, while the least square means of the birth weight of kittens born in litters with at least one stillborn was 95.2 g (95CI: 92.9–97.5) versus 97.5 g (95CI: 95.6–99.4) for kittens from litters without stillborn. Birth weight increased with the age of the mother at queening ($P = 0.012$) but decreased with increasing litter size ($P < 0.001$). With every increase of one kitten in the litter, the birth weight decreased by 2.6 ± 0.2 g (estimate ± standard error). Finally, there was a significant effect of season of birth, with kittens born in summer or autumn weighing significantly less than those born in spring or winter (Fig. 3).

3.3. Breed clustering

Based on the optimal number of clusters defined by the silhouette method, 3 groups of feline breeds were identified by the K-means algorithm (Fig. 4). The three clusters were significantly different from each other in terms of both birth weight and litter size. The first cluster contained four breeds (Sphynx, Birman, Persian/Exotic and Abyssinian/Somali) and was characterised by smaller litter size (3.8 ± 1.1 kittens) and lower birth weight (93.0 ± 14.0 g) as compared with the two other groups ($P < 0.001$ for each pairwise comparison). The second group included 8 breeds (Balinese/Mandarin/Oriental/Siamese, Bengal, British, Egyptian Mau, Ragdoll, Russian Blue/Nebelung, Scottish/Highland and Siberian) and was intermediate in both litter size (5.0 ± 1.5 kittens) and birth weight (97.1 ± 16.2 g). Finally, Maine Coon, Norwegian Forest and Chartreux kittens defined a third group characterised by higher birth weights (113.8 ± 18.8 g) and intermediate litter sizes (5.2 ± 1.7 kittens) compared with the other groups. Fig. 5 shows the

Table 1
Description of the 15 feline breeds represented in the population studied.
*some catteries produced kittens from different breeds; **sex ratio: number of males/number of females.

Breed	Number of kittens included	% of the total population	Number of catteries*	Number of litters	Mean birth weight, grams (±SD)	Mean litter size (±SD)	Sex ratio**	Litters with at least one stillborn (%)
Abyssinian/Somali	179	5.0	5	59	96.2 ± 11.6	3.2 ± 1.2	1.3	6.8
Balinese/Mandarin/Oriental/Siamese	96	2.7	5	25	95.5 ± 13.2	4.3 ± 2.3	1.2	12.0
Bengal	102	2.9	7	28	88.6 ± 13.3	4.5 ± 1.6	1.1	17.9
Birman	276	7.8	20	87	96.2 ± 14.7	3.6 ± 1.2	0.9	17.2
British	458	12.9	14	117	97.5 ± 15.9	4.4 ± 1.5	1.2	21.4
Chartreux	106	3.0	2	27	117.6 ± 17.6	4.1 ± 1.1	1.1	7.4
Egyptian Mau	114	3.2	6	28	92.3 ± 21.5	4.6 ± 1.3	1.2	32.1
Maine Coon	582	16.4	32	143	118.7 ± 19.3	4.6 ± 2.1	1.3	23.8
Norwegian Forest	506	14.3	11	120	107.4 ± 16.5	4.5 ± 1.7	1.2	13.3
Persian/Exotic	214	6.0	12	72	87.0 ± 11.8	3.3 ± 1.2	1.0	16.7
Ragdoll	258	7.3	6	61	100.1 ± 14.1	4.6 ± 1.5	1.1	21.3
Russian Blue/Nebelung	94	2.7	3	20	91.7 ± 14.8	4.8 ± 1.7	1.1	5.0
Scottish/Highland	55	1.6	6	14	90.4 ± 12.0	4.4 ± 1.3	0.8	21.4
Siberian	427	12.0	13	106	100.7 ± 16.5	4.5 ± 1.7	1.2	20.8
Sphynx	80	2.3	8	25	90.8 ± 16.2	3.7 ± 1.7	0.9	24.0
Total	**3547**	**100**	**139**	**932**	**101.9 ± 18.8**	**4.2 ± 1.7**	**1.1**	**18.2**

comparison of the birth weight distribution of the three clusters.

4. Discussion

The kitten birth weight range (from 41 to 182 g) of this study was similar to that reported in the literature [13,22–24]. For the first time, the influence of various factors on birth weight was examined in a large population of purebred kittens (n = 3,547).

The present study confirmed the influence of breed on kitten birth weight [13,23,24]. As expected, the heaviest birth weights were measured in breeds of the largest adult size, namely Maine Coon and Norwegian Forest cat. Chartreux, despite being of average adult weight, was seen to have kittens whose birth weight was among the heaviest (Table 1, Appendix A). Such a discrepancy between birth and adult weights was also observed when comparing Birman and Oriental kittens (Table 1, Appendix A), thus with similar birth weights whereas their adult weight varied considerably [15].

Intra-uterine capacity could be a factor in explaining these breed differences as it can have an impact on the individual foetal growth of kittens and consequently on their birth weight. Indeed, in placental mammals, the birth weight of new-borns decreases as the litter size increases [25]. The average litter sizes observed in the present study were consistent with those reported in previous studies [24,26–28] and the present study confirmed the negative relationship between litter size and birth weight in the feline species [13,22]. Nevertheless, the relationship is complex, as evidenced by the K-means algorithm which identified three groups of breeds with significantly different birth weights and litter sizes (Fig. 4). Thus, differences in birth weight between breeds cannot be explained by differences in litter size only. These results suggest differences in growth kinetics within the feline species, with proportionally different intrauterine and postnatal growths, depending on the breed. The comparison of intrauterine growth through birth weight between breeds would be completed interestingly by a comparison of the postnatal growth of the various feline breeds. Moreover, in this work, data were asked from breeders over a restricted period of time (5 years from 2016 to 2020): a historical perspective, comparing more ancient birth weights within breeds, would allow show whether any modification occurs, especially when analysed with regard to the parallel potential modification of adult weight.

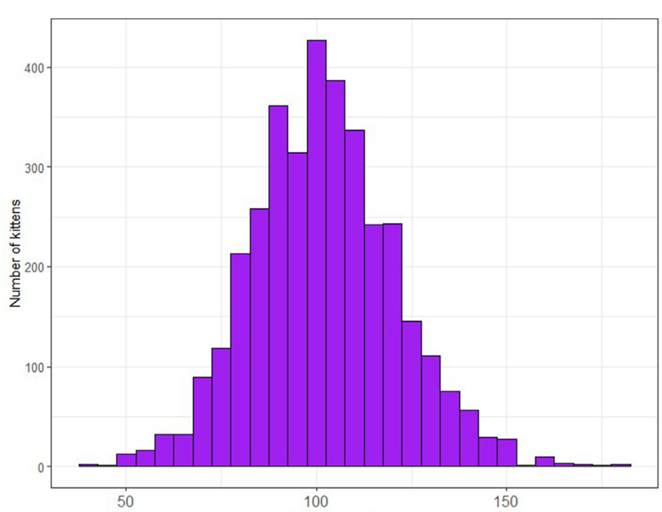


Fig. 1. Birth weight distribution (n = 3,547 kittens).

Concerning the other factors assessed, first, as in the adult cat [15], kittens exhibited marked sexual dimorphism at birth, with males born approximately 5% heavier that females (Table 2). This result is consistent with a previous study conducted on 279 Maine Coon kittens [22]. Naturally, the reproductive activity in the feline species is seasonal (occurring in spring and summer in the Northern hemisphere). Thus, the influence of season on birth weight was assessed in the present work. Birth weights were observed to be higher in spring and winter compared with summer and autumn. The season of birth is known to influence birth weight in various species, seasonal (lambs born heavier in spring [29]) or not (human infants born heavier in spring [30] and guinea pig pups heavier in autumn and winter [31]), but not in pigs (non-seasonal) [32]. In rabbits, heat stress is responsible for birth weight decrease in summer compared with winter [10,33] whereas in ruminants, the photoperiod together with nutrition variations could be involved [9,34]. To the best of our knowledge, no other study has tested the influence of season on birth weight in the feline species. Since most purebred cats are managed indoors with no modification of their diet with season, an influence of photoperiod on foetal growth could be hypothesized and would require further investigations. In the present study, the age of the dam was positively correlated with the birth weight of kittens but this relationship will need to be

Table 2
Linear mixed regression model analysis for kitten birth weight (n = 3,547 kittens). Cattery and queen were included in the model as random-effects. Coeff, coefficient; SE, standard error.

Parameter		Coeff.	SE	p
	Intercept	99.865	3.565	
Breed	Abyssinian/Somali			<0.001
	Balinese/Mandarin/ Oriental/Siamese	2.313	5.138	
	Bengal	−3.762	5.110	
	Birman	1.648	3.977	
	British	2.914	4.126	
	Chartreux	19.124	5.217	
	Egyptian Mau	1.837	5.161	
	Maine Coon	29.585	3.787	
	Norwegian Forest	14.224	4.129	
	Persian/Exotic	−8.634	4.359	
	Ragdoll	9.271	4.731	
	Russian Blue/Nebelung	3.157	6.192	
	Scottish/Highland	0.363	5.537	
	Siberian	7.802	4.210	
	Sphynx	−3.123	4.987	
Litter size		−2.610	0.214	<0.001
Sex	Female			<0.001
	Male	5.000	0.401	
Season of birth	Autumn			<0.001
	Spring	2.827	0.725	
	Summer	−0.682	0.784	
	Winter	2.910	1.051	
Presence of stillborn in the litter	No			0.006
	Yes	−2.297	0.833	
log(Age of queen)		1.465	0.582	0.012

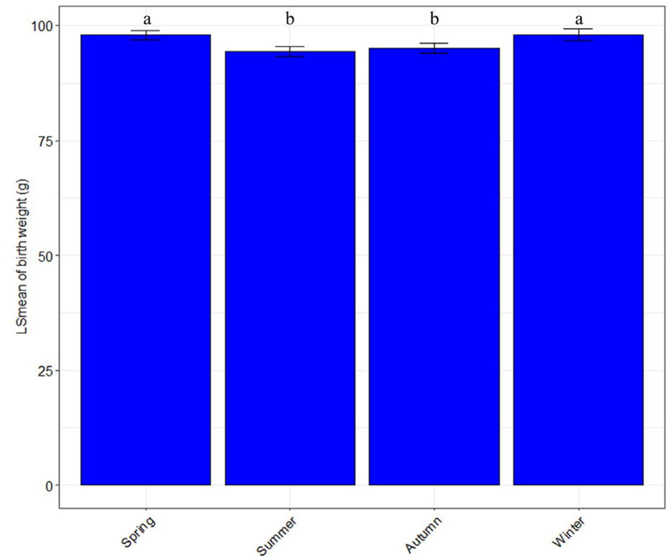


Fig. 3. Least square mean of birth weight according to season of birth.
Any two seasons receiving the same letter at the top of the bar were not significantly different, as per Tukey's HSD method. The error bars represent the standard error of the least square mean values.

studied further. Indeed, in this study population, 75% of the kittens were born to queens under the age of 4 years. A further study could be conducted by specifically recruiting cats that give birth at older ages.

The data collection performed to build the dataset led to the inclusion of 15 feline breeds out of the 71 officially registered. The 10 most represented breeds in France belonged to the study population [12]. To the best of our knowledge, this study was based on one of the largest populations of cats in field conditions (n = 3,547 live-born kittens). However, the data was collected from volunteer breeders and such sampling may lead to selection bias. For example, breeders who are more sensitive to health issues and wish to better understand them could be over-represented. Another bias comes from the different birth weight measurement conditions, including different scales and non-standardized delays after birth (immediately or after a few hours). These drawbacks are inherent in multisite data collection and the retrospective nature of the study.

Not all the parameters influencing birth weight can be discussed in this study. Further investigation and the collection of new data on other potential factors influencing birth weight described in other species (e.g., queen nutrition, weight of queen and tomcat, etc.) are warranted. Moreover, additional data recording would be necessary to collect data on the missing breeds and, if conducted

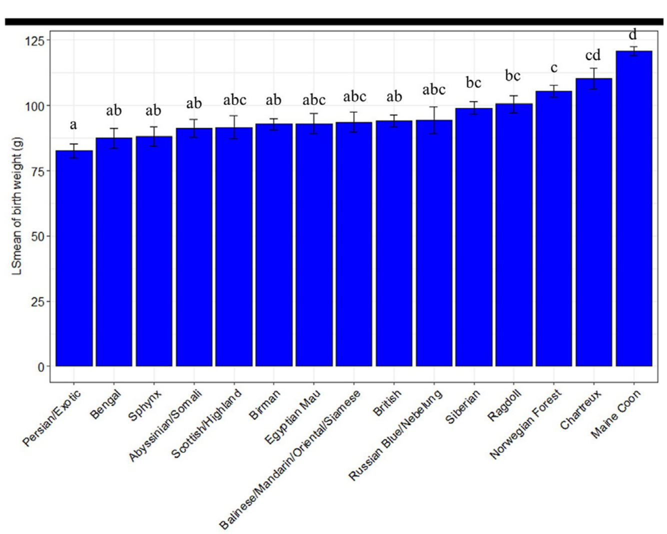


Fig. 2. Least square mean of birth weight for the 15 breeds represented.
Any two breeds receiving the same letter at the top of the bar were not significantly different as per Tukey's HSD method. The error bars represent the standard error of the least square mean values. Number of kittens included for each breed is detailed in Table 1.

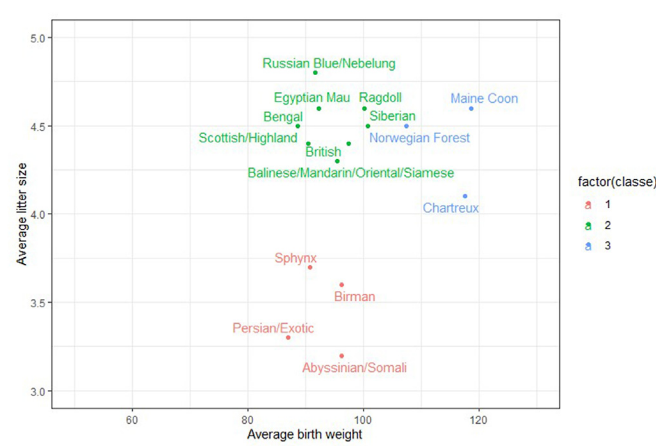


Fig. 4. Representation of the three clusters of feline breeds identified by K-means algorithm depending on their average birth weight and their average litter size.
Cluster 1 (in red): small litter sizes and average birth weights (n = 4 breeds),
Cluster 2 (in green): average litter sizes and average birth weights (n = 8 breeds),
Cluster 3 (in blue): average litter sizes and high birth weights (n = 3 breeds).

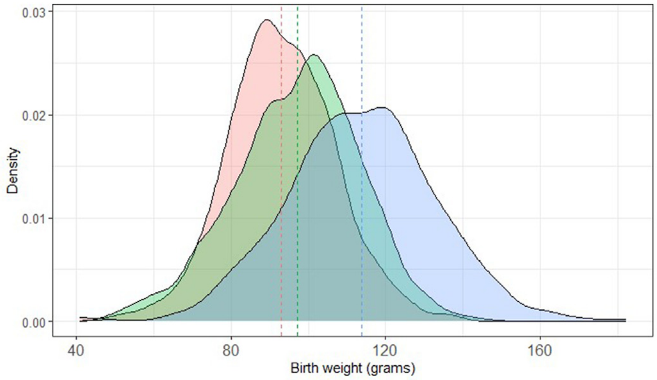


Fig. 5. Distributions of birth weights in the three clusters of breeds identified in feline species.
Cluster 1 (in red): Abyssinian/Somali, Birman, Persian/exotic and Sphynx.
Cluster 2 (in green): Balinese/Mandarin/Oriental/Siamese, Bengal, British, Egyptian Mau, Ragdoll, Russian Blue/Nebelung, Siberian and Scottish/Highland.
Cluster 3 (in blue): Chartreux, Maine Coon and Norwegian Forest

internationally, would also allow exploring whether birth weight diverges according to country, lineages, management and selection process. In the near future it will also be necessary to explore the consequences of birth weight on the health of kittens and cats in a large population. Indeed, as in dogs [1,35], birth weight, which is an easily measurable criterion, would help breeders and veterinarians to identify early kittens that need special attention and care.

5. Conclusions

In conclusion, this large-scale epidemiological study provided knowledge on birth weight in purebred kittens. It described the birth weight values and the factors of variation, the most important of which was found to be breed. This result suggests that further analysis should not be conducted at the species level but at the breed or cluster level. The next step could be to study the relationship between birth weight and kitten health.

CRediT authorship contribution statement

Amélie Mugnier: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Resources, Writing – original draft, Writing – review & editing, Visualization. **Thibault Cane:** Formal analysis, Data curation, Resources, Writing – original draft. **Virginie Gaillard:** Investigation, Funding acquisition, Writing – review & editing. **Aurélien Grellet:** Conceptualization, Investigation, Writing – review & editing. **Sylvie Chastant:** Conceptualization, Methodology, Investigation, Resources, Writing – review & editing, Supervision, Project administration, Funding acquisition.

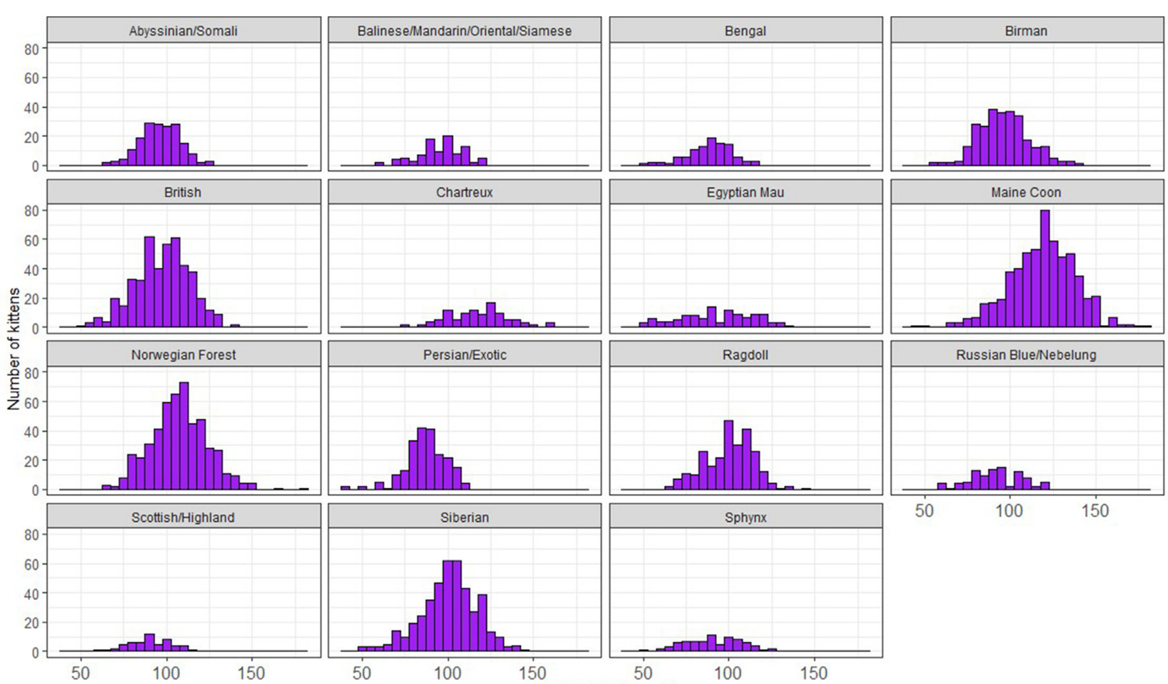
Declaration of competing interest

VG is employed by Royal Canin, which produces products and services for cat breeding. She participated in the investigation and in the reviewing of the paper but her commercial affiliation does not interfere with the full and objective presentation of the results of this work. The other authors have no conflicts of interest to declare.

Acknowledgements

The authors would like to thank Carine Cisek, Betty Duc, Florine Guiraud, Camille Lecourtois and Louise Ribard for their help with data collection and entry. The authors also thank all the breeders who cooperated in the study.

Appendix A. Birth weight distribution by feline breed



References

[1] Mugnier A, Mila H, Guiraud F, Brévaux J, Lecarpentier M, Martinez C, et al. Birth weight as a risk factor for neonatal mortality: breed-specific approach to identify at-risk puppies. Prev Vet Med 2019;171:104746. https://doi.org/10.1016/j.prevetmed.2019.104746.

[2] Johanson JM, Berger PJ. Birth weight as a predictor of calving ease and perinatal mortality in holstein cattle. J Dairy Sci 2003;86:3745–55. https://doi.org/10.3168/jds.S0022-0302(03)73981-2.

[3] Fix JS, Cassady JP, Holl JW, Herring WO, Culbertson MS, See MT. Effect of piglet birth weight on survival and quality of commercial market swine. Livest Sci 2010;132:98–106. https://doi.org/10.1016/j.livsci.2010.05.007.

[4] Wu G, Bazer FW, Wallace JM, Spencer TE. Intrauterine growth retardation: implications for the animal sciences. J Anim Sci 2006;84:2316–37. https://doi.org/10.2527/jas.2006-156.

[5] Godfrey KM, Barker DJ. Fetal programming and adult health. Publ Health Nutr 2001;4:611–24. https://doi.org/10.1079/PHN2001145.

[6] Barker DJP. The origins of the developmental origins theory. J Intern Med 2007;261:412–7. https://doi.org/10.1111/j.1365-2796.2007.01809.x.

[7] Gluckman PD, Hanson MA, Morton SMB, Pinal CS. Life-long echoes – a critical analysis of the developmental origins of adult disease model. Neonatology 2005;87:127–39. https://doi.org/10.1159/000082311.

[8] Assan N. Various factors influencing birth weight in animal production. Sci J Rev 2013;2:156–75.

[9] Holland MD, Odde KG. Factors affecting calf birth weight: a review. Theriogenology 1992;38:769–98. https://doi.org/10.1016/0093-691X(92)90155-K.

[10] Szendrő Zs, Cullere M, Atkári T, Zotte AD. The birth weight of rabbits: influencing factors and effect on behavioural, productive and reproductive traits: a review. Livest Sci 2019;230:103841. https://doi.org/10.1016/j.livsci.2019.103841.

[11] Čechová M. Analysis of some factors influencing the birth weight of piglets. Slovak J Anim Sci 2006;39:139–44.

[12] LOOF - Statistiques n.d. https://www.loof.asso.fr/stats/intro_stats.php#nais. [Accessed 16 December 2021].

[13] Gatel L, Rosset E, Chalvet-Monfray K, Buff S, Rault DN. Relationships between fetal biometry, maternal factors and birth weight of purebred domestic cat kittens. Theriogenology 2011;76:1716–22. https://doi.org/10.1016/j.theriogenology.2011.07.003.

[14] Lawler DF. Neonatal and pediatric care of the puppy and kitten. Theriogenology 2008;70:384–92. https://doi.org/10.1016/j.theriogenology.2008.04.019.

[15] Kienzle E, Moik K. A pilot study of the body weight of pure-bred client-owned adult cats. Br J Nutr 2011;106:S113–5. https://doi.org/10.1017/S0007114511001802.

[16] Core Team R. R: a language and environment for statistical computing. R Found Stat Comput Vienna Austria; 2018.

[17] Lipinski MJ, Froenicke L, Baysac KC, Billings NC, Leutenegger CM, Levy AM, et al. The ascent of cat breeds: genetic evaluations of breeds and worldwide random-bred populations. Genomics 2008;91:12–21. https://doi.org/10.1016/j.ygeno.2007.10.009.

[18] Menotti-Raymond M, David VA, Pflueger SM, Lindblad-Toh K, Wade CM, O'Brien SJ, et al. Patterns of molecular genetic variation among cat breeds. Genomics 2008;91:1–11. https://doi.org/10.1016/j.ygeno.2007.08.008.

[19] Bates D, Mächler M, Bolker B, Walker S. Fitting linear mixed-effects models using lme4. J Stat Software 2015;67:1–48. https://doi.org/10.18637/jss.v067.i01.

[20] Kassambara A, Mundt F. factoextra: extract and visualize the results of multivariate data analyses. R Package Version 107 n.d, https://CRAN.R-project.org/package=factoextra.

[21] LOOF - Races/annee n.d. https://www.loof.asso.fr/stats/recap.php?complet&ordre=total#table. [Accessed 13 December 2021].

[22] Socha P, Lengling R, Bonecka J, Janowski T. Obstetric and newborn parameters in the Maine Coon cats. Pol J Vet Sci 2019;22:439–43. https://doi.org/10.24425/pjvs.2019.129303.

[23] Moik K, Kienzle E. Birth weight and postnatal growth of pure-bred kittens. Br J Nutr 2011;106:S32–4. https://doi.org/10.1017/S0007114511003333.

[24] Sparkes AH, Rogers K, Henley WE, Gunn-Moore DA, May JM, Gruffydd-Jones TJ, et al. A questionnaire-based study of gestation, parturition and neonatal mortality in pedigree breeding cats in the UK. J Feline Med Surg 2006;8:145–57. https://doi.org/10.1016/j.jfms.2005.10.003.

[25] Gardner DS, Buttery PJ, Daniel Z, Symonds ME. Factors affecting birth weight in sheep: maternal environment. Reproduction 2007;133:297–307. https://doi.org/10.1530/REP-06-0042.

[26] Fournier A, Masson M, Corbière F, Mila H, Mariani C, Grellet A, et al. Epidemiological analysis of reproductive performances and kitten mortality rates in 5,303 purebred queens of 45 different breeds and 28,065 kittens in France. Reprod Domest Anim 2017;52:153–7. https://doi.org/10.1111/rda.12844.

[27] Ström Holst B, Frössling J. The Swedish breeding cat: population description, infectious diseases and reproductive performance evaluated by a questionnaire. J Feline Med Surg 2009;11:793–802. https://doi.org/10.1016/j.jfms.2009.01.008.

[28] Romagnoli S, Bensaia C, Ferré-Dolcet L, Sontas HB, Stelletta C. Fertility parameters and reproductive management of Norwegian Forest Cats, Maine Coon, Persian and Bengal cats raised in Italy: a questionnaire-based study. J Feline Med Surg 2019;21:1188–97. https://doi.org/10.1177/1098612X18824181.

[29] Chniter M, Hammadi M, Khorchani T, Krit R, Lahsoumi B, Sassi MB, et al. Phenotypic and seasonal factors influence birth weight, growth rate and lamb mortality in D'man sheep maintained under intensive management in Tunisian oases. Small Rumin Res 2011;99:166–70. https://doi.org/10.1016/j.smallrumres.2011.03.046.

[30] McGrath JJ, Barnett AG, Eyles DW. The association between birth weight, season of birth and latitude. Ann Hum Biol 2005;32:547–59. https://doi.org/10.1080/03014460500154699.

[31] Czarnecki R, Adamski M. Factors influencing litter size and birthweight in the newborn long-haired Guinea pigs (*Cavia aperea f. porcellus*). J Appl Anim Res 2016;44:71–6. https://doi.org/10.1080/09712119.2015.1013961.

[32] Chimonyo M, Dzama K, Bhebhe E. Genetic determination of individual birth weight, litter weight and litter size in Mukota pigs. Livest Sci 2006;105:69–77. https://doi.org/10.1016/j.livsci.2006.04.034.

[33] Marai IFM, Habeeb AAM, Gad AE. Rabbits' productive, reproductive and physiological performance traits as affected by heat stress: a review. Livest Prod Sci 2002;78:71–90. https://doi.org/10.1016/S0301-6226(02)00091-X.

[34] Koch RM, Clark RT. Influence of sex, season of birth and age of dam on economic traits in range beef cattle. J Anim Sci 1955;14:386–97. https://doi.org/10.2527/jas1955.142386x.

[35] Mugnier A, Morin A, Cellard F, Devaux L, Delmas M, Adib-Lesaux A, et al. Association between birth weight and risk of overweight at adulthood in Labrador dogs. PLoS One 2020;15:e0243820. https://doi.org/10.1371/journal.pone.0243820.