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Recovering missing data: estimating position and size of caudal vertebrae in *Staurikosaurus pricei* Colbert, 1970

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ABSTRACT

Missing data is a common problem in paleontology. It makes it difficult to reconstruct extinct taxa accurately a restrains the inclusion of some taxa on comparative and biomechanical studies. Particularly, estimating the positi of vertebrae on incomplete series is often non-empirical and does not allow precise estimation of missing parts. this work we present a method for calculating the position of preserved middle sequences of caudal vertebrae in t saurischian dinosaur *Staurikosaurus pricei*, based on the length and height of preserved anterior and posterior cau vertebral centra. Regression equations were used to estimate these dimensions for middle vertebrae and, consequent to assess the position of the preserved middle sequences. It also allowed estimating these dimensions for non-preserv vertebrae. Results indicate that the preserved caudal vertebrae of *Staurikosaurus* may correspond to positions 1-3, 7, 14-19/15-20, 24-25/25-26, and 29-47, and that at least 25 vertebrae had transverse processes. Total length of the t was estimated in 134 cm and total body length was 220-225 cm.

Key words: missing data, caudal vertebra, regression, *Staurikosaurus pricei*.

INTRODUCTION

Missing data is a major problem in the reconstruction of extinct taxa (Paul 1987, 1988, Czerkas 1997) and has several implications in phylogenetic analyses (Nixon and Davis 1991, Novacek 1992, Maddison 1993, Anderson 2001, Kearney and Clark 2003, Norell and Wheeler 2003) and also on biomechanical studies (Holliday et al. 2010). Comparisons to phylogenetic related taxa are often used to make assumptions about shape and dimensions of missing parts in order to allow the reconstruction of fossil taxa (Paul 1987, 1988, Czerkas 1997). However, when we compare closely related organisms we notice that, despite the close relationship, they can be distinguished not just by their autapomorphies, but also by some morphometric and biomechanical properties (Miller and Gross 1998). When we deal w complete materials, some of the divergences ma been lost as missing data. The use of data from related taxa to "fill these gaps" is a common strat plied on most reconstructions of fossil taxa (Pau 1988, Czerkas 1997), but this approach, evidentl the possible differences among them and disca taxon as a potential material for comparative stu

Some authors have developed formulas to struct general dimensions of extinct organisms, total body length, based on the dimension of hi elements (Christiansen 1999) or the skull length rien and Henderson 2007). Unfortunately, total is not sufficient to determine the size of speci ments of the body.

muscles are necessary to determine body mass, position of the center of mass and also to estimate muscle lengths and volumes (Gunga et al. 2007, Hutchinson et al. 2007). For example, the muscle *caudofemoralis longus*, which inserts in the caudal vertebrae, is the main femoral extensor in archosaurs with the exception of birds (Gatesy 1990). A larger *caudofemoralis longus* would move the center of mass to a more posterior position. Accordingly, a correct estimation of the size of this muscle is necessary to make assumptions about the biomechanics of archosaurs. A longer muscle would also lead to a larger muscle moment arms since it would be farther from the center of rotation of the femur (Hutchinson et al. 2005). Gatesy (1990) proposed that the length of the muscle *caudofemoralis longus* is related to the number of caudal vertebrae that possess transverse processes. Therefore, to estimate the size of this muscle in fossil taxa that have not preserved a complete series of caudal vertebrae, it is necessary to correctly estimate the position of the preserved caudal vertebrae and, also, to estimate the dimension of the missing ones, especially of those that have transverse processes.

In this work we present a method for estimating the position of the preserved caudal vertebrae and the dimensions (length and height of vertebral centra) of non-preserved vertebrae. As an example, we reconstructed the tail of the basal saurischian dinosaur *Staurikosaurus pricei* Colbert, 1970 (Santa Maria Formation, Late Triassic of Rio Grande do Sul, Brazil). This taxon is known by an almost complete skeleton that includes 35 preserved caudal vertebrae, of which six are isolated anterior vertebrae, a posterior sequence of 19 vertebrae (which lack transverse processes) and three middle portion sequences (with seven, two and two vertebrae, from which the first and second sequences have transverse processes) (Fig. 1). Accordingly, in order to accurately determine the number of vertebrae that have transverse processes, it is necessary to correctly determine the position of the middle sequences.

Some authors (Colbert 1970, Galton 1977) indicated that *Staurikosaurus* had about 20 vertebrae with transverse processes, but they did not provide an accu-

Also, the methodology presented in this work allowed a more precise estimation of the total length of *Staurikosaurus*. The vertebral column of *Staurikosaurus* holotype MCZ 1669 is almost complete: it lacks the atlas, axis and the third cervical vertebra, and about twelve vertebrae in the mid portion of the tail (Bittencourt and Kellner 2009). Consequently, as mandibles are also present, a correct estimation of the total length of this taxon is centered on a correct estimation of the size of the missing caudal vertebrae and on the total length of the tail.

MATERIALS AND METHODS

In order to determine the position of the preserved caudal vertebrae of *Staurikosaurus pricei* it was initially assumed that this taxon had a total number of vertebrae similar to *Herrerasaurus ischigualastensis*, which is considered its closest related taxon (Novas 1993, 1996, 1997, Sereno and Novas 1993, Sereno 1999, Rauhut 2003, Langer 2004, Langer and Benton 2006, Bittencourt and Kellner 2009). Novas (1993) indicated that the holotype of *Herrerasaurus* (PVL 2566) has 43 caudals preserved, with a hiatus separating the eight most posterior from the rest of the tail, and considered that a total of 47 caudals should have been present.

It was assumed that the first four preserved anterior caudals of *Staurikosaurus* correspond to positions 1, 2, 3 and 5 (Table I). The gap between caudals 3 and 5 was assumed because, despite both have centra with similar height, the prezygapophyses of the fourth preserved vertebra do not articulate correctly with the postzygapophyses of the third vertebra (Fig. 1). We believe that just one vertebra is missing between them, due to the very similar dimensions of the centrum and the general shape of these two vertebrae. The distal articulated sequence corresponds to positions 29 to 47 (Table I). All other preserved vertebrae were initially treated as of undetermined position (Table I).

The first preserved vertebra is considered the third sacral by some authors (Langer 2004, Bittencourt and Kellner 2009; but see Colbert 1970, Galton 1977, 2000), therefore two analyses were conducted: including and

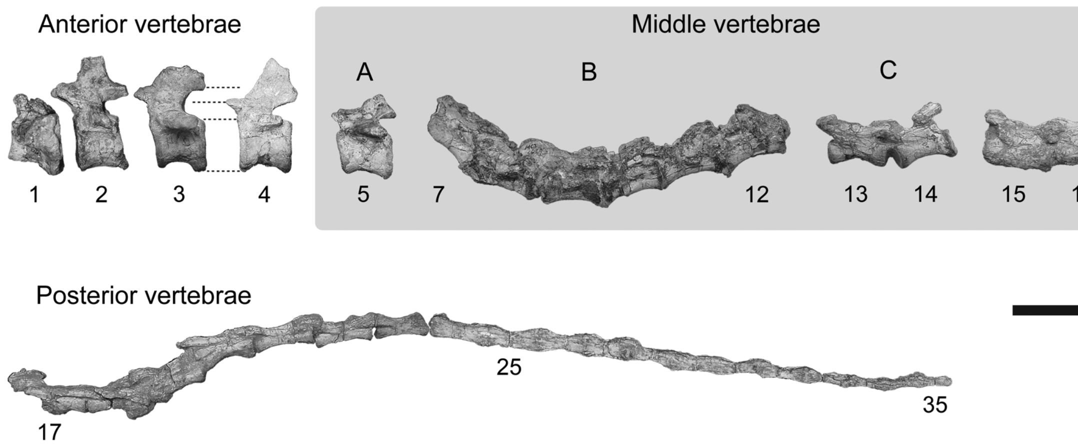

Fig. 1 – Preserved caudal vertebrae of Staurikosaurus and nomenclatures used in this paper. The positions are relative to the total nu preserved caudal vertebrae (fragment of the sixth preserved caudal not shown). Dashed lines between vertebrae 3 and 4 indicate the simil of the centra, but misalignment between pre- and postzygapophyses indicate that they are not consecutive vertebrae. Sequence 15-16 was from the analyses (see text). Scale bar equals 5 cm.

lysis. One of the middle sequences composed of two vertebrae (15-16 in Fig. 1) was also ignored because the bone surface is quite fragmented, and the general appearance of the bones and the disposition of the surface fragments suggest that the crystallization of calcite and hematite caused the break and dislocation of the natural bone structure, increasing the volume of these vertebrae (Holz and Schultz 1998). As proposed by Holz and Schultz (1998), fossils from the Mid-Triassic of south Brazil may be classified according to three levels of deformation/disruption: 1) non-deformed, 2) internally altered (with volumetric change of bones not always apparent, but with small fractures visible on the external layer of the compact bone), and 3) disrupted. External observations of the holotype of *Staurikosaurus* indicate that most bones belong to level 2, including all caudal vertebrae, except this middle sequence composed of two caudals, which was excluded from our analyses. As fractures on most caudal vertebrae are scarce, we consider volumetric changes absent or insignificant, not affecting our measurements.

Measurements of the centrum length and height at the anterior articular surface of all preserved vertebrae in the holotype MCZ 1669 were computed. Measure-

estimating these values for the non-preserved ar positioned vertebrae (referred as 'middle verte The estimated values were compared to the ob values in the middle vertebrae using the de equation

$$D = (o - e)/e$$

in that o corresponds to the observed value and responds to the estimated value. The position middle vertebrae was determined in order to obt best fit to all regressions (deviation smaller than The non-positioned vertebrae are referred in thi as sequences A (5th preserved vertebra), B (7th preserved vertebrae) and C (13th to 14th preserved brae).

Regressions were produced for length, heig height/length ratios using PAST v2.0 (Hamme 2001). The type of regression curve (linear, lo mic, binomial or polynomial) was chosen accor the R^2 correlation value. Values of R^2 were o using the RMA methodology because it is a mo equate one in the case the measurements may errors (Bohonak and Linde 2004).

After positioning the middle vertebrae, their

TABLE I
Heights and lengths (mm) of preserved caudal centra in *Staurikosaurus pricei*. The positions are relative to the total number of preserved caudal vertebrae.

		Preserved position	Assumed position	Height	Length
Anterior vertebrae		1*	1	25.0	28.5
		2	2	26.0	24.0
		3	3	23.5	22.5
		4	5	23.0	23.5
Middle vertebrae	A	5	?	22.0	24.0
	Excluded	6**	-	-	-
	B	7	?	17.0	25.5
		8	?	17.3	31.5
		9	?	17.0	28.0
		10	?	16.8	28.0
		11	?	16.5	28.5
		12	?	17.0	29.0
	C	13	?	13.0	29.0
		14	?	13.5	29.0
	Excluded	15**	-	-	-
		16**	-	-	-
Posterior vertebrae		17	29	11.25	30.5
		18	30	11.25	30.5
		19	31	11.25	30.0
		20	32	10.5	26.5
		21	33	8.8	29.0
		22	34	8.8	28.5
		23	35	9.0	28.0
		24	36	8.5	27.0
		25	37	8.5	27.0
		26	38	8.0	22.5
		27	39	8.0	22.0
		28	40	7.3	23.5
		29	41	7.0	23.0
		30	42	6.7	20.0
		31	43	6.0	20.0
		32	44	5.0	18.5
		33	45	5.0	21.5
		34	46	5.0	15.5
		35	47	5.0	16.0

*The first preserved caudal vertebra is considered the third sacral by some authors (Langer 2004, Bittencourt and Kellner 2009). **The sixth, fifteenth and sixteenth preserved vertebrae were excluded from the analysis due to difficulties to measure dimensions accurately (see text for explanation).

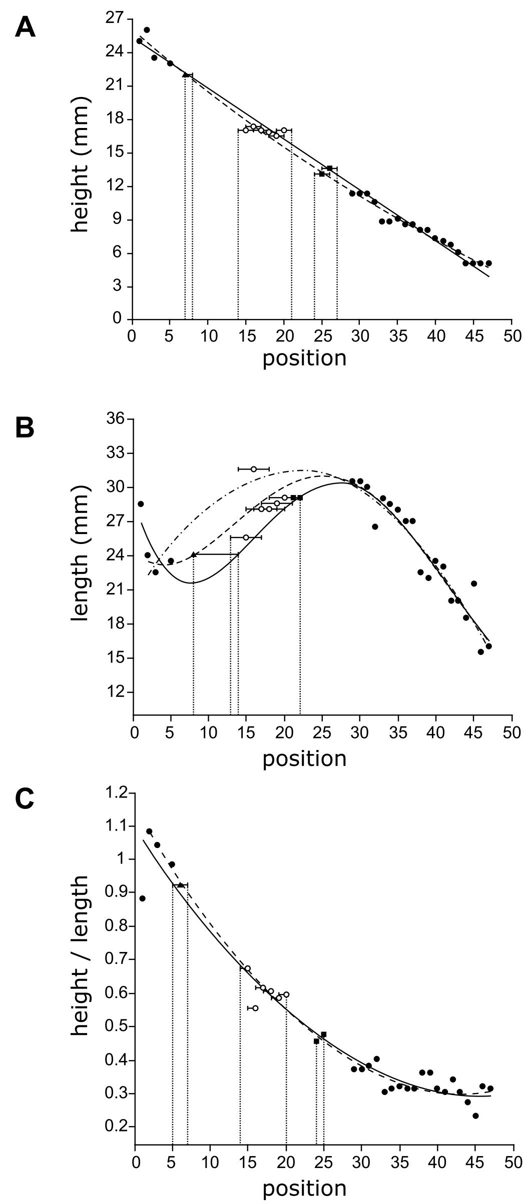

Fig. 2 – Positioning of the middle sequences A (triangle), B (open circles), and C (squares) based on regressions obtained from data of anterior and posterior vertebrae (filled circles). A – Linear (full line) and binomial (dashed line) regressions for height values. B – Fourth order polynomial regressions including the first caudal (full line) and excluding the first caudal (dashed line), and binomial regression excluding first caudal (dash and dot line). C – Binomial regressions including the first caudal (full line) and excluding the first caudal (dashed line).

RESULTS

Height and length of preserved caudal vertebrae centra are indicated in Table I. Regression equations are presented in Table II. Regression graphs obtained from the data of the anterior and posterior vertebrae are shown in Figure 2.

Height of centrum – The analysis of the height values

TABLE II
Regression equations obtained from the analyses. The x value corresponds to the position of the vertebra.

	Anterior and posterior sequences only		
	Equation	R^2	Type
Height	$H = –0.4579x + 25.398$	0.990	Linear; including 1st caudal
	$H = –0.4574x + 25.377$	0.988	Linear; excluding 1st caudal
	$H = 0.0026x^2 – 0.5742x + 25.9385$	0.995	Binomial; including 1st caudal
	$H = 0.0028x^2 – 0.5851x + 26.1109$	0.993	Binomial; excluding 1st caudal
Length	$L = 5.356E\text{-}5x^4 – 0.0061x^3 + 0.2105x^2 – 2.2355x + 28.9536$	0.899	4th order polynomial; including 1st caudal
	$L = 0.0243x^2 + 1.043x + 20.2811$	0.898	Binomial; excluding 1st caudal
	$L = 3.154E\text{-}5x^4 – 0.0035x^3 + 0.105x^2 – 0.6770x + 24.4428$	0.912	4th order polynomial; excluding 1st caudal
Height/length	$y = 0.0004x^2 – 0.0349x + 1.0912$	0.965	Binomial; including 1st caudal
	$y = 0.0005x^2 – 0.0398x + 1.1624$	0.988	Binomial; excluding 1st caudal
	Positioned middle sequences included*		
	Equation	R^2	Type
Height	$H = –0.4467x + 24.853$	0.987	Linear; including 1st caudal
	$H = –0.4437x + 24.747$	0.985	Linear; excluding 1st caudal
	$H = 0.0028x^2 – 0.5787x + 25.8325$	0.993	Binomial; including 1st caudal
	$H = 0.0029x^2 – 0.5862x + 25.9312$	0.992	Binomial; excluding 1st caudal
Length	$L = 3.386E\text{-}5x^4 – 0.0038x^3 + 0.1242x^2 – 1.0822x + 26.7966$	0.871	4th order polynomial; including 1st caudal
	$L = 1.908E\text{-}5x^4 – 0.0023x^3 + 0.0667x^2 – 0.2885x + 23.6239$	0.892	4th order polynomial; excluding 1st caudal
Height/length	$y = 0.0004x^2 – 0.0348x + 1.0896$	0.961	Binomial; including 1st caudal
	$y = 0.0005x^2 – 0.0398x + 1.1580$	0.982	Binomial; excluding 1st caudal

* Middle sequences A, B, and C were considered to be in positions 7, 14-19, and 24-25, respectively.

The exclusion of the first caudal produced very similar R^2 values: 0.988 for the linear regression and 0.993 for the binomial regression.

These results indicate that the middle sequence A could be at positions seven or eight (Fig. 2A). The sequence B would correspond to positions 14-19 or 15-20 according to the binomial regression, and to positions 15-20 or 16-21 according to the linear regression. Sequence C could be at positions 24-25 to 26-27, being the position 25-26 a better approximation to both regressions (Fig. 2A).

Length of centrum – The second vertebra in sequence B deviated largely from other vertebrae in this sequence

The analysis of the length values including t caudal indicates that a fourth order polynomial 0.899) was the only equation capable of predict observed values for anterior and posterior vertebr a R^2 value close to 0.9. The resultant from this reg suggests that middle sequences A and B correspo spectively, to positions 14 and 16-21 or 17-22. Se C would also fit position 21-22, since lengths ar to those of the most posterior vertebrae of sequ (Fig. 2B).

Excluding the first caudal, a binomial equati dicted the values with a similar accuracy (R^2 = but the estimated positions for sequences A, B (4, 6-11, and 12-13) are incompatible with the s

TABLE III
Estimated height and length (mm) of non-preserved caudal centra in *Staurikosaurus pricei*.

Estimated position	4	6*	8	9	10	11	12	13	20	21	22	23	26	27	28
Height	23.6	22.5	21.4	20.8	20.3	19.8	19.3	18.8	15.4	14.9	14.4	14.0	12.7	12.2	11.8
Length	23.4	23.8	24.5	24.9	25.3	25.8	26.3	26.7	29.5	29.8	30.0	30.1	30.2	30.1	30.0

*Only a fragment of the centrum of the sixth vertebra was preserved, so that its dimensions were also estimated.

predict the position of the middle sequences. This suggests that sequences A, B, and C correspond to positions 8, 13-18, and 16-17/17-18, and also resulted in overlapping the position of sequences B and C (Fig. 2B).

Height/Length ratio – Binomial regressions predicted the values for anterior and posterior vertebrae with a R^2 of 0.965 (including the first caudal) and 0.988 (excluding the first caudal).

The first caudal vertebra deviated largely from the predicted value (16-22%), but its inclusion or exclusion does not influence the results for the middle sequences, except for sequence A (Fig. 2C). Sequence A could be at position six or seven (based on the equation that excludes the first caudal), or at position five (based on the equation that includes the first caudal), overlapping with the fifth already positioned vertebra. The sequences B and C fit to positions 14-19/15-20 and 24-25, respectively (Fig. 2C).

Size of non-preserved vertebrae – Considering that the most reasonable positions for sequences A, B, and C are, respectively, 7, 14-19/15-20 and 24-25/25-26 (see discussion), new regressions including the data from these vertebrae (Table II) allowed estimating the length and height values for the centrum of non-preserved caudal vertebrae (Table III). The new regressions were generated in order to obtain a single and more precise value for each non-preserved vertebra because the positioning of middle vertebrae relied on two regressions for length and four for height. Also, using these regressions to estimate the size of non-preserved middle vertebrae would produce less precise values because data from preserved middle sequences are not considered. The estimated values were obtained from the resulting regressions: a binomial equation that excludes data from the first caudal (for the length value).

Total caudal length and total body length – The total length of the tail can be estimated by the sum of the length of centra from all vertebrae plus the distance among vertebrae that is occupied by cartilage discs. This distance corresponds to about 10% of the length of the vertebrae (Paul 1988). The estimation, including real values for preserved vertebrae and estimated values for non-preserved ones, indicates that the tail was 1343 mm long. The length of the portion of the tail that comprises vertebrae with transverse processes (vertebrae 1 to ∼25) is 738 mm.

The total length of the body of *Staurikosaurus* can be estimated by the sum of the estimated caudal length and the length of the anterior portion of the body (head to pelvis). As the holotype of *Staurikosaurus* has an almost complete pre-sacral vertebrae series, lacking the three anteriormost cervical vertebrae (Bittencourt and Kellner 2009), the length can be estimated from the length of the preserved vertebrae (accounting for the natural curvature of the trunk and neck), considering also the space of the cartilage discs, plus the length of the mandibles and of the missing cervical vertebrae (it was used the length of the fourth cervical vertebra as a reference). This calculation provided a value of 85-90 cm for the head-pelvis, depending on the inclination of the trunk (10° to 25°; see Fig. 3), so that the total length of *Staurikosaurus* can be estimated as 220 to 225 cm.

DISCUSSION

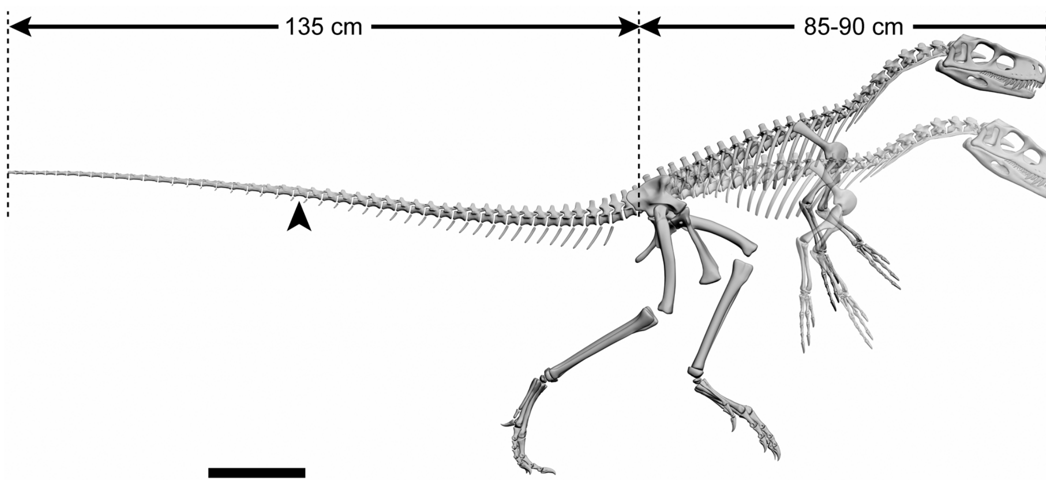

Fig. 3 – Reconstruction of the skeleton of *Staurikosaurus* indicating how alternative postures may change total length estimations. Ar
indicates the position of the most posterior preserved vertebra that has transverse processes (position 25). Scale bar equals 20 cm.

this procedure does not provide accurate and testable ways of predicting vertebral position and, also, does not provide a simple way of estimating dimensions of non-preserved vertebrae in the sequence. The results obtained from the regressions in this work allowed an accurate positioning of the caudal vertebrae in *Staurikosaurus price*.

Comparing results predicted by the fourth order polynomial regressions for length values that include and exclude the first caudal, sequence A could be positioned anywhere between positions 8 and 14. These equations also predict that the first vertebra of sequence B would be in position 13 to 17. The centrum height and width of the vertebra of sequence A are much larger than those of the first vertebra in sequence B. Also, the vertebra of sequence A is quite similar in size to the fifth caudal vertebra and has a general morphology similar to the more anterior vertebrae. This indicates that sequence A should correspond to a more anterior position, suggesting that the results predicted by the equations that exclude the first caudal are more accurate. This result is also in agreement with the regression of the height values that indicates that this vertebra corresponds to position seven or eight. Also, analyzing the regression for the height/length ratio, it can be observed

cordingly, regressions that do not include the first
should provide more accurate results. This does n
essarily suggest that this vertebra should be con
a sacral; this conclusion needs to be based on a
ical studies since sacral vertebrae have modified
verse processes and ribs that allow them to c
to the ilium (Williston 1925, Romer 1956). Seve
thors, based on anatomical analyses of vertebr
also pelvic bones, discussed the classification
vertebra as the third sacral (Langer 2004, Lang
Benton 2006, Bittencourt and Kellner 2009), or t
caudal (Colbert 1970, Galton 1977, 2000) and n
rerasaurid material (Alcober and Martinez 201
contribute to clarify this question. We consider t
divergence in dimensions compared to predicted
is associated with the difference in dimension
centrum of the second sacral vertebra relative to t
ond caudal (as defined in this work), being much
in the former. The dimensions of the centrum of t
caudal (or third sacral) correspond to a transitio
between these two vertebrae.

Considering that regressions that exclude t
caudal are more accurate, sequence A would mos
ably belong to positions six to eight, as it is pr
by regressions of the three analyses (height, leng

dicted height values, and position eight would not fit the height/width ratio estimation. Changing it to a more anterior or posterior position would reduce the deviation for one regression, but increases the deviation for the other.

The position of sequence B is also better predicted by the regressions that exclude the first caudal. The binomial regressions for height and height/length values both indicate that the position of sequence B is either 14-19 or 15-20. Linear regression for height values suggests a slightly posterior position (16-21), but the regression of length values indicates a more anterior position (13-18). Furthermore, both equations are predicting the position of sequence B with less accuracy than binomial regressions for height and height/length values, and the sequence B should, therefore, be considered as corresponding to vertebrae 14-19 or 15-20.

The sequence C is positioned as 24-25 or 25-26 according to regressions of height and height/length values, but the regression of length values indicates a much more anterior position (16-17 or 17-18). When the first caudal is included in the length value analysis, the regression indicates that sequence C should be at position 21-22. These results for length values are inconsistent with the position predicted for sequence B (14-19 or 15-20) because an obviously impossible overlap would occur. Thus, the most probable scenario would be that of the vertebrae in sequence C being shorter than the prediction, and they shall belong to position 24-25 or 25-26.

Considering the most probable positioning for sequences A, B and C as being 7, 14-19/15-20 and 24-25/25-26, respectively, it is possible to conclude that the binomial regression for height values produced the most precise results, even if the first caudal is included in the analysis. Also, the binomial regression of height/length values provided accurate results for the three sequences when the first caudal was excluded.

The position of the middle sequence C, which is the most posterior sequence in which transverse processes are present, indicates that at least ∼25 caudal vertebrae have this structure. The vertebrae that follow cesses. According to Galton (1977), *Staurikosaurus* had a total of 45 or more caudal vertebrae from which about 20 had transverse processes, which differs from the present results.

Gatesy (1990) suggested that transverse processes correspond to the area of insertion of the muscle *caudofemoralis longus*, so that the number of vertebrae that have this process would be an indicative of the length of this muscle. In *Staurikosaurus* this muscle would insert in the 25 most proximal caudal vertebrae and, consequently, it was larger than it was supposed by previous studies. Considering that *Staurikosaurus* had just 20 vertebrae with transverse processes (according to Colbert 1970, Galton 1977), the area of insertion of the muscle *caudofemoralis longus* would be 543 mm long, which corresponds to 74% of the estimated length in the present study. This muscle is generally the bulkier in archosaurs and it helps to balance the anterior part of the body (Gatesy 1990). Consequently, it has a major importance in the question of positioning the center of mass because a longer muscle would move the center of mass posteriorly. Also, a longer insertion area may increase the moment arm for this muscle, and this also may have implications in posture and locomotion patterns adopted by *Staurikosaurus*. Biomechanical studies are required to evaluate these hypotheses, but these observations point to the importance of the correct estimation of each body part for biomechanical studies that require the estimation of total body mass and, more importantly, the correct positioning of the center of mass (Allen et al. 2009). We believe that our method may be applied to dorsal and cervical vertebrae as well. In this case, it would also contribute to correctly estimate dimensions of body parts such as the trunk and neck in other taxa, increasing the precision in the skeletal reconstructions used in biomechanical studies.

This methodology may also be useful to estimate some character states used in systematic studies. Gauthier (1986) and Rauhut (2003) included in their analysis data of the number of caudal vertebrae that have transverse processes. Our result on the number of transverse processes in the caudals of *Staurikosaurus*, condition, and smaller numbers as derived conditions. Gauthier (1986) does not mention the number of vertebrae that have transverse processes in the plesiomorphic condition, just indicating that theropods have less than half vertebrae with this structure, and that transverse processes are restricted to the base of the tail in Maniraptora. Considering the definition made by Gauthier (1986), the condition of *Staurikosaurus* would be derived if it had 20 of 47 vertebrae with transverse processes, but our results point that it has the plesiomorphic condition, with more than half vertebrae having this structure.

These observations suggest that the correct positioning of preserved vertebrae may be important to define a character state on some taxa that do not have a complete series of vertebrae, because characters, other than presence of transverse processes, may vary along vertebral series and may be included in systematic analyses.

Considering the dimensions of other skeletal elements (mandible and cervical, dorsal, and sacral vertebrae), it was estimated that *Staurikosaurus* had a total body length of 220-225 cm, from which 60% would correspond to the tail. By comparison, in *Herrerasaurus* the tail corresponds to 54%, which was calculated from the skeletal reconstruction presented by Sereno (1993). The total body length estimated here is much larger than it was supposed by Colbert (1970), who proposed a length of 160 cm for *Staurikosaurus*. However, it is close to what was estimated by Paul (1988). He estimated that *Staurikosaurus* was 208 cm long, and the tail would have 125 cm (in contrast to ∼135 cm in the present work), so that the 10 cm difference in tail length from the value presented in this study accounts for most of the divergence.

Other length estimation methods (Christiansen 1999, Therrien and Henderson 2007), which are based on the length of the femur, tibia or head (here estimated from the mandible length), suggest that *Staurikosaurus* had a total length varying from 1.99 to 2.57 m. All these methods are based on data from neotheropod dinosaurs, but the present results fit well in the middle of this range.

The methodology employed here to estim
missing data in the holotype of *Staurikosaurus*
a useful way of estimating the total body length
as parts of the body of other fossil vertebrates. T
of complete vertebral series is extremely comm
an empirical methodology for the estimation o
ing data is necessary to obtain better and more
measurements.

Despite the benefits of the use of our metho
it is important to point out that it has limitatio
requirements to be properly applied:

1) The problem of determining the total num
vertebrae is the first limitation of the tec
This assumption is necessary and needs to b
on closely related taxa and, consequently,
sents a consideration that may hide possib
ation among taxa;
2) The preserved vertebrae must comprise th
rior and most posterior vertebrae, but the
sary number in each sequence is uncertain a
be determined by the analysis of complete
mens from the most exclusive supraspecifi
that includes the specimen being analyze
analyses with *Staurikosaurus* indicated regr
based on height data including just the poste
quence (19 or even just the 17 posteriorm
tebrae), provided accurate estimations for t
served anterior vertebrae. However, this v
observed with length data. In this case it w
essary to include data on at least three anter
tebrae to obtain a regression compatible w
results suggested by height values;
3) Deviation of dimensions relative to predict
ues contributes to reduce or increase the ac
of the methodology. As deviation increases
increases the number of vertebrae that must
served in order to obtain accurate results.
served that deviations in length values ar
larger than that of heights in *Staurikosau*
pecially in the posterior sequence, and the
were less precise with the former data.

equation may vary from one taxon to the other. Variation in length values should not be necessarily described by a fourth order polynomial equation. If a binomial equation describes accurately length values and deviation is small, data from just posterior vertebrae may be sufficient, even though the analysis with other taxa is necessary to evaluate this supposition.

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RESUMO

Dados lacunares são um problema comum na paleontologia. Eles dificultam a reconstrução acurada de táxons extintos e limitam a inclusão de alguns táxons em estudos comparativos e biomecânicos. Particularmente, estimar a posição de vértebras em séries incompletas tem sido feito com base em métodos não empíricos que não permitem estimar corretamente as partes ausentes. Neste trabalho apresentamos uma metodologia que permite estimar a posição de sequências médias preservadas de vértebras caudais no dinossauro saurísquio *Staurikosaurus pricei*, com base no comprimento e altura dos centros das vértebras anteriores e posteriores preservadas. Equações de regressão foram usadas para estimar essas dimensões para as vértebras médias e, consequentemente, para posicionar as seàs posições 1-3, 5, 7, 14-19/15-20, 24-25/25-26 e 29-47, e que pelo menos 25 vértebras possuíam processos transversos. O comprimento total da cauda foi estimado em 134 cm e o comprimento total do corpo em 220-225 cm.

Palavras-chave: dados lacunares, vértebra caudal, regressão, *Staurikosaurus pricei*.

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