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# *Morphometry and allometry of outer body in three species of the genus* Callithrix *Erxleben, 1777 (Callitrichidae, Primates)*

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***Abstract.*** The present study analyzed the morphometric data of three species of the *Callithrix* genus (90 *C. kuhli* Wied, 1826 [43 females], 76 *C. geoffroyi* Humboldt, 1812 [34 females], and 25 *C. aurita* E. Geoffroy, 1812 [16 females]) at different ages, and also their allometric relationship and sexual dimorphism. Their body size and head-body length variables were assessed, as was the difference between the means by the Student *t* test. Allometry was used to evaluate the differences among the species. Regarding the mean body weight values in adults, all females were heavier, except for *C. geoffroyi*. However, regarding the head-body length, all females were shorter than males, except *C. kuhli*. Sexual dimorphism analysis through the Student *t* test and the interspecific comparisons using allometric slopes were also performed, although no statistical significance was found (p>0.05).This study showed the existence of monomorphism regarding sexes for the body size of the three *Callithrix* species studied, confirming the monomorphic pattern attributed to this genus in the literature.

***Key words***: Marmosets, *Callithrix*, body, morphometry, allometry.

***Resumo: Morfometria e alometria do corpo de três espécies do gênero*** *Callithrix* ***Erxleben, 1777 (Clalitrichidae, Primates).*** O presente estudo analisou dados morfométricos de três espécies do gênero *Callithirx* (90 *C. kuhli* Wied, 1826 [43 fêmeas], 76 *C. geoffroyi* Humboldt, 1812 [34 fêmeas],e 25 *C. aurita* E. Geoffroy, 1812 [16 fêmeas]) com diferentes idades além das relações alométricas e do dimorfismo sexual. As variáveis tamanho do corpo e compirmento cabeça-corpo assim como as diferenças entre as médias pelo teste t de student. Alometria foi utilizada para a valiar as diferenças entre as espécies. Com relação a média da massa corporal em adultos, todas as fêmeas possuiam maior massa, exceto para *C. geoffroyi.* Entretanto, com relação ao comprimento cabeça-corpo, todas as fêmeas foram menores que os machos, com exceção de *C. kuhli*. A análise do dimorfismo sexual através do teste t de student a as comparações inter=específicas utilizando curvas alométricas também foram efetuadas, embora não tenha sido possível evidenciar diferenças estatísticas significativas (p> 0.05). Este estudo demonstra a existência de monomorfismo em relação ao sexo no tamanho do corpo para as três espécies de *Callithrix* estudadas, confirmando o padrão monomórfico atribuído ao gênero na literatura.

***Palavras-chave:*** *Callithrix*, corpo, morfometria, alometria.

## *INTRODUCTION*

The taxonomy of New World Primates has undergone considerable changes for the past 20 years (RYLANDS *et al.*, 2000). Twenty-two new species were described, eight of which belonging to the *Callithrix* (Erxleben, 1777) genus (RYLANDS *et al.*, 2000).

In the past, the *Callithrix* genus was divided into three groups: the first was known as *humeralifer*, the second as *argentata* and the third as *jacchus*. The third group was composed of the following taxa: *Callithrix jacchus* Linnaeus, 1758; *Callithrix penicillata*

E. Geoffroy, 1812; *Callithrix kuhlii* Wied, 1826; *Callithrix geoffroyi* Humboldt, 1812; *Callithrix aurita* E. Geoffroy, 1812 and *Callithrix flaviceps* Thomas, 1903), which later received the status of valid species (MITTERMEIER & COIMBRA-FILHO, 1981; COIMBRA-FILHO, 1990; VIVO, 1991). Nevertheless, based on a report about the Brazilian simian systematics, geographical distribution, and situation, in 1990 COIMBRA-FILHO suggested that *Callithrix aurita* and *Callithrix flaviceps* be classified as subspecies, *C. aurita* being the nominal taxon.

Currently, only the *jacchus* group (Atlantic Forest marmoset) maintains the name *Callithrix* for the genus, because the *humeralifer* and *argentata* (marmosets from Amazon) groups were placed in the *Mico* group (Lesson, 1840) based on morphological and molecular evidence (RYLANDS *et al.*, 2000).

Morphologically, the *Callithrix* genus has been included in the *Callitrichidae* family, because it has the following characteristics: small size (250-600g); usual multiple birth; presence of claws, except for the big toe; dentition composed of 32 teeth, with 2, instead of 3, molars in each half of the maxilla, like the Cebidae; "v-shaped" mandible, showing the so-called "short tusked" condition (COIMBRA-FILHO & MITTERMEIER, 1977), with incisor-like canines and long incisors, adapted to tree-gouging for obtaining exudates; presence of quadrupedalism, with vertical trunk climbing, both for protection and foraging; and absence of a prehensile tail (HERSHKOVITZ, 1977; STEVENSON & RYLANDS, 1988; ROSENBERGER, 1992; NAPIER & NAPIER, 1996).

The study of the *Callithrix* morphometry began with BEATTIE (1927) and continued with HILL (1957) and HERSHKOVITZ (1977). More recently, some authors have devoted their studies to the morphological aspects of this genus (FORD & DAVIS, 1992; NATORI, 1994a and 1994b; BURITY *et al.*, 1995).

In this study, allometry was used in its broader sense, according to GOULD (1966), to designate the differences in proportions correlated to changes in absolute magnitude.

Allometric studies have been frequently referred in the scientific literature as powerful tools for interpreting biological features, such as body measurements (STAHL & GUMMERSON, 1967), body proportions (AIELLO, 1981), organ weights (LARSON, 1984; BURITY *et al.*, 1995), and limb proportions (STRASSER, 1992).

Primates have morphological sexual differences in a wide range of characteristics, including body size, dentition, cranial features, locomotor apparatus, internal organs, and external features. However, these characteristics vary considerably among species (LEUTENEGGER & CHEVERUD, 1985).

A number of different features have been analyzed in search for sexual dimorphism in New World monkeys. LEUTENEGGER (1982), OXNARD (1983), GAULIN & SAILER (1984), LEUTENEGGER & LARSON (1985), and FORD & DAVIS (1992) studied sexual dimorphism regarding body size. HARTWIG (1993) studied sexual differences in the Platyrrhini *cranium*. HARVEY *et al.* (1978) and OXNARD *et al.* (1985) analyzed sexual dimorphism in primate dental morphology, while PISSINATTI *et al.* (1992) and TANGUE (1995) described sexual dimorphism in the pelvis (hip bone) of *Leontopithecus* and nonhuman primates (including callitrichids), respectively. The vocal structure of *Leontopithecus* was found sexually dimorphic by BENZ *et al.* (1990). Yet, in regard to the *Leontopithecus* genus, BURITY *et al.* (1997a, 1997b, and 1999) reported the occurrence of dimorphic aspects in the cranium of adult animals kept in captivity. The present study evaluated the morphometric data of three species of *Callithrix* genus regarding their allometric relationship and sexual dimorphism.

## *MATERIAL AND METHODS*

*C. kuhli, C. geoffroyi,* and *C. aurita* nonhuman primates (marmosets) housed at the Center of Primatology of Rio de Janeiro (CPRJ-FEEMA) were evaluated. The facility is located 100 km northeast of the city of Rio de Janeiro, in a protected forest area of the Serra dos Órgãos mountain range.

The marmosets (*Callithrix*) were housed in groups in enclosures located outdoors, being thus exposed to the Atlantic Forest conditions (e.g. sounds, temperature, and rainfall). The enclosures were large, measuring 6.0 x 3.0 x 2.5 $m^3$. The south wall of each enclosure was made of concrete, and the other three walls were made of wire mesh. Food and fresh water were provided twice a day. The diet consisted of bread, bananas, eggs, raisins, meat, several commercially prepared protein supplements, and invertebrate larvae (Coimbra-Filho & Maia, 1977).

Although no animal was euthanized for this study, those dying of different natural causes underwent necropsy and dissection, being fixed by immersion in a 10% buffered formaldehyde solution.

The study sample consisted of 191 monkeys of the *Callithrix* genus of various ages: 90 *C. kuhli* (43 females), 76 *C. geoffroyi* (34 females), and 25 *C. aurita* (16 females). These animals were part of the museum collection of the Center of Primatology of Rio de Janeiro (CPRJ-FEEMA), were born in captivity, were maintained under similar rearing regimens, their sexes and ages being known (Coimbra-Filho *et al.*, 1981).

The following data were recorded in the museum necropsy protocol (CPRJ-FEEMA): a) body weight (BW in grams); b) head-body length (HBL in millimeters); and c) age (in days). Measurements were taken with measuring closes and digital scale, with respective accuracies of 1 cm and 0.01 g.

Descriptive statistics was calculated for each measurement in all forms of adult *Callithrix* (i.e., aged at least 12 months, according to Stevenson & Rylands, 1988). In order to analyze univariate differences between sexes, we initially compared the means by using the Student *t* test (Zar, 1984).

A one-way analysis of variance (ANOVA) was used to determine the differences between species by sex. A multiple comparison procedure was carried out using the Bonferroni test (B-method) due to the different sample sizes (Fisher & Van Belle, 1993).

The sexual dimorphism index (SDI) was computed based on the single ratio of the size of the larger sex divided by the size of the smaller sex (Gibbons & Lovich, 1990). In order to make the SDI more comparable to those based on linear measurements, the cubic roots of all mean body weights were used (Ralls, 1976).

In the bivariate ontogenetic study (cross-sectional data, all ages computed) BW and HBL were correlated with age. To overcome the heterocedasticity of the standardized residuals due to the increasing variability in Y with increasing values of X, data were analyzed after undergoing logarithmic transformation (Zar, 1984).

The following simple allometric equation was used to determine the relationships between variables (Huxley, 1932):

$$\text{Ln } Y = \text{Ln } a + (b) \text{ Ln } X$$

To overcome the problem of biased estimated slopes of Y on X, when both variables may have a measurement error, the reduced major axis (RMA) was computed (Sokal & Rohlf, 1981). The *t* test was used both for assessing the significance of slopes between sexes and for performing interspecific analysis.

## Results

The results are shown in Tables and Figures 1 and 2. Regarding the mean BW values found in adults,

***Table 1.*** Body weight (BW) and head-body length (HBL) in males and females of three species of the *Callithrix* genus.

| Species | Sample size by sex | Variables | Males | Females | *t*-Test | SDI** |
|---|---|---|---|---|---|---|
| *C. aurita* | 14 (M), 6 (F) | (BW) | 365.6334.03* | 404.6735.5 | 0.45 | 1.034 |
| | | (HBL) | 227.872.23 | 221.177.28 | 0.339 | 1.03 |
| *C. geoffroyi* | 40 (M), 19 (F) | (BW) | 357.7124.74 | 341.3722.13 | 0.628 | 1.016 |
| | | (HBL) | 214.383.63 | 211.683.57 | 0.601 | 1.012 |
| *C. kuhli* | 40 (M), 20 (F) | (BW) | 331.7123.54 | 347.7618.48 | 0.591 | 1.016 |
| | | (HBL) | 207.529.21 | 220.383.03 | 0.176 | 1.061 |

* - Mean ± standard error of mean;
**- Sexual dimorphism index, ratio of size of the larger sex divided by size of the smaller sex;
(M) – Males and (F) – Females.

all females were heavier, except for the *C. geoffroyi*. However, regarding HBL, all females were shorter than males, except for the *C. kuhli* females, which were bigger than the males (Tab. 1). Considering both body weight and head-body length, the species showed the following sequences for males and females, respectively: *aurita* > *geoffroyi* > *kuhli*; and *aurita* > *kuhli* > *geoffroyi* (Tab. 1). However, the sexual dimorphism tested by the difference between means through the *t* test was not statistically significant (P>0.05, Tab. 1).

Figure 1 depicts a graph where the sexes are pooled for interspecific comparison with ANOVA. The interspecific comparisons were not statistically significant, either for body weight (F=0.97, p=0.382) or for head-body length (F=1.53, P=0.223).

The results obtained through the sexual dimorphism index (SDI) for BW and HBL classified the species as monomorphic (Tab. 1). In bivariate analysis, the slope of the logarithmic equivalent of the simple allometric equation was used with standard growth coefficients. All correlation coefficients obtained were greater than 0.80 (Tab. 2).

The sexual size dimorphism in growth coefficients (slopes) did not show statistically significant differences (P> 0.05) in the three species, considering both BW and HBL. In interspecific analyses (pooled sexes), the growth coefficients were also not significant (Tab. 2 and Fig. 2).

## Discussion

Studies on the morphology and morphometry of New World monkeys are scarce in the scientific literature (except for the description of holotypes). Most studies have been restricted to BW analysis and compilation of data originated from old studies, in which the information was based on mixed samples (wild and captive animals), mainly of *C. jacchus*.

It is worth mentioning that BW is a very difficult variable to analyze, mainly due to physiological variations, which can or cannot be environmentally induced, and to captivity conditions as well (the case of this study). Dietz *et al.* (1994) showed that the weight of *L. rosalia* males and females in nature can vary depending on the dry or rainy season, or as the result of social interactions, such as reproduction and competition.

Regarding body size, the *Callithrix genus* has been represented in the literature by adult females slightly bigger than males (Leutenegger & Larson, 1985; Ford & Davis, 1992; Garber, 1992). This study confirmed that pattern, because both *C. aurita* and *C. kuhli* females showed a greater body weight than males did. However, regarding head-body length, only *C. kuhli* females were greater.

The morphometric studies by Natori (1986; $1994_a$; $1994_b$) and by Natori & Kobayashi (1995) on

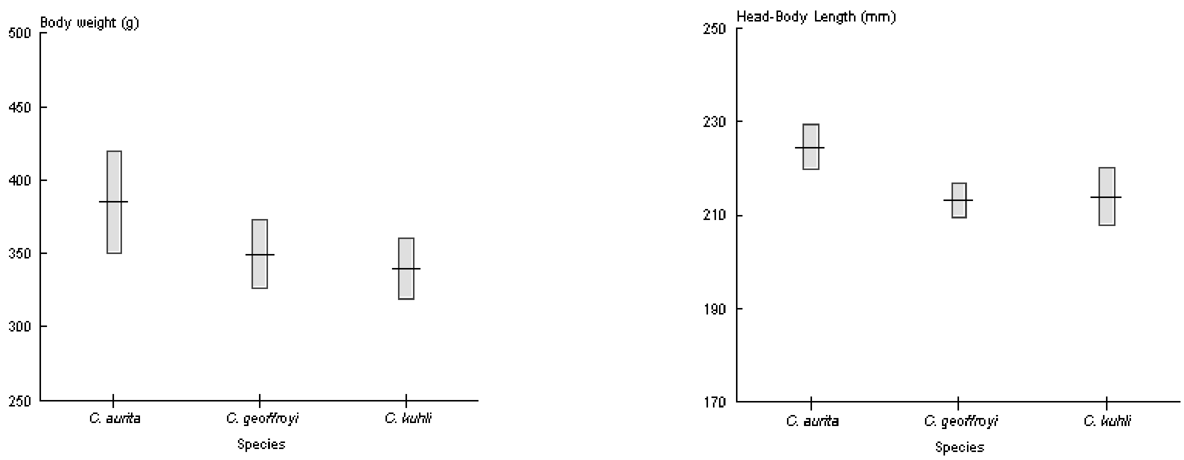


***Figure 1.*** Graphs (mean ± standard error of mean) of the pooled sexes to body weight (BW) and head-body length (HBL) in three species of the *Callithrix* genus.

***Table 2.*** Body weight and head-body length as the dependent variable Y analyzed regarding age (independent variable X). All variables were transformed into natural logarithms using the allometric formula LnY = Lna + (b) LnX.

| Y | | Slope* | 95% CI (b)** | Intercept | r*** |
|---|---|---|---|---|---|
| Body weight (BW) | | | | | |
| *C. kuhli* | (M)† | 0.418 | -0.628/1.464 | 2.895 | 0.91 |
| | (F) | 0.435 | -0.524/1.394 | 2.764 | 0.93 |
| | (M+F) | 0.425 | -0.468/1.318 | 2.861 | 0.93 |
| *C. geoffroyi* | (M) | 0.376 | -0.411/1.163 | 3.269 | 0.95 |
| | (F) | 0.345 | -0.503/1.192 | 3.314 | 0.92 |
| | (M+F) | 0.361 | -0.442/1.165 | 3.286 | 0.94 |
| *C. aurita* | (M) | 0.426 | -0.387/1.24 | 2.855 | 0.92 |
| | (F) | 0.385 | -0.72/1.491 | 3.383 | 0.9 |
| | (M+F) | 0.371 | -0.565/1.308 | 3.349 | 0.92 |
| Head-body length (HBL) | | | | | |
| *C. kuhli* | (M) | 0.157 | -0.368/0.681 | 4.318 | 0.83 |
| | (F) | 0.163 | -0.242/0.568 | 4.25 | 0.91 |
| | (M+F) | 0.159 | -0.262/0.58 | 4.297 | 0.89 |
| *C. geoffroyi* | (M) | 0.149 | -0.078/0.375 | 4.335 | 0.97 |
| | (F) | 0.135 | -0.144/0.414 | 4.383 | 0.95 |
| | (M+F) | 0.143 | -0.107/0.392 | 4.353 | 0.96 |
| *C. aurita* | (M) | 0.138 | -0.028/0.304 | 4.438 | 0.97 |
| | (F) | 0.149 | -0.189/0.487 | 4.395 | 0.94 |
| | (M+F) | 0.122 | -0.122/0.413 | 4.401 | 0.96 |

*- Reduced Major Axis slopes;
**- 95% confidence interval for the slope;
***- Coefficient of correlation ($p<0.001$);
†- Analyses performed with males (M), females (F) and pooled sexes (M+F).

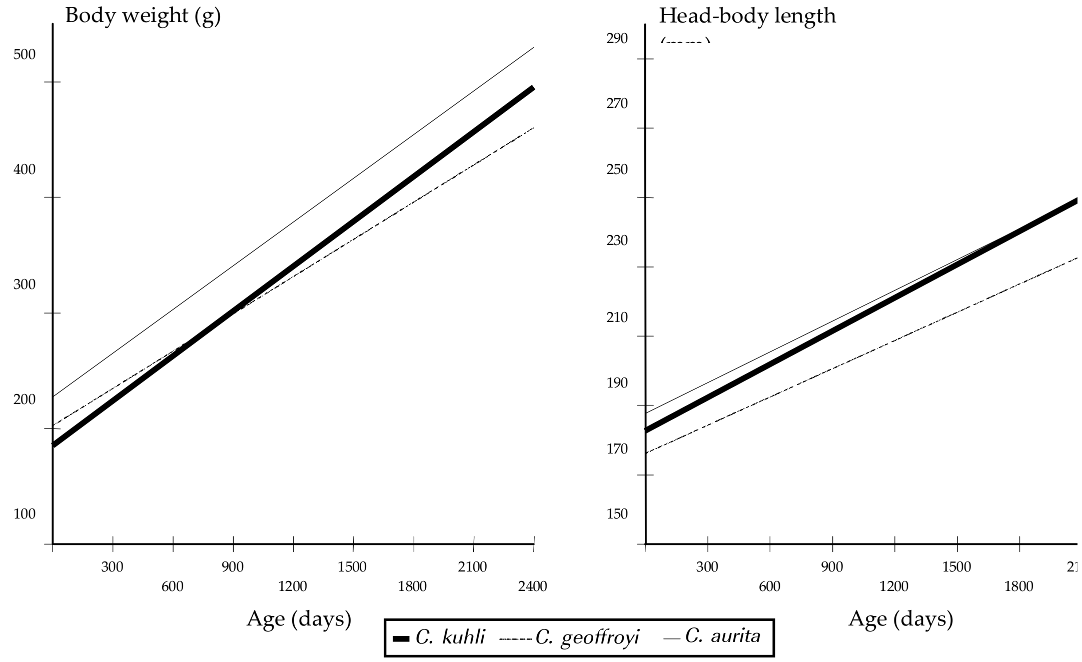


***Figure 2.*** Graphs of the growth curves of body weight (BW) and head-body length (HBL) versus age for three species of the *Callithrix* genus.

the *Callithrix* genus based on both odontometric and craniometric variables reported the similarity among the *C. kuhli*, *C. geoffroyi* and *C. aurita* species, differentiating them from the *C. jacchus* and *C. penicillata* species. Natori related those morphologic characteristics to ecological characteristics of the species, thus justifying this morphocline. Natori ($1994_b$) highlighted the greater morphological similarity between *C. kuhli* and *C. geoffroyi*. Our results were based on body variables and showed no statistically significant differences among those species, somehow confirming their morphological relation, as proposed by Natori.

In the regression analysis (bivariate) performed by Leutenegger & Larson (1985) regarding the postcranial skeleton of New World primates, including the *Callithrix* (represented by *C. jacchus*), the authors detected the occurrence of sexual dimorphism in the regression slope values. However, among the 24 osteometric variables studied by those authors, seven were dimorphic, while univariate analysis showed only two. Leutenegger & Larson (1985) also emphasized the allometric limitations in adults, the so-called static allometry. The bivariate analysis performed in our study took into consideration the wide age range, and yet the body variables studied did not differ between the sexes. Thus, regression with pooled sexes was analyzed to show interspecific differences, which were also not statistically significant.

Sexual dimorphism in size varies widely in primates, being pronounced in Old World monkeys, but usually only minimum in prosimians. Sexual dimorphism was suggested to be absent, or only slightly developed, in marmosets and tamarins (Mace, 1992). Herhkovitz (1977) noted that, although available, the *Leontopithecus* material was insufficient for analyzing sexual dimorphism in size. However, the median ventral laryngeal sac is notably enlarged in male lion tamarins and reduced or absent in females. Rosenberger & Coimbra-Filho (1984) were the first to quantitatively recognize sexual dimorphism in the dentition of *L. rosalia.* The authors considered the two other available samples of lion tamarins too small to allow a conclusion concerning sexual dimorphism. The studies by the following authors also identified the presence of sexual dimorphism in *Leontopithecus*: Benz *et al.,* 1990 (in vocalization); Pissinatti *et al.,* 1992 (in pubic skeleton); and Burity *et al.*, 1997a, 1997b and 1999 (in cranial skeleton). They also suggested absence of sexual dimorphism in body weight in this *L. rosalia* population. In 1994, Dietz *et al.* reported that, although *L. rosalia* was not dimorphic, adult males were 4% bigger than females, unlike that which was found in our study, where females were heavier and *C. geoffroyi* males were around 15% heavier than females. Burity and colleagues (not published data) confirmed the absence of sexual dimorphism in body weight only in L. rosalia and L. chrysopygus chrysopygus, which is also true in regard to the Callithrix species here presented. Ford & Davis (1992) mentioned that the *Callithrix* genus was monomorphic considering body weight (i.e., no sexual dimorphism) in a long study on body size of New World primates. Overall, our study confirmed the absence of sexual dimorphism concerning the *Callithrix* body size. Nevertheless, Ford & Davis (1992) showed no data concerning *C. aurita* and *C. kuhli*, although those authors showed sexual dimorphism in *C. geoffroyi*. This was not confirmed in our study, where these species were shown to be monomorphic through the Student *t* test and the sexual dimorphism index calculated.

By evaluating the evolution of sexual dimorphism in platyrrhines, Ford (1994) again called our attention to the particular case of the evident sexual dimorphism in *C. geoffroyi*, even considering the *Callithrix* genus monomorphism. This dimorphism, as mentioned above, contradicts the data obtained in our study.

Although the sample of the present study consisted of animals raised and/or kept in captivity, it is worth pointing out that the sample was homogeneous, i.e., animals originating from nature were not analyzed. Thus, no bias was observed in the data obtained, which is usually condemned in the literature on morphometric studies. The data obtained and analyzed in this study contributed to a better knowledge of the biological features of those endangered marmosets.

In conclusion, differences in body size were observed in interspecific analysis, but they could not be statistically proven by ANOVA. The dispersion values of the mean were similar among the species, thereby hindering their distinction through both univariate and bivariate analyses.

Finally, this study showed monomorphism (regarding sexes) for body size in the three *Callithrix* species studied, confirming the monomorphic pattern attributed to this genus in the literature.

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