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Bone Anatomy of the Thoracic Limb in the Common Hippopotamus (*Hippopotamus amphibius*) and White Rhinoceros (*Ceratotherium simum*)

Anatomía Ósea del Miembro Torácico en el Hipopótamo Común (*Hippopotamus amphibius*) y el Rinoceronte Blanco (*Ceratotherium simum*)

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SUMMARY: Although megaherbivores do not belong to the Brazilian fauna, they can be found in national zoos, which makes it important to know the anatomy of the locomotor apparatus to contribute to the clinical routine of zoos and veterinary rehabilitation centers. Thus, the aim of this study was to describe the anatomical structures of the thoracic limb bones in the common hippopotamus (*Hippopotamus amphibius*) and white rhinoceros (*Ceratotherium simum*) and to compare them with the bone structures described for other ungulates. The scapula had a triangular appearance in the common hippopotamus, whereas in the white rhinoceros it had a rectangular appearance. The acromion was observed only in the common hippopotamus scapula. The hippopotamus humerus did not have the intermediate tubercle, only the greater and lesser tubercles, unlike the rhinoceros which also has the intermediate tubercle. The two megamammals studied had an ulna not incorporated to the radius and seven carpal bones distributed in two bone rows. The common hippopotamus had four digits and four metacarpal bones, while the white rhino had three digits, hence three metacarpal bones. Although with some species-specific differences, the bone anatomy found in the studied megaherbivores was similar to that described for domestic ungulates, such as horses and cattle. The fact that the bones studied belong to articulated skeletons of the collection of the Museum of Anatomy made it difficult to identify some anatomical structures. This study can help veterinarians in bone health care, animal welfare and comfort of such species present in Brazilian zoological parks.

KEY WORDS: Hippopotamus; Megaherbivores; Osteology; Rhino; Thoracic limb.

INTRODUCTION

Ungulates mammals are characterized by the presence of a hoof with a digital appendage. These animals stand on the hoofed distalmost phalanx (Clifford, 2010). They are subdivided into two orders: artiodactyls, such as the common hippopotamus and cattle, and perissodactyls, such as white rhinoceros and horses (Miller & Fowler, 2012). Hippopotamuses are artiodactyls mammals of the Hippopotamidae family that comprises two species: the common hippopotamus (*Hippotamus amphibius*) and the pygmy hippopotamus (*Hexaprotodon liberiensis*). The latter has a much smaller size compared to the common hippopotamus and is rarer (Pachaly & Monteiro-Filho, 2014). Rhinoceros belong to the Rhinocerothidae family, which has five species, two from Africa and three from Asia. The African species are black rhinos (*Diceros bicornis*) and white rhinos (*Ceratotherium simum*). The Asian species are Indian rhinos (*Rhinoceros unicornis*), Javan rhinos (*Rhinoceros probeicus*) and Sumatran rhinos (*Dicerorhinus sumatrensis*). Rhinoceroses inhabit savannas, shrubby regions and dense forests in tropical and subtropical regions. In addition, they are ungulates with an odd number of toes that support their body weight on their three digits and, unlike other perissodactyls, do not have a guttural pouch (Malta *et al*., 2014).

Some studies on the locomotor apparatus anatomy of rhinos and hippopotamus have been published. There are studies about the bone pathology in the rhinos foot

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(Galateanu *et al*., 2013; Regnault *et al*., 2013), radiography anatomy of the white rhinoceros hind foot (Dudley *et al*., 2015), morphofunctional study of the shape variation of the limb long bones using dimensional geometric morphometrics (Mallet *et al*., 2019), an influence of body mass in the morphological integration of the limb long bones (Mallet *et al*., 2020), and limb myology and muscle architecture (Etienne *et al*., 2021). In addition, regarding hippopotamus, there are descriptions of the muscular anatomy of the thoracic limbs in the pygmy hippopotamus (Fisher *et al*., 2007), pelvic limbs in the common hippopotamus (Fisher *et al*., 2010), three-dimensional computed tomography examination of the hand (manus) and feet in the hippopotamus during a semiaquatic walking (Endo *et al*., 2019), and a morphofunctional examination of the carpal bones of pygmy hippopotamus (Georgitsis *et al*., 2022).

Although rhinoceros and hippopotamus are not part of the Brazilian fauna, they can be found in national zoos. Therefore, it is important to know the anatomy of the locomotor system to support the clinical routine of zoos and veterinary rehabilitation centers. Thus, this study aims to describe the bone structures of the hippopotamus and rhinos thoracic limbs, aiming to collaborate with the management and clinical care for captive megaherbivores in the zoo and rehabilitation centers.

MATERIAL AND METHOD

The skeletons of common hippopotamus (*Hippopotamus amphibius*) and white rhinoceros (*Ceratotherium simum*) were used in this study. The articulated skeletons belonging to the collection of the Museum of Veterinary Anatomy Prof. Dr. Plínio Pinto e Silva, School of Veterinary Medicine and Animal Science, University of São Paulo, USP. The skeletons were from animals in Brazilian zoological parks, that died of natural causes, or from clinical complications compatible with their age, respecting the welfare and biology of the specimens. The white rhino skeleton belonged to an eight- year-old female, with body mass of approximately 230 kilograms according to museum's information. There was no information regarding the hippopotamus skeleton in the Veterinary Anatomy Museum archives, except that it was from the Zoological Park of the Municipality of São Paulo and arrived at the Museum in the 1970s. The images were taken without moving the articulated skeletons at their exhibition site inside the Museum, according to the physical possibility. Cranial and medial views were difficult to reach because the skeletons are articulated. The forelimb bones were described and the bone structures identified and named according to the Nomina Anatomia Veterinaria (International Committee on Veterinary Gross Anatomical Nomenclature, 2017).

RESULTS

The thoracic limb bones in the common hippopotamus and white rhinoceros were represented by the scapula, humerus, radius, ulna, carpus, metacarpus and digits. No clavicle was observed in the animals of this study.

In the common hippopotamus, the scapula was flat and triangular, with its wide and thick cranial margin, and having rounded and irregular angles. The lateral surface presented the spine of the scapula with a large spine tuberosity of the scapula, which continued tapered to the acromion, had a rounded characteristic and prominently surpassed the scapular neck. The spine of the scapula divided the lateral face into two fossae: supraspinous and infraspinous fossae. The infraspinatus fossa had a rounded appearance, being more extensive than the supraspinatus fossa, which had an oval appearance with an irregular margin. The supraglenoid tubercle was slightly triangular in lateral view. The scapula showed three angles: cranial, caudal and ventral. The ventral contained the glenoid cavity that articulated with the head of the humerus in forming the shoulder joint. This cavity had a shallow convexity and a slightly deeper one (Fig. 1). In the white rhinoceros, the scapula was shaped like a rectangle. The spine of the scapula had an important tuberosity in the proximal region of the spine, with an irregular and rough margin, continuing to taper the spine, being smoothed up to the distal part of the bone, with the absence of the acromion. The infraspinatus and

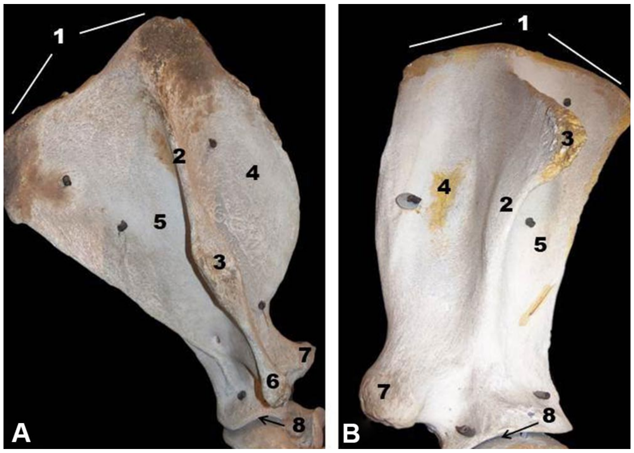

Fig. 1. Lateral views of scapula in the common hippopotamus (A) and in the white rhinoceros (B). 1, dorsal margin of scapula; 2, spine of the scapula; 3, spine tuberosity; 4. supraspinous fossa; 5, infraspinous fossa; 6, acromion; 7, supraglenoid tubercle; 8, glenoid cavity.

supraspinatus fossae had rectangular aspects, being almost the same size in centimeters. However, the supraspinatus fossa was slightly larger and with rough areas, while the infraspinatus fossa was smaller and smooth. The scapular neck was extensive and smooth, approaching the size of the glenoid cavity. The supraglenoid tubercle was slightly bulky and had a rough appearance. The glenoid cavity was wider than that presented by the hippopotamus, with a slight shallow convexity (Fig. 1).

The humerus was a long bone in two species of this study. The proximal epiphysis of the humerus in the common hippopotamus presented three eminences: greater and minor tubercles, and head of the humerus. The greater tubercle was lateral. The head is rounded, concave, and slightly short compared to the greater and minor tubercles. The humeral neck showed a smooth appearance. The humeral shaft (diaphysis) was smooth and curved. The deltoid tuberosity appeared in the cranial margin of the humerus and it was rough, slightly rectangular, but irregular. In the distal epiphysis of the bone, the shallow radial fossa, not as deep, was observed, and was located between the lateral and medial epicondyles, in the ventral view. Dorsally, the olecranon fossa was observed, it was deep and oval, centralized and divided by the lateral and medial epicondyles, which had an irregular, and oval aspect (Fig. 2). In the white rhinoceros, the proximal epiphysis of the humerus presented four eminences: greater, minor and intermediate tubercles, and head of the humerus. The humeral head was small and concave, its neck was tapered, and its tubercles were irregular. The humeral shaft was smooth, widest in the region of the proximal epiphysis, and was smooth andnarrow to the epicondyles in the distal epiphysis. The medial and lateral epicondyles were irregular and rounded in appearance. The radial fossa was shallow on the ventral aspect of the bone, and the olecranon fossa was also shallow compared to the common hippopotamus (Fig. 2).

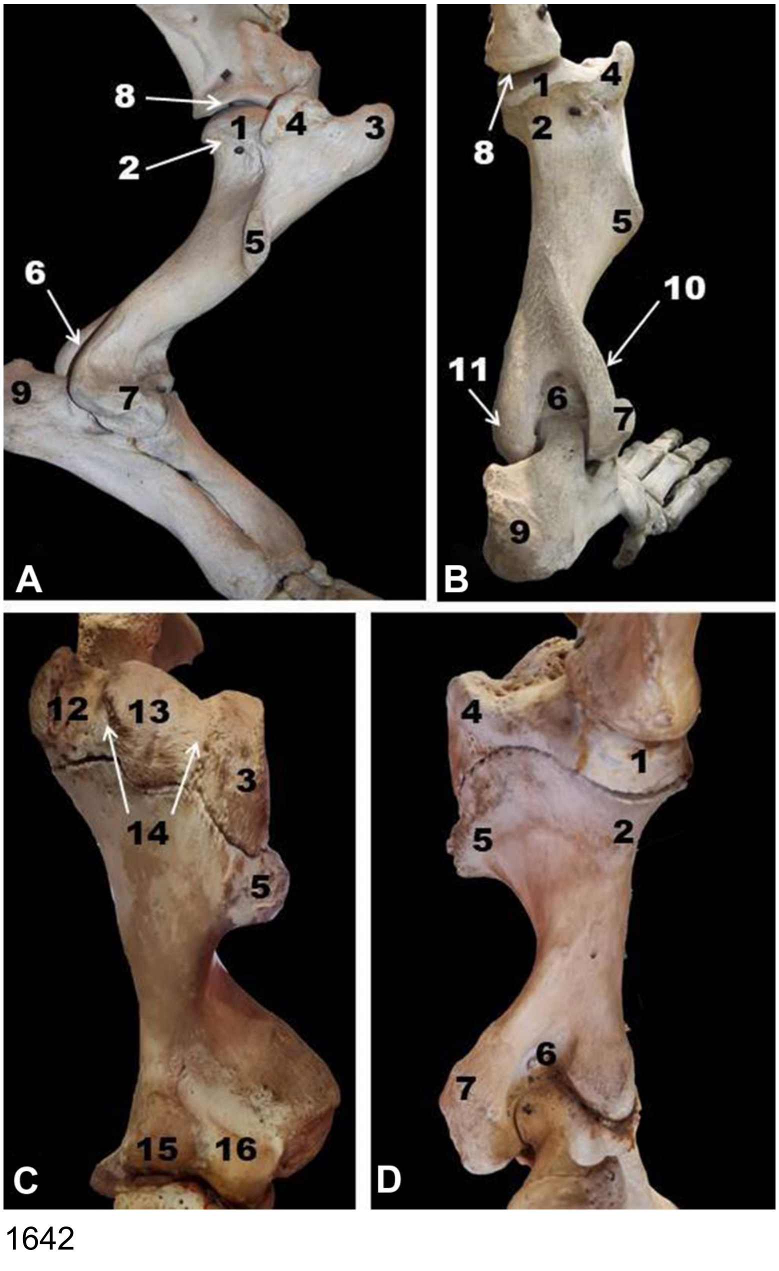

Fig. 2. Lateral (A) and caudal (B) views of hippopotamus humerus. Cranial (C) and caudal (D) views of rhinoceros humerus. 1, head of the humerus; 2, humeral neck; 3, cranial part of the greater tubercle; 4, caudal part of the greater tubercle; 5, deltoid tuberosity; 6, olecranon fossa; 7, lateral epicondyle; 8, glenoid cavity of the scapula; 9, olecranon; 10, epicondylar crest; 11, medial epicondyle; 12, minor tubercle; 13, intermediate tubercle; 14, bicipital sulcus; 15, trochlea; 16, capitulum.

In this study, the two species presented an ulna independent of the radius. Thus, radio-ulna bones articulated at their limbs, leaving an interosseous space between their diaphysis. The ulna exceeded the length of the radius in two megaherbivores studied. In the common hippopotamus, the ulna was a long bone with a more regular, and prominent olecranon when compared to the rhinoceros olecranon. The process anconeus was rounded and short. Apparently, the trochlear notch was deep and with adequate circumference to articulate with the humerus. The shaft of the ulna was uniformly wide and short. The distal epiphysis showed an irregular appearance. The styloid process of the ulna was almost straight, and subtly tapered as it ended the bone. The radius of the common hippopotamus was smaller than the ulna. On its proximal epiphysis was the trochlear notch which fused with the ulna at a slight angulation. The articular fovea of the radius was concave and shallow. The radial tuberosity was almost imperceptible, and its diaphysis was wide, short and uniform. At the distal epiphysis of the radius, the trochlea was slightly pointed towards the carpals. The distal epiphysis of the radius and ulna was almost fused, with irregular margins (Figs. 3 and 4). Compared to the white rhinoceros, the ulna was larger than the radius, but thinner. The ulna at its proximal epiphysis had a wide olecranon, with irregular margins and an almost square shape, and a notable olecranon tuber. The trochlear notch was discreet. The diaphysis of the ulna was a smooth and uniform structure. In the distal epiphysis of the ulna, the ulnar styloid process was observed, which was porous and irregular. The radio of white rhino had a wide proximal epiphysis with a shallow radius joint fovea. The radial tuberosity presented a small relief. The diaphysis was smooth, curved, and had an important interosseous space. The radial styloid process found in the distal epiphysis was irregularly shaped (Figs. 3 and 4).

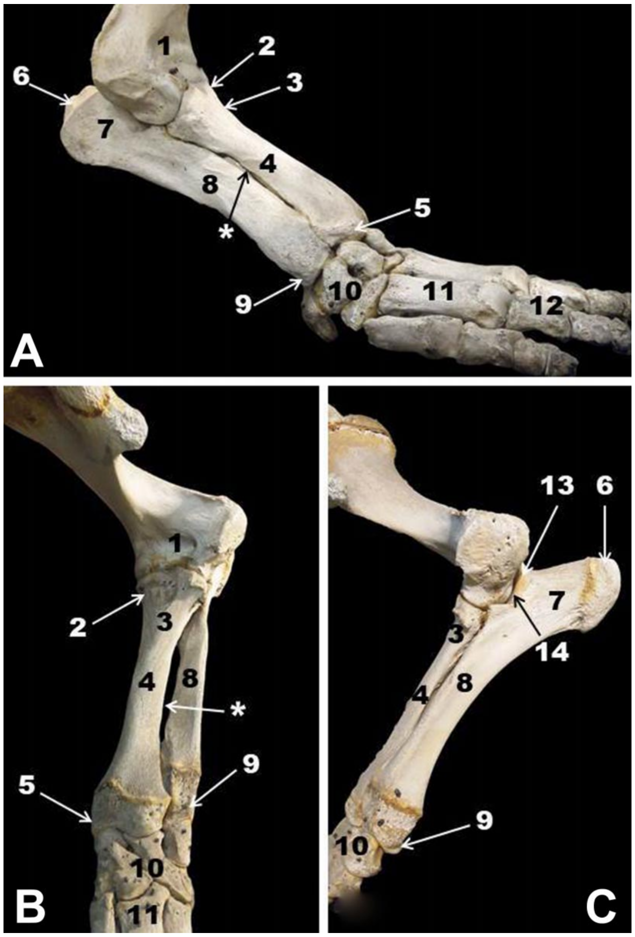

Fig. 3. Lateral view (A) of radio-ulna bones in the hippopotamus. Cranial (B) and craniolateral (C) views of radio-ulna bones in the rhinoceros. 1, radial fossa of humerus; 2, radial tuberosity; 3, radial head; 4, radial diaphysis; 5, styloid process of radius; 6, olecranon tuberosity; 7, olecranon; 8, diaphysis of the ulna; 9, styloid process of ulna; 10, carpal bones; 11, metacarpal bones; 12, phalanges; 13, anconeus process; 14, trochlear notch; asterisk, interosseous space.

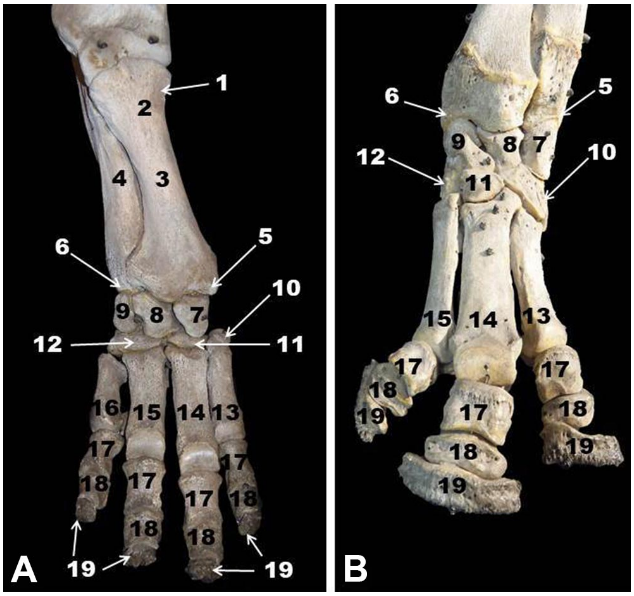

Fig. 4. Cranial views of radio-ulna and hand bones in the hippopotamus (A) and rhinoceros (B), 1, radial tuberosity; 2, radial head; 3, radial shaft; 4, shaft of the ulna; 5, styloid process of radius; 6, styloid process of ulna; 7, radial carpal bone; 8, intermediate carpal bone; 9, ulnar carpal bone; 10, second carpal bone; 11, third carpal bone; 12, fourth carpal bone; 13, second metacarpal bone; 14, third metacarpal bone; 15, fourth metacarpal bone; 16, fifth metacarpal bone; 17, proximal phalange; 18, middle phalange; 19, distal phalange.

The skeleton of the hand consisted of carpal and metacarpal bones. The carpus in the common hippopotamus and the white rhinoceros was composed of seven bones, distributed in two rows. The proximal (or antebrachial) row comprised the radial, intermediate, ulnar, and accessory carpal bones, while the distal (or metacarpal) row comprised the second, third, and fourth carpal bones (Figs. 4 and 5). The fourth carpal bone of rhinoceros showed a remarkable caudal process (Fig. 5). No sesamoid bones were observed in the animals in this study. The common hippopotamus showed four metacarpal bones, while the white rhinoceros had three metacarpal bones. Regarding the digits bones, four digits were observed in the hippopotamus and three digits in the rhinoceros. Each digit included three phalanges: proximal, middle and distal phalanges. In the common hippopotamus, the proximal phalanges were longer than the other phalanges, but with similar widths. The middle phalanges were shorter than the proximal ones and the distal phalanges had a semilunar shape (Figs. 4 and 5). In the white rhino, the proximal phalanges were rectangular, smooth on their cranial surface, with the proximal and distal ends more elongated, to articulate with the metacarpals and middle phalanges. In turn, the middle phalanges were short but wide. The distal phalanges were almost twice the width of the middle phalanx (Figs. 4 and 5).

DISCUSSION

In this study, we have described the osteology of the thoracic limb in the ungulate megaherbivores common hippopotamus (Hippopotamus amphibious) and white rhinoceros (*Ceratotherium simum*) of the articulated skeletons of a Brazilian museum. The term ungulate refers to hoofed animals, comprising about one-third of all living and extinct mammalian genera. Ungulates include Perissodactyls such as rhinoceros, horses, and tapirs, and Artiodactyls such as hippopotamus, deer, camels, pigs, and cattle. Etienne *et al*. (2021) stated that the thoracic limbs of rhinoceros (Indian and white rhinoceros) are stronger than the pelvic limbs and that this is probably due to the great support of body weight and that this differs from horses which also are perissodactyls. According to these authors, the strongest muscles are located in the proximal region of the thoracic limb, which is advantageous, as it allows the muscles to have a greater volume due to the anatomical space available in the proximal region of the limb and in the trunk, and also because the large concentration of muscle mass in the proximal region of the limb, prevents the animal from having heavy distal segments, which would make locomotion difficult. And these muscles are fixed, having origin or insertion, in the bones of the proximal regions of the thoracic limb such as the scapula and humerus.

The scapula is a flat, oval, irregular bone that is attached obliquely to the cranial part of the thoracic wall and articulates distally with the head of the humerus through the glenoid cavity. In this study, the common hippopotamus had a triangular-shaped scapula, while the white rhinoceros, in turn, had a more rectangular-shaped scapula. This shape of the scapula in the white rhinoceros is different from that found in the horse (König & Liebich, 2021), although both are perissodactyls. The scapula is usually triangular in shape, as described for other wild animals such as the Patagonian huemul deer (Salinas *et al*., 2020). In the two species studied, the lateral face is divided by the spine of the scapula, which is quite elongated and prominent, as in ruminants (König & Liebich, 2021). The supraspinous fossa is smaller when compared to the infraspinous fossa. The supraspinous and infraspinous fossae are the sites of origin for the supraspinatus and infraspinatus muscles, respectively. These muscles are the strongest muscles in the shoulder region of rhinoceros, playing an important role in extending and stabilizing the scapulohumeral joint (Etienne *et al*., 2021).

The tuberosity of the spine of the scapula was observed on the lateral aspect of the scapula, which serves as an insertion for the trapezius muscle

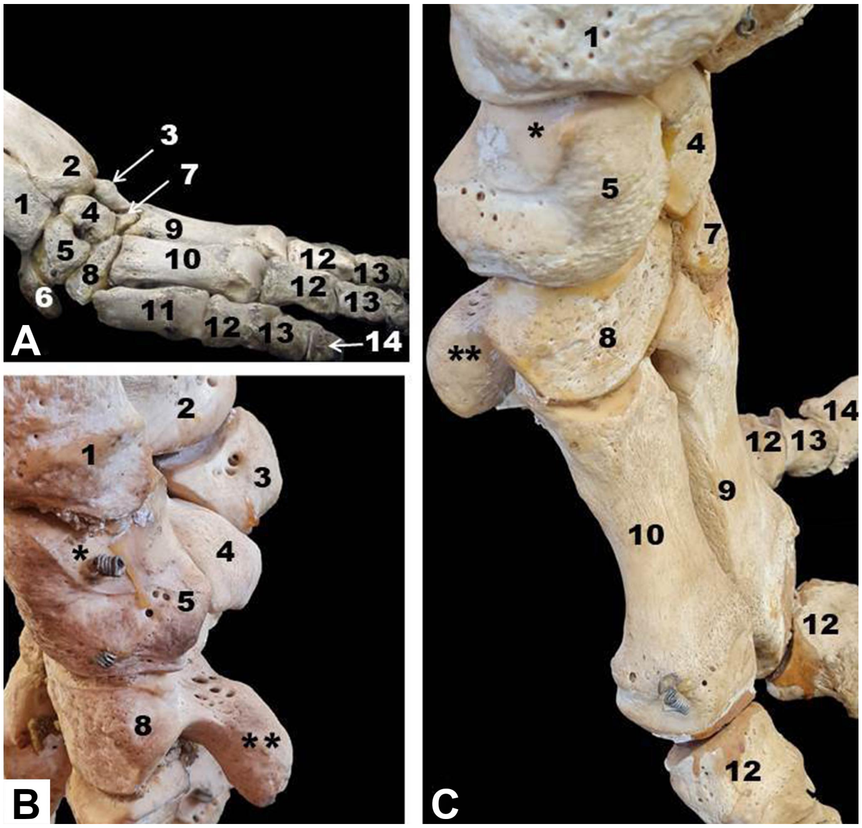

Fig. 5. Lateral view (A) of the hand bones in the hippopotamus. Caudolateral (B) e craniolateral (C) views of the hand bones in the rhinoceros. 1, distal epiphysis of the ulna; 2, distal epiphysis of the radius; 3, radial carpal bone; 4, intermediate carpal bone; 5, ulnar carpal bone; 6, accessory carpal bone; 7, third carpal bone; 8, fourth carpal bone; 9, third metacarpal bone; 10, fourth metacarpal bone; 11, fifth metacarpal bone; 12, proximal phalange; 13, middle phalange; 14, distal phalange; asterisk, articular surface to accessory carpal bone; asterisks, caudal process of the fourth carpal bone.

(Fisher *et al*., 2007). The common hippopotamus presented the acromion, similar to that found in in the pygmy hippopotamus (Fisher *et al*., 2007), and in the Patagonian huemul deer (Salinas *et al*., 2020), whereas the white rhinoceros did not have an acromion. The acromion represents the site of origin of the acromial part of the deltoid muscle (Fisher *et al*., 2007; Etiene *et al*., 2021). Thus, in these mammals that present acromion, the deltoideus muscle is subdivided into pars acromialis and pars scapularis in both pygmy and common hippos (Fisher *et al*., 2007). Moreover, the absence of acromion in the white rhinoceros could suggest that the shoulder joint has reduced motility, with limited movements (Salinas *et al*., 2020). According to Kardong (2019), the abduction capacity of the shoulder joint is based on the presence of an acromion.

The humerus is a typical long bone and presented two epiphyses (proximal and distal) and a diaphysis (shaft). The proximal epiphysis articulates with the glenoid cavity of the scapula, and the distal epiphysis articulates with the radius and ulna (König & Liebich, 2021). The greater and minor tubercles have been observed on the proximal epiphysis of the common hippopotamus, and a single intertubercular groove, since there is no intermediate tubercule. This anatomical feature is similar to that described of Patagonian huemul deer (Salinas *et al*., 2020) and cattle (König & Liebich, 2021). The white rhino humerus presented three eminences in the proximal epiphysis: greater, intermediate, and minor tubercules, and a intertubercular groove divided into two parts, similar to that reported for the horse, which has the intertubercular sulcus divided into two parts by the presence of the intermediate tubercle (König & Liebich, 2021). The humeral shaft is cylindrical and the deltoid tuberosity is located on its lateral surface, which has a rough appearance and was highly developed in the two species of megamammals studied. The deltoid tuberosity represents the insertion site of the deltoid muscle (Fisher *et al*., 2007; Etienne *et al*., 2021). The deltoid muscle flexes and abducts the scapulohumeral joint (Fisher *et al*., 2007). On the medial surface of the humerus, it was possible to observe the greater round tuberosity, which corresponds to the insertion site of the teres major and latissimus dorsi muscles (Fisher *et al*., 2007; Etienne *et al*., 2021). The latissimus dorsi muscle found in rhinos is much stronger than the homonymous muscle seen in horses (Etienne *et al*., 2021). The distal epiphysis of the humerus in the animals studied did not show differences in relation to that reported for this region in other animals such as wild animals (Salinas *et al*., 2020), and domestic animals (König & Liebich, 2021).

The radius-ulna bones are closely united in the common hippopotamus, with a small interosseous space, whereas in the white rhinoceros, the radius and ulna have a larger interosseous space. In any case, the ulna can be visualized in its entirety similar to what occurs in ruminants such as Patagonian huemul deer (Salinas *et al*., 2020) and cattle and, unlike what is found in horses, where the ulna fuses with the radius (König & Liebich, 2021). The fusion of the ulna with the radius, when it occurs, prevents supination and pronation movements in domestic mammals such as horses (Singh, 2019). Therefore, the radius and ulna of the megaherbivores studied, are strong and long bones. Probably the strong shape of these bones such as the humerus is associated with body mass of these megaherbivores (Mallet *et al*., 2019).

The radius is a long bone that articulates proximally with the distal articular surface of the humerus and the ulna, and distally articulates with the ulna and the proximal row of carpal bones. In the proximal epiphysis of the radius, the radial tuberosity can be observed, which appeared in the radius of the two megamammals studied herein. The radial tuberosity represents the insertion site of the biceps brachii muscle. This muscle originates from the supraglenoid tubercle of the scapula, passes through the intertubercular sulcus of the humerus, and inserts into the radial tuberosity of the radius (Fisher *et al*., 2007; Etienne *et al*., 2021). The biceps brachii muscle is a powerful muscle that promotes flexion of the scapulohumeral joint and flexion of the forearm (Etienne *et al*., 2021). This area of insertion of the biceps brachii muscle is more developed and robust in animals with high body mass such as rhinos (Mallet *et al*., 2019; Etienne *et al*., 2021).

The ulna articulates proximally with the humerus and radius and distally with the proximal row of carpal bones. The ulna has a proximal epiphysis that projects beyond the articular surface to form the olecranon. The olecranon constitutes a reference point in the thoracic limb of the animals and represents the place of attachment of the triceps brachii muscle and it was well developed in the animals of this study. The triceps brachii muscle is formed by three heads in common hippos and white rhinos, all of them inserted in the olecranon (Fisher *et al*., 2007; Etienne *et al*., 2021). This muscle, especially the long head, is among the strongest muscles in these animals. Probably, the action of the powerful triceps brachii, biceps brachii, infraspinatus, and supraspinatus muscles is of great importance for supporting the thoracic limb of rhinos against the action of gravity (Etienne *et al*., 2021).

According to Clifford (2010), ungulates mammals are those that stand on the hoofed distal-most phalange. The skeleton of the hand (autopodium) is composed of the carpal and metacarpal bones and, the digitis bones (acropodium) are composed of proximal, middle, and distal phalanges (Salinas *et al*., 2020). The carpal bones are arranged in two rows: one proximal and one distal. The proximal row is formed, in mediolateral sequence, by the radial carpal (or scaphoid), intermediate carpal (or lunate), ulnar carpal (or triquetrum), and accessory carpal (or pisiform) bones, while the distal row consists of the first carpal (or trapezium), second carpal (or trapezoid), third carpal (or capitate) and fourth carpal (or hamate) bones (International Committee on Veterinary Gross Anatomical Nomenclature, 2017). The proximal row articulates with the radius and ulna at the antebrachiocarpal joint, and the distal row articulates with the metacarpal bones to form the carpometacarpal joint. In this study, the common hippopotamus and the white rhinoceros presented all the carpal bones ofthe proximal row (radial carpal, intermediate carpal, ulnar carpal, and accessory carpal bones). In the distal row, the megaherbivores studied showed second carpal, third carpal, and fourth carpal bones. The same bones in the proximal and distal rows were described for other ungulates such as pygmy hippopotamus (Fisher *et al*., 2007; Georgitsis *et al*., 2022), rhinos (Galateanu *et al*., 2013), tapir (MacLaren & Nauwelaerts, 2017; Pereira *et al*., 2017), Patagonian huemul deer (Salinas *et al*., 2020), and pigs (König & Liebich, 2021).

The common hippopotamus and white rhinoceros of this study have four and three metacarpal bones, respectively, always named from medial to lateral. The hippopotamus are semiaquatic artiodactyls (Fisher *et al*., 2007) and the rhinoceros are perissodactyls such as equids and tapirs (MacLaren & Nauwelaerts, 2017). The third and fourth metacarpal bones are larger when compared to second and fifth metacarpal bones in the common hippopotamus, similar to described for other artiodactyl such as pig, which also has four metacarpal bones in the forelimb (König & Liebich, 2021), and different from the reported to ruminant artiodactyl Patagonian huemul deer that present two metacarpal bones (Salinas *et al*., 2020). The perissodactyl white rhinoceros present three metacarpal bones, being the third metacarpal bone larger than others metacarpals. This anatomical feature was described in the previous study about imaging diagnosis of bone pathology in distal limb in the rhinos (Galateanu *et al*., 2013), despite that of Brazilian tapir that are perissodactyl mammal and present four metacarpal bones in the hand (MacLaren & Nauwelaerts, 2017; Endo *et al*., 2019).

In the digits of the animals in this study, three phalanges were found: proximal, middle and distal, which is similar to that described for other wild ungulates such as tapir (MacLaren & Nauwelaerts, 2017; Endo *et al*., 2019), and Patagonian huemul deer (Salinas *et al*., 2020), and domestic ungulates animals such as horses, cattle and pigs (König & Liebich, 2021). Sesamoid bones were not observed in the animals in this study, although described for the pygmy hippopotamus (Fisher *et al*., 2007) and rhinoceros (Galateanu *et al*., 2013), perhaps because this study was carried out on skeletons from the Museum's collections and these bones have been lost over time, although Regnault *et al*. (2013) also did not cite distal sesamoid bones in white and black rhinos.

The dorsal aspect of the phalanges represents the insertion site for the common digital extensor and lateral digital extensor muscles, while the palmar aspect of the phalanges is the insertion site for the superficial digital flexor (in the middle phalanges) and deep digital flexor (in the distal phalanges) muscles (Etienne *et al*., 2021). In addition to these extrinsic hand muscles, otherintrinsic hand muscles also insert into the phalanges, such as the muscles described for the pygmy hippopotamus by Fisher *et al*. (2007). For these authors, these intrinsic muscles correspond, for example, to the short digital flexor, lumbricals, digit V abductor, digit V adductor, digit II adductor, interosseous muscles. Endo *et al*. (2019) suggested from a study on hippopotamus and tapirs, using computed tomography, that the mediolateral widening of the hand and foot of these animals, adductor-abductor motility, could be adaptations for hippopotamus locomotion during a semiaquatic walking. According to these authors, when walking in water, the mediolateral movement (abduction and adduction) of the phalanges could reduce water resistance and could stabilize the body on wet land or bodies of water.

The megamammals analyzed in this study were the white rhinoceros, which has three digits and is classified as a perissodactyl, and the common hippopotamus, which has four digits and is classified as an artiodactyl. The study of the bone structures of the thoracic limbs of the studied megaherbivores was hampered by the fact that the studied bones belong to articulated skeletons belonging to the collection of the Museum of Anatomy of the School of Veterinary Medicine and Animal Science, University of São Paulo. No sesamoid bones were identified in these megaherbivores for example of this difficulty, which could suggest the loss of these bones during the bone maceration process or their absence in these animals. Only one specimen of rhinoceros and hippopotamus was studied and it was a limitation of this study. Although only one animal of each species was analyzed, we can suggest that, with some species-specific differences, the bone anatomy found in the megaherbivores common hippopotamus and white rhino studied herein, was similar to that described for other wild and domestic ungulates, such as tapir, deer, and cattle. In addition, this study can help veterinarians in bone health care, animal welfare and comfort of these species in zoological parks, since foot disorders or possible handling errors, differences in the environment, differences in the feeding management of these animals can impact the bone structure of the thoracic limbs, mainly the distal parts of these limbs.

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GALLINA, P. L. S. & SCHIMMING, B. C. Anatomía ósea del miembro torácico en el hipopótamo común (*Hippopotamus amphibius*) y el rinoceronte blanco (*Ceratotherium simum*). *Int. J. Morphol., 41(6)*:1640-1647, 2023.

RESUMEN: Aunque los megaherbívoros no pertenecen a la fauna brasileña, se pueden encontrar en zoológicos nacionales, lo que hace importante conocer la anatomía del aparato locomotor para contribuir a la rutina clínica de los zoológicos y de los centros de rehabilitación veterinaria. Por tanto, el objetivo de este estudio fue describir las estructuras anatómicas de los huesos de los miembros torácicos en el hipopótamo común (*Hippopotamus amphibius*) y el rinoceronte blanco (*Ceratotherium simum*) y compararlas con las estructuras óseas descritas para otros ungulados. La escápula tenía una apariencia triangular en el hipopótamo común, mientras que en el rinoceronte blanco tenía una apariencia rectangular. El acromion se observó sólo en la escápula del hipopótamo común. El húmero del hipopótamo no tenía el tubérculo intermedio, sólo los tubérculos mayor y menor, a diferencia del rinoceronte que también tiene el tubérculo intermedio. Los dos ejemplares de megamamíferos estudiados tenían una ulna no incorporada al radio y siete huesos del carpo distribuidos en dos filas óseas. En el hipopótamo común se observaron cuatro dedos y cuatro huesos metacarpianos, mientras que en el rinoceronte blanco se encontraron tres dedos, por lo tanto, tres huesos metacarpianos.A pesar de algunas diferencias específicas de cada especie, la anatomía ósea encontrada en los megaherbívoros estudiados fue similar a la descrita para los ungulados domésticos, tal como los caballos y el ganado. El hecho de que los huesos estudiados pertenezcan a esqueletos articulados de la colección del Museo de Anatomía dificultó la identificación de algunas estructuras anatómicas. Este estudio puede ayudar a los veterinarios en el cuidado de la salud ósea, el bienestar animal y el confort de las especies presentes en los parques zoológicos brasileños.

PALABRAS CLAVE: Hipopótamo; Megaherbívoros; Osteología; Rinoceronte; Miembro torácico.

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