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BIOLOGY

Radiographic pelvimetry in the *Tamandua tetradactyla*

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ABSTRACT: The pelvis, formed by the ilium, ischium and pubis, forms the coxal, which is the largest of the flat bones of the skeleton, with an important role in the physiology of birth. Vastly studied in domestic animals, there is still much to be investigated regarding the anatomical classification in wild animals, mainly aiming to improve the understanding of the reproductive management of the species. *Tamandua tetradactyla* is one of these species in which morphological studies are still scarce, especially when it comes to reproductive aspects. In this context, we carried out the pelvimetry of *T. tetradactyla* using radiographic images to anatomically and obstetrically classify the pelvis of this species, classifying it as dolicopelvic, with evidence of homoscedasticity of the samples. Verification of the existence of a relationship between the variables studied by the statistical method of Pearson coefficients showed positive correlations of high intensity for the diameters studied ($P < 0.01$). Thus, we believed that our findings may support future reproductive studies in this species.
Key words: obstetrics, pelvic classification, anteater, X-ray, Xenarthra.

Pelvimetria radiográfica em *Tamandua tetradactyla*

RESUMO: A pelve, constituída pelo ílio, ísquio e púbis, forma o coxal, sendo este o maior dos ossos planos constituintes do esqueleto, com importante papel na fisiologia do parto. Vastamente estudada em animais domésticos, ainda existe muito à se investigar quanto a classificação anatômica nos animais selvagens, visando principalmente melhorar a compreensão do manejo reprodutivo das espécies. *Tamandua tetradactyla* é uma dessas espécies em que estudos morfológicos ainda são escassos, principalmente quando se trata de aspectos reprodutivos. Neste contexto realizamos a pelvimetria do *T. tetradactyla* por meio de imagens radiográficas para classificar anato-obstetricamente a pelve desta espécie classificando-a como dolicopélvica, sendo evidenciada homoscedasticidade das amostras. A verificação da existência de relação entre as variáveis estudadas pelo método estatístico dos coeficientes de Pearson mostrou correlação positivas de alta intensidade para os diâmetros estudados ($P < 0,01$). Assim, acreditamos que nossos achados poderão subsidiar futuros estudos reprodutivos nesta espécie.
Palavras-chave: obstetrícia, classificação pélvica, tamanduá-mirim, raios X, Xenarthra.

INTRODUCTION

Belonging to the family Myrmecophagidae, Superorder Xenarthra and, Order Pilosa, the *Tamandua tetradactyla* is a eutherian mammal native to South America and popularly known as the lesser anteater. It has a characteristic yellowish coat on the head, limbs, and cranial part of the back and a black body, alluding to a vest (MIRANDA, 2012; MIRANDA, 2014). Geographically, it is distributed east of the Andes throughout Venezuela to northern Argentina, including Brazil. It living in all biomes (SUPERINA et al., 2010; MIRANDA, 2014).

In general, the literature on the species usually addresses behavioral issues and management (MCDONALD et al., 2008), reproductive (HOSSOTANI et al., 2016), and anatomical studies (ROSSI et al, 2011; PINHEIRO et al., 2012; CARDOSO et al., 2013; MACEDO et al., 2013; PINHEIRO et al., 2014a; PINHEIRO et al., 2014b; PINHEIRO et al., 2014c; PINHEIRO et al., 2016; AZEVEDO, et al., 2018).

Among the anatomical approaches, we highlighted the pelvis. Radiographic pelvimetry studies of this bony framework can reveal essential data for reproductive management (VALLE et al., 2006).

In domestic mammals, the pelvis is almost circular in females but more oval in males, and the tip is turned towards the ventral direction

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forming the pelvic floor. Using the distance between bony landmarks allows the definition of various diameters of the pelvic cavity (KÖNIG & LIEBICH, 2016), enabling animal classification by pelvis type (dolicopelvic, mesatipelvic, or platypelvic) (TONIOLLO & VICENTE, 2003). A simple and effective way to perform these measurements is through radiographic pelvimetry (direct study) (VALLE et al., 2006).

The pelvis plays an important role in parturition by expanding for the passage of the fetus. Determining the pelvimetric pattern of a breed or species enables the anatomical and obstetric classification of the pelvis. Consequently, it supports the execution of prophylactic methods against possible dystocia during parturition (GETTY et al., 1986).

It is important to determine the anatomical and obstetric classification in the pelvis in *Tamandua tetradactyla* through radiographic pelvimetry to support future reproductive studies of these animals under captive and semi-captive conditions.

MATERIALS AND METHODS

We used 14 specimens, six males and eight females, adults. Theses total animals studied, eight belonging to the Núcleo de Pesquisa e Extensão A Casa da Ciência (NUPECC) of the Universidade Federal Rural da Amazônia (UFRA) and six from the collection of the Laboratório de Pesquisa Morfológica Animal (LaPMA) UFRA-Belém, SISBIO N° 23401-5/2019.

Initially we performed crow rump length. Some cadavers had their pelvises macerated to guarantee the reliability of the pelvimetric values obtained in the intact cadaver and then X-rayed in ventrodorsal (VD) and right lateral (LLD) projections (X-ray apparatus - Developer CR-30XAGFA). A 1.5 cm metal plate placed near the pelvis provided a size reference to correct the projection differences.

With the X-ray images digitized, the following pelvic measurements for all animals were determined using AGFA's NX software: upper bi-iliac diameter (UBIID), lower bi-iliac diameter (LBIID), middle bi-iliac diameter (MBIID), right diagonal diameter (RDD), left diagonal diameter (LDD), true conjugate diameter (TCD), diagonal conjugate diameter (DCD), vertical diameter (VD), sacral diameter (SAD), sagittal diameter (SGD), pelvis entry area (PEA), and pelvis exit area (PExA).

These measurements were performed according to protocols established by MONTEIRO et al. (2012), PINHEIRO et al. (2016), and FAVORETTO et al. (2018), under the following conditions: upper bi-iliac diameter (AB), drawing a straight line across the longitudinal diameter of the pelvis at the smallest diameter of the sacroiliac joint; lower bi-iliac diameter (CD), drawing a straight line parallel to the AB diameter, which was measured at the ilio-pubic junction. We also measured two diameters diagonally: the right diameter, which went from point A to D; the left diameter, which started at point B and went on to C, at the intersection point of the diagonal diameters, parallel to the upper bi-iliac and lower bi-iliac diameters, and a third transverse diameter was drawn, that is, the middle bi-iliac (EF), which went from the medial face of the right ilium to the left ilium (Figure 1).

The sacropubic diameter, also called the true conjugate (GH), was obtained from a line projected from the promontory to the cranial margin of the pelvic symphysis. The sagittal diameter (LI) was determined by drawing a line between the caudal end of the sacrum and the caudal edge of the symphysis. The vertical diameter (JH) was obtained from measuring the distance between the medial region of the sacrum and the cranial face of the pubic symphysis. The diagonal conjugate diameter (GI) originated from the same insertion point of the true conjugate (GH), which is the perimeter between the promontory and the caudal portion of the symphysis. The demarcation from the caudoventral border of the sacrum to the medial portion of the symphysis generated the sacral diameter (LM) (Figure 2).

In addition, as recommended by CELIMLI et al. (2008), the AEP and ASP were calculated using the following equations: $AEP = (DCV/2 + DBIM/2)^2 \times \pi$, and another where $ASP = (DV/2 + DBII/2)^2 \times \pi$. Finally, we performed descriptive statistical analyses (mean, variance, and standard deviation), in addition to Student's t-test, to check the normality of the data and whether there was a statistical difference between the measurements obtained for males and females, juveniles, and adults. In addition, Pearson correlation coefficients were calculated for all possible combinations of the parameters studied. For all tests, differences were considered significant when $P < 0.05$ and highly significant when $P < 0.01$. For negative coefficients, the correlation between measurements was inversely proportional, and for positive coefficients, the established correlation resulted in a direct proportion.

RESULTS

Biometrically, the specimens presented the following averages: crown-rump length (CRL)

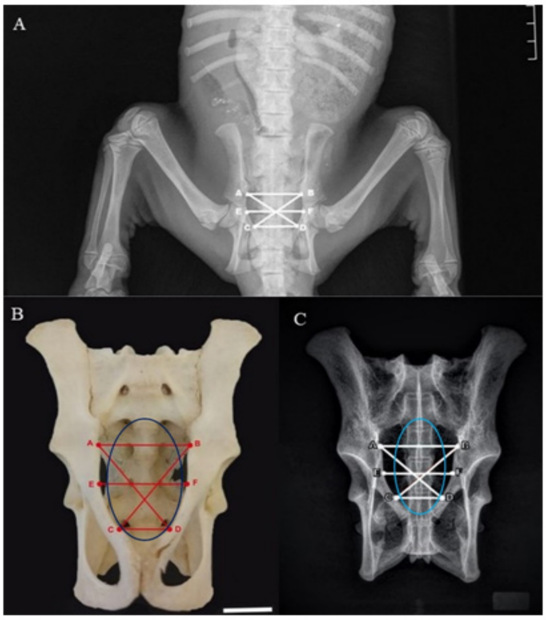

Figure 1 - Pelvis of *Tamandua tetradactyla*: A-Radiographic image; B-Photomacrograph of the macerated pelvis. Scale bar: 2 cm; C - Digitalized radiographic image of the macerated pelvis. Note the markings of the diameters studied, ventrodorsal positioning: AB - upper bi-iliac diameter; CD - lower bi-iliac diameter; AD - right diagonal diameter; BC - left diagonal diameter; EF - middle bi-iliac diameter. C and D: pelvic inlet with oval shape (circle).

42.78 cm, skull circumference (CC) 6.36 cm, and tail length (CCa) 51.86 cm.

Tamandua tetradactyla pelvis was classified as dolicopelvic, wherein the true conjugate diameter is larger than the mean bi-iliac diameter in both sexes (0.42). Furthermore, homoscedasticity of the samples was evident; there was no statistical difference between the

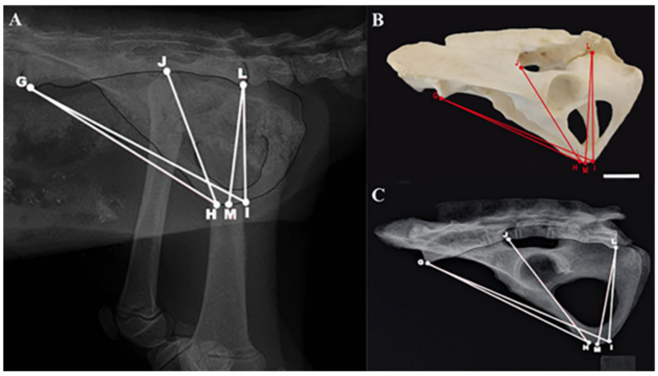

Figure 2 - *Tamandua tetradactyla* pelvis: Diameter markings studied, right lateral lateral positioning: GH - true conjugate diameter; LI - sagittal diameter; JH - vertical diameter; GI - diagonal conjugate diameter; LM - sacral diameter. A - Digitized radiographic image of the pelvis; B - Photomacrograph of the macerated pelvis. Scale bar: 2 cm; C - Digitalized radiographic image of the macerated pelvis.

Table 1 - Values related to radiographic pelvimetry (cm) in ventrodorsal and right lateral projections of male and female *Tamandua tetradactyla*.

Animals/Sex	UBID	MBID	BIID	RDD	LDD	TCD	DCD	VD	SAD	SGD	PEA	PExA
1/ Male*	2.91	2.97	2.48	3.05	3.13	7.04	7.72	5.11	4.12	4.01	7.86	4.52
2/ Male	3.31	3.06	2.21	3.24	3.44	7.84	8.81	5.70	4.70	4.54	9.32	4.91
3/ Male	2.78	2.53	1.89	3.38	3.25	7.17	8.49	5.00	4.17	4.05	7.38	3.72
4/ Male	3.11	2.51	1.93	3.67	3.64	7.05	7.75	5.13	4.44	4.23	7.17	3.91
5/ Male	2.96	2.65	1.90	3.22	3.38	7.04	7.48	5.26	4.59	4.41	7.37	4.02
6/ Male	3.26	3.07	2.43	3.59	3.70	7.09	7.84	5.04	4.22	4.21	8.10	4.38
7/ Female	2.84	2.50	1.86	3.25	3.09	7.24	7.95	5.18	4.41	4.06	7.44	3.89
8/ Female	2.77	2.35	1.97	3.13	3.06	7.21	7.73	5.34	4.28	4.20	7.17	4.19
9/ Female	2.89	2.66	2.39	3.54	3.71	7.55	7.78	5.04	4.15	4.08	8.18	4.33
10/ Female	3.03	2.78	1.85	3.83	3.72	8.28	9.19	5.78	4.82	4.76	9.60	4.57
11/ Female	2.98	2.83	2.32	3.25	3.29	7.99	8.83	4.76	4.25	3.99	9.19	3.93
12/ Female	3.34	2.97	2.41	3.85	3.90	8.25	9.23	5.67	4.50	4.49	9.88	5.12
13/ Female	3.24	2.88	2.31	3.72	3.47	7.97	9.02	5.86	4.68	4.46	9.24	5.13
14/ Female	2.81	2.84	1.96	3.20	3.32	7.63	8.54	5.15	3.96	3.97	8.60	3.96
Mean	3.02	2.76	2.14	3.42	3.43	7.52	8.31	5.29	4.38	4.25	8.32	4.33
Variance	0.04	0.05	0.06	0.07	0.07	0.22	0.39	0.11	0.06	0.06	0.94	0.22
SD	0.20	0.23	0.25	0.27	0.26	0.46	0.62	0.33	0.25	0.24	0.97	0.47

SD – Standard Deviation; UBIID – upper bi-iliac diameter; MBIID – mean bi-iliac diameter; BIID – lower bi-iliac diameter; DDD – right diagonal diameter; DDE – left diagonal diameter; TCD – true conjugate diameter; SGD – sagittal diameter; VD – vertical diameter; DCD – diagonal conjugate diameter; SAD – sacral diameter; PEA – pelvis entry area; PExA – pelvis exit area*. Pelvimetry performed on radiographic image of live animal.

pelvimetric measurements evaluated for males and females, juveniles, or adults (Table 1).

Verifying of the existence or absence of a relationship between the variables studied by the statistical method of Pearson's coefficients showed a positive correlation for most of the diameters analyzed. However, a negative correlation was determined for certain parameters (Table 2).

The same method indicated that there were negative correlations varying only in the degree of significance, when external body measurements were evaluated, with pelvimetric values between crown-rump length and the upper bi-iliac, right diagonal, true conjugate, diagonal conjugate, vertical, sacral, and sagittal diameters, in addition to the pelvis entry and exit areas. The cranial circumference showed negative correlation only with four diameters (RDD, DV, DAS, and SGD). Tail length showed an inversely proportional relationship with all internal pelvis measurements (Table 3).

DISCUSSION

Studies on pelvimetry in wild animals are lacking, with records limited to primates and rodents and more emphasis on domesticated animals such as carnivores and ruminants. Therefore, data on more species, including the lesser anteater, are needed.

Even though computed tomography (CT) is the "gold standard" for pelvimetric investigations, this tool is still restricted to large centers in Brazil. This is, among other factors, due to the high cost when compared to radiography. Literature still counts on research using radiography for the same purpose, such as in cows (TSOUSIS et al., 2010), dogs (OCAL et al., 2003; DOBAK et al., 2018), and pacas (SMARGIASSI et al., 2019). For the reasons above, a conventional radiographic examination was the method of choice to evaluate pelvimetric parameters in *Tamandua tetradactyla.*

Based on the pelvimetric measurements, in which the mean bi-iliac diameters are smaller than the true conjugate diameters in both males and females, we classified the pelvis of *Tamandua tetradactyla* as dolicopelvic, based on the classification recommended by TONIOLLO & VICENTE (2003).

The pelvis diameter area not only helps in the classification of pelvis types but also determines whether the female is fit for breeding (PAFARO et al., 2010). SMARGIASSI et al. (2019) further stated that in pacas, it is possible to estimate the age of females of this species from the 1st to the 12th month of life due

Table 2 - Values concerning Pearson's correlation coefficient (R) between pelvimetric measurements obtained in male and female *Tamandua tetradactyla* studied.

	UBID	MBID	BIID	RDD	LDD	TCD	DCD	VD	SAD	SGD	PEA	PExA
UBID	0	0.69 p = 0.006	0.49 p = 0.073	0.59 p = 0.025	0.68 p = 0.007	0.44 p = 0.117	0.44 p = 0.114	0.54 p = 0.045	0.56 p = 0.035	0.62 p = 0.017	0.61 p = 0.021	0.75 p = 0.002
MBID	0.69 p = 0.006	0	0.69 p = 0.006	0.18 p = 0.532	0.41 p = 0.145	0.42 p = 0.138	0.44 p = 0.118	0.26 p = 0.364	0.11 p = 0.699	0.26 p = 0.368	0.70 p = 0.005	0.64 p = 0.013
BIID	0.49 p = 0.073	0.69 p = 0.006	-	0.12 p = 0.692	0.31 p = 0.281	0.20 p = 0.501	0.10 p = 0.729	-0.04 p = 0.887	-0.20 p = 0.491	-0.11 p = 0.723	0.41 p = 0.145	0.57 p = 0.033
RDD	0.59 p = 0.025	0.18 p = 0.532	0.12 p = 0.692	0	0.86 p = 0.001	0.51 p = 0.061	0.48 p = 0.078	0.47 p = 0.087	0.47 p = 0.085	0.59 p = 0.027	0.47 p = 0.086	0.46 p = 0.097
LDD	0.68 p = 0.007	0.41 p = 0.145	0.31 p = 0.281	0.86 p = 0.001	0	0.46 p = 0.095	0.35 p = 0.218	0.34 p = 0.233	0.34 p = 0.229	0.54 p = 0.044	0.52 p = 0.056	0.48 p = 0.084
TCD	0.44 p = 0.117	0.42 p = 0.138	0.20 p = 0.501	0.51 p = 0.061	0.46 p = 0.095	0	0.91 p = 0.001	0.57 p = 0.031	0.46 p = 0.099	0.53 p = 0.048	0.94 p = 0.001	0.60 p = 0.024
DCD	0.44 p = 0.114	0.44 p = 0.118	0.10 p = 0.729	0.48 p = 0.078	0.35 p = 0.218	0.91 p = 0.001	0	0.56 p = 0.039	0.42 p = 0.139	0.48 p = 0.083	0.88 p = 0.001	0.52 p = 0.054
VD	0.54 p = 0.045	0.26 p = 0.364	-0.04 p = 0.887	0.47 p = 0.087	0.34 p = 0.233	0.57 p = 0.031	0.56 p = 0.039	0	0.79 p = 0.001	0.87 p = 0.001	0.56 p = 0.039	0.79 p = 0.001
SAD	0.56 p = 0.035	0.11 p = 0.699	-0.20 p = 0.491	0.47 p = 0.085	0.34 p = 0.229	0.46 p = 0.099	0.42 p = 0.139	0.79 p = 0.001	0	0.91 p = 0.001	0.41 p = 0.144	0.52 p = 0.053
SGD	0.62 p = 0.017	0.26 p = 0.368	-0.11 p = 0.723	0.59 p = 0.027	0.54 p = 0.044	0.53 p = 0.048	0.48 p = 0.083	0.87 p = 0.001	0.91 p = 0.001	0	0.53 p = 0.053	0.65 p = 0.011
PEA	0.61 p = 0.021	0.70 p = 0.005	0.41 p = 0.145	0.47 p = 0.086	0.52 p = 0.056	0.94 p = 0.001	0.88 p = 0.001	0.56 p = 0.039	0.41 p = 0.144	0.53 p = 0.053	0	0.71 p = 0.004
PExA	0.75 p = 0.002	0.64 p = 0.013	0.57 p = 0.033	0.46 p = 0.097	0.48 p = 0.084	0.60 p = 0.024	0.52 p = 0.054	0.79 p = 0.001	0.52 p = 0.053	0.65 p = 0.011	0.71 p = 0.004	0

SD – Standard Deviation; UBIID – upper bi-iliac diameter; MBIID – mean bi-iliac diameter; BIID – lower bi-iliac diameter; DDD – right diagonal diameter; DDE – left diagonal diameter; TCD – true conjugate diameter; SGD – sagittal diameter; VD – vertical diameter; DCD – diagonal conjugate diameter; SAD – sacral diameter; PEA – pelvis entry area; PExA – pelvis exit area*. Pelvimetry performed on radiographic image of live animal.

to the variation of the pelvis diameter in this period. However, we emphasized that this is plausible when the animals are bred in captivity, which is impossible with free-living animals, as is the case with the animals studied here.

In this study, we improved the reliability of the pelvimetric values obtained from the intact cadavers by macerating part of the *T. tetradactyla* pelvises, obtaining similar values between the macerated and unmacerated pelvises.

The results obtained in the Pearson correlation analysis for the studied diameters indicated positive correlations of high significance ($P < 0.01$), that is, there are directly proportional measurements between certain pelvis diameters, such as true conjugate diameter and pelvis entrance area. Our findings correspond with those of VALLE et al. (2006) and PINHEIRO et al. (2016) in neotropical nonhuman primates, whose pelvimetric values indicated highly significant positive correlations between these diameters.

Table 3 - Values regarding Pearson's correlation coefficient (R) between biometry and pelvimetric measurements obtained in male and female *Tamandua tetradactyla* studied.

	UBID	MBID	BIID	RDD	LDD	TCD	DCD	VD	SAD	SGD	PEA	PExA
CRL	-0.16 p = 0.587	0.21 p = 0.463	0.31 p = 0.274	-0.31 p = 0.278	0.01 p = 0.970	-0.35 p = 0.216	-0.56 p = 0.038	-0.27 p = 0.349	-0.30 p = 0.300	-0.19 p = 0.516	-0.20 p = 0.484	-0.04 p = 0.883
Skull	0.30 p = 0.301	0.70 p = 0.005	0.48 p = 0.078	-0.09 p = 0.760	0.15 p = 0.608	0.16 p = 0.577	0.13 p = 0.662	-0.15 p = 0.605	-0.20 p = 0.488	-0.11 p = 0.705	0.39 p = 0.170	0.18 p = 0.547
Tail	-0.15 p = 0.600	-0.07 p = 0.811	-0.13 p = 0.646	-0.08 p = 0.789	-0.18 p = 0.525	-0.18 p = 0.527	-0.08 p = 0.787	-0.25 p = 0.389	-0.21 p = 0.465	-0.18 p = 0.535	-0.16 p = 0.572	-0.29 p = 0.320

*CRL: *crown-rump length.*

Pearson's test also indicated negative correlations for most of the variables analyzed, varying only in the degree of significance, when external body measurements were evaluated with pelvimetric values, s, biometry does not influence the internal diameters of the pelvis of *Tamandua tetradactyla*. These results differ from those presented by PINHEIRO et al. (2016) in *Callithrix jacchus* and CAMPOS et al. (2019) in French Bulldog, which obtained positive values when correlating body biometry with pelvic diameters, thus indicating that there is a directly proportional relationship between the variables analyzed.

As for the ideal radiographic projections, VALLE et al. (2006) and MONTEIRO et al. (2012), when using a methodology for the measurement of pelvic diameters similar to that performed in our study, found positive values for the correlation indices between the variables evaluated in adult domestic cats of various breeds. However, the authors estimated the diameter values only with a radiographic examination in ventrodorsal projection and found that the structures that serve as reference points for taking pelvic diameters are difficult to delimit in radiographs in lateral projections due to the effects of summation.

Our results confirmed the importance of using two projections, right or left laterolateral and ventrodorsal, when aiming for a more thorough pelvic evaluation, making it possible to evaluate the dimensions of both the entrance and exit areas of the pelvis, a fact not considered by SMARGIASSI et al. (2019) who only used the measurement of the ventrodorsal view in pacas. It is important to highlight that there are diameters that can only be measured on radiographs in lateral projections, such as the diagonal, vertical, sacral, and sagittal conjugate diameters.

CONCLUSION

Our findings confirm that radiographic pelvimetry in *Tamandua tetradactyla* is an effective method for reliably determining the distance between pelvic diameters, making it an important tool for better understanding the reproductive and obstetric management of this species.

BIOETHICS AND BIOSECURITY COMMITTEE APPROVAL

We, authors of the article entitled Radiographic pelvimetry in lesser anteater, declare that the data from this study were not submitted for evaluation to the Ethics and Biosafety Committee of Universidade Federal Rural da Amazônia (UFRA) in Belém, Para State, as only animals that died on highways and mining areas in the interior of the state were used. We have authorization from the Chico Mendes Institute for Biodiversity Conservation (ICMBio) SISBIO N° 23401-5/2019 for use in these animals. Thus, the authors assume full responsibility for the data and are available for possible questions.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and writing of this manuscript. All authors critically revised the manuscript and approved the final version.

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