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Retrospective Study of Fractures in both Appendicular and Axial Skeletons of Birds Belonging to the Families Falconidae and Cariamidae

Michelle Colpani Fernandes[1,*], Sheila Canevese Rahal[1], Carlos Roberto Teixeira[1], Maria Jaqueline Mamprim[1], Cristianne Dantas Freirias[1], Heloisa Coppini Lima[1], Jeana Pereira da Silva[1], and Anneke Moresco[2]

[1]Department of Veterinary Surgery and Animal Reproduction, School of Veterinary Medicine and Animal Science, São Paulo State University (UNESP), Botucatu, Brazil
[2]Reproductive Health Surveillance Program, Morrison, CO, USA

***Corresponding author:** Michelle Colpani Fernandes, School of Veterinary Medicine and Animal Science, São Paulo State University (UNESP), Botucatu, 18618970, Brazil, Email: michelle.colpani@outlook.com

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Abstract

This retrospective study aimed to identify and classify fractures in the appendicular and axial skeletons of birds from the Cariamidae and Falconidae families presented to a referral centre. Twelve of thirteen adult red-legged seriemas (*Cariama cristata*) had appendicular skeleton fractures and one an axial skeleton fracture. All appendicular skeleton fractures occurred in pelvic limbs, but one bird also had a thoracic limb fracture. Among the long-bone fractures, ten were of the tibiotarsus. Among these fractures, six were comminuted, two transverse and two spiral. One seriema had an ulnar spiral fracture, and two had exposed fractures of the tibiotarsus. The Falconidae included nine *Carcara plancus,* five *Falco sparverius* and two *Falco femoralis*. Appendicular skeleton fractures were detected in 14 Falconidae, axial skeleton fractures in one,and another bird had fractures in both skeletons. Three fractures occurred in pelvic limbs, and the other was thoracic limb fractures. Out of all the long-bone fractures, eight were found in the humerus, three of which were exposed, two comminuted, two spiral, and one oblique. Four ulna fractures were found; two of them were comminuted, one spiral and transverse. There were two comminuted radius fractures. Tibiotarsus fractures included two transversal and one comminuted fracture. In conclusion, in both families the highest prevalence of fractures was in the appendicular skeleton; however, the fractures in Cariamidae occurred mainly in the pelvic limbs, whereas the fractures in Faconidae were found more frequently in the thoracic limbs.

Keywords: Red-legged seriemas; *Cariama cristata*; *Carcara plancus; Falco sp.*; Trauma; Bone

Introduction

The family Cariamidae is endemic to South America and has only two living species; one of them, the red-legged seriema *(Cariama cristata),* occurs in Brazil [1-3]. Red-legged seriemas are common in the central region of Brazil, especially in areas of the Cerrado. They are usually found in pairs or small flocks [2,3]. These birds have long legs and three short, very sharp forward-pointing toes, characteristics of a bird that has predominantly terrestrial habits [4,5]. The short and strong beak helps them capture insects and small vertebrates, such as lizards and snakes [3,6]. When it comes to hunting strategies, the red-legged seriema relies mainly on its running abilities (they can reach up to 70 km/h), and generally only flies when it is not capable of running faster than its pursuer [5]. Studies have demonstrated taxonomic proximity between the family Cariamidae and the order Falconiformes [7].

The order Falconiformes contains around 63 different species, 21 of these are found in Brazil [2,8,9]. The Falconidae are birds of prey, so their diet consists of other animals [6]. These birds fly when hunting their prey and use their pelvic limbs to capture the prey, so the presence of thick scales, the hallux (digit 1), and curved and sharp talons are essential for that task [2,10].

Although each species adopts different behaviours, most birds have alterations in their musculoskeletal system to adapt to flight [11]. Such modifications make the avian skeleton light, resistant, and compact, and it can be subdivided into an axial skeleton (comprised of the vertebral column, ribs, sternum, and pelvis) and an appendicular skeleton (thoracic and pelvic limbs) [12]. The skeleton has several functions, such as support, locomotion-offered by a lever system and soft tissue protection, as well as playing a secondary role in mineral homeostasis, since the skeleton is a reservoir of calcium and phosphorus [12,13].

Few studies have investigated the occurrence of traumatic injuries in Brazilian birds [14-18]. One of them, a 5-year retrospective study about skeletal alterations found on plain radiographs of 201 birds, showed that traumatic disorders were the most common, represented by fractures, dislocations, and amputations, with the highest prevalence in Psittacines, followed by Passerines [14]. Likewise, lesions of bones and joints caused by traumatic processes were the most common cause of euthanasia in Falconiformes and Strigiformes admitted to the Division of Wildlife in São Paulo [15]. In a three-year survey, 253 birds were admitted to the wild animal ambulatory service of a veterinary school, from which a high prevalence of traumatic

conditions was detected in the Psittaciformes, most frequently associated with fractures [16]. Similarly, in an 8-year retrospective study of 75 avian surgeries performed in a veterinary school, 27 of 90 surgeries were orthopaedic surgeries performed most frequently in Psittaciformes [17]. In addition, a 2-year radiologic study with 32 raptors observed that 16 birds had fractures due to a traumatic event [18]. The present study aimed to identify and classify fractures in both appendicular and axial skeletons of birds from families Cariamidae and Falconidae presented to a referral centre for wild animals. The hypothesis is that differences in fracture location may correspond to behavioural differences between the two families.

Materials and Methods

This study was approved by the Institutional Ethics Committee for the Use of Animals (nº.0088/2019-CEUA).

Six years of medical records and radiographic exams of birds belonging to the families Cariamidae and Falconidae presented to a referral centre for wild animals were retrospectively analysed. Signalment data on birds (age: categorized as young or adult), history (if available), and fracture location (appendicular and/or axial skeletons) were analyzed.

Long bone fractures were classified as previously described [19]: complete (both cortices are affected) or incomplete/fissure (one cortex is broken); simple (fracture line that results in two fracture fragments: transverse, oblique, or spiral) or comminuted (multiple fracture lines with more than two fracture fragments); closed or exposed (fractured bone pointed beyond the dermal surface or air is presented within the soft tissue). If the bird had one or multiple fractures was also evaluated.

Descriptive analysis was conducted on the data obtained.

Results

Twenty-nine records of patients with fractures were retrieved, 13 in the Cariamidae family and 16 in the Falconidae family. Within Cariamidae, all 13 birds were adult red-legged seriemas (*Cariama cristata*), representing 44.83% of all the birds analysed. The available histories for all individuals were similar, indicating that the birds had been found on a road or highway, which raised suspicion of having been hit by a vehicle. Appendicular skeletal fractures were detected in 12 of 13 (92.30%) red-legged seriemas and axial fractures occurred in one of 13 (7.69%), with no birds showing fractures in both axial and appendicular skeletons. Twelve red-legged seriemas with appendicular fractures had fractures only of the pelvic limbs, and one bird (8.33%) had fractures in both thoracic and pelvic limbs. One red-legged seriema (7.69%) had an abnormal space above the synsacrum, suggesting a fracture or luxation of the axial skeleton lesion. In eight (61.53%) red-legged seriemas, only one long bone was broken, while the other five (38.47%) had more than one broken bone. No fractures involved the femur. Ten of 12 appendicular fractures (83.33%) occurred in the tibiotarsus: six of 10 (60%) were comminuted (Figure 1a), two (20%) were transverse, and the other two (20%) were spiral fractures (Figure 1b). Only one red-legged seriema (8.33%) had an ulnar fracture, which was a spiral fracture. Two of the 13 (15.38%) red-legged seriemas evaluated had exposed fractures, both in the tibiotarsus, one on the right side and one on the left side.

A total of 16 birds (55.17%) in the Falconidae family were identified with fractures: nine (56.25%) were *Caracara plancus*, five (31.25%) *Falco sparverius,* and two (12.50%) *Falco femoralis*. All were adults and had similar histories: birds had been found prostrated with drooping wings and unable to fly. All of them were found in urban areas, such as shopping malls and household properties. Out of the 16 birds evaluated in this family, 14 (87.50%) sustained fractures in the appendicular skeleton, one (6.25%) in the axial skeleton, and one *C. plancus* (6.25%) had fractures in both axial and appendicular skeletons. Regarding the birds with appendicular skeletal fractures (n=14), 12 (80%) had fractured wings, and only three (20%) had fractured pelvic limbs. Regarding the axial skeleton, one *F. sparverius* presented with a right clavicle fissure, and one *C. plancus* had a sternal fissure and a concomitant spiral fracture of the humerus.

Figure 1: Radiographic images of red-legged seriema's (*Cariama cristata*) legs. Craniocaudal projection shows comminuted fractures in both tibiotarsus (a), and mediolateral projection shows a simple spiral fracture in the medial third in the left tibiotarsus (b).

Ten birds (62.50%) of the family Falconidae had only one fractured bone, while the other six birds (37.50%) had multiple broken bones. Eight fractures (53.33%) occurred in the humerus, three were exposed (37.5%), two were closed comminuted (25%) (Figure 2a), one was closed oblique (12.5%) (Figure 2c), and two were closed spiral (25%) fractures. There was no record of singly ulna fracture. Ulna fractures occurred concomitantly with a humeral fracture (6.66%) in one bird (Figure 2b), and with a radial fracture (13.33%) in two other birds. Among these three ulna fractures, two were comminuted (66.67%), and one was transverse (33.33%). The two radius fractures were comminuted. Of the tibiotarsus fractures (20%), two (66.66%) were transverse and one (33.34%) was comminuted. One bird (6.66%) presented with a carpometacarpal comminuted fracture. Three (20%) fractures were exposed, all in the humerus (one transverse, one spiral, and one oblique).

The classification and location of the appendicular skeletal fractures of birds from Cariamidae and Falconidae are shown in tables 1 and 2, respectively. Figure 3 shows fractures of birds from the Falconidae family. Out of the 29 birds evaluated, seven (24.14%) were successfully treated with surgical treatment, six of them (85.71%) were seriemas with pelvic limb fractures, and one was an *F. femoralis* with a wing fracture. The other 22 birds were either euthanized due to the severity of the lesion or died before any type of treatment could be performed.

Discussion

This study evaluated fractures in birds belonging to the families Cariamidae and Falconidae and showed differences in the occurrence of fracture sites between families. Most seriemas (*C. cristata*), birds

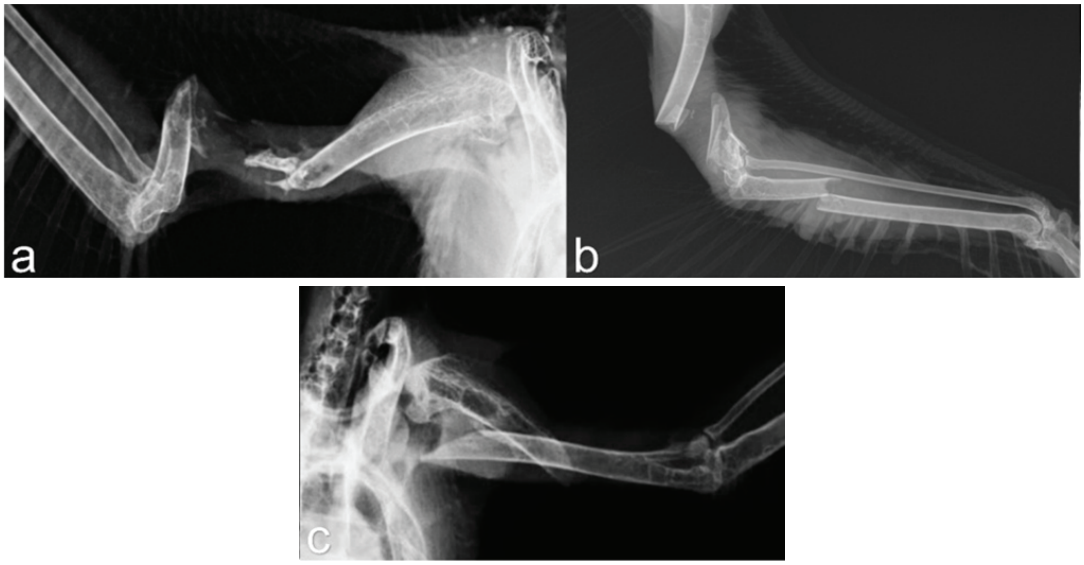

Figure 2: Radiographic images in mediolateral projections of the wings in three *Carcara plancus*. Observe a comminuted fracture in the middle/distal third of the right humerus (a); a comminuted fracture in the distal third of the left humerus and a transverse fracture in the proximal third of the ulna (b); a simple spiral fracture in the medial third in the left humerus.

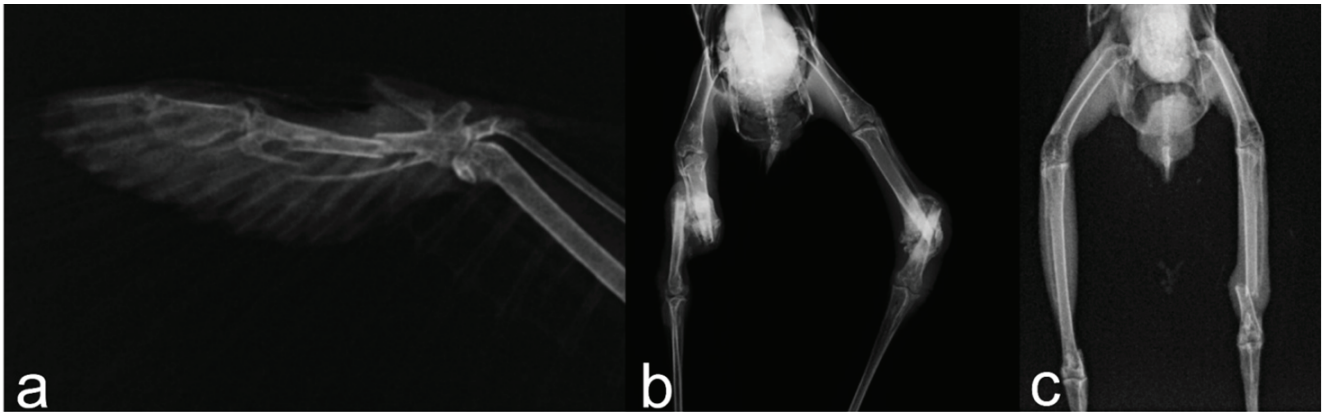

Figure 3: Radiographic images of birds from the Falconidae family. Observe a comminuted fracture in the middle/proximal third of the right carpus-metacarpus (a); bilateral fracture in the middle third of the tibiotarsus suggesting hypertrophic non-union (b); a transverse fracture in the distal third of the left tibiotarsus (c).

with terrestrial habits and bodies adapted for bipedal locomotion [4] presented with more pelvic limb fractures (92.30%), while birds that are more adapted to flight [2] had a higher number of wing fractures (75%). The exact cause of fractures in both families cannot be determined since all were free-ranging birds, but the histories suggested traumatic events related to vehicular collisions, especially in birds from the family Cariamidae. Mortality due to roads has been considered a greater threat to wildlife than hunting [20]. Birds represented 52.9% of the deaths in a study about roadkill of wildlife on a highway, being the cause attributed to dense arboreal-shrubby vegetation and high vehicle traffic during the day that corresponds to the activity period of the birds [21]. The roadkill is a significant impact on Cerrado mammals as well [22].

The highest prevalence of fractures in red-legged seriemas was found in tibiotarsal bones (83.33%), six (60%) of which were classified as comminuted. In general, high-energy forces are more likely to shatter a bone, resulting in comminuted fractures [23]. In addition, bird bones are thin and brittle due to high calcium content, which makes them easier to fragment or shatteron impact [23,24]. In birds, fractures located in distal extremities are mainly covered by tendons and skin, which usually favours the occurrence of exposed fractures [24]. However, in our study, although the tibiotarsal bone has a paucity of soft tissue coverage, only two open fractures were found (15.38%). It should also be noted that exposed comminuted fractures are more prone to develop osteomyelitis than closed fractures since they are more easily infected [25].

In birds of the Falconidae family, regardless of which bone was fractured, 37.50% were comminuted. In general, comminuted fractures located in the humerus, radius, and ulna are more frequently located in the diaphysis [26]. Data from the current study concurred with that previously described [26] in which 85.71% of comminuted fractures were in the diaphyseal area and just one bird had a comminuted fracture in the distal humeral condyle. Transverse (20%), spiral (20%), and oblique (13.33%) fractures were found in Falconidae. A previous

Table 1: Classification and location of appendicular skeleton fractures in 12 birds of family Cariamidae, represented by *Cariama cristata*.

No.	Location	Fracture description
1	tibiotarsus	open; comminuted, middle third
2	tibiotarsus	open; transversal, distal third
3	tibiotarsus	comminuted, proximal third
4	tibiotarsus	comminuted, middle third
5	tibiotarsus	comminuted, proximal third
6	tibiotarsus	transverse, proximal third
7	tibiotarsus	spiral, proximal third
8	tibiotarsus	spiral, middle third
9	-tibiotarsus -tarsometatarsus	-comminuted, distal third -transversal, distal third
10	tarsometatarsus	comminuted, distal third
11	tarsometatarsus	oblique, middle third
12	-ulna -tibiotarsus -tarsometatarsus	-spiral, middle third -comminuted, middle third -comminuted, middle third

Table 2: Classification and location of appendicular skeleton fractures in 15 birds of family Falconidae.

No.	Species	Location	Fracture description
1	*C. plancus*	humerus	comminuted, middle third
2	*C. plancus*	humerus	comminuted, distal condyle
3	*C. plancus*	humerus	open; oblique, proximal third
4	*C. plancus*	humerus	oblique, middle-distal third. Suggesting nonunion (bone ends were tapered and rounded, without periosteal proliferation)
5	*C. plancus*	humerus	spiral, middle third
6	*C. plancus*	-humerus -ulna	humerus: comminuted, distal third ulna: transverse, proximal third
7	*C. plancus*	radiusand ulna	both comminuted, middle and proximal thirds
8	*C. plancus*	radiusand ulna	both comminuted, middle-proximal third
9	*C. plancus*	tibiotarsus	Transverse middle third. Suggesting hypertrophic nonunion (bone ends were displaced and there was intense periosteal proliferation)
10	*F. sparverius*	humerus	open; spiral, middle third
11	*F. femoralis*	humerus	open; transverse, middle third
12	*F. sparverius*	humerus	spiral, middle third
13	*F. femoralis*	carpus-metacarpus	comminuted, middle-proximal third, multifocal
14	*F. sparverius*	tibiotarsus	comminuted, middle third
15	*F. sparverius*	tibiotarsus	transverse, distal third

study found that simple fractures (transverse or oblique) in the wings are most commonly located in the diaphysis [26]. In the current study, simple fractures were located in the diaphysis, with 50% of them found in the middle third. In general, simple transverse or oblique fractures are most frequently caused by a low-energy force, such as the bird flying into a stationary object [23].

The most frequently fractured bone seen in birds of the family Falconidae was the humerus (53.33%). This is problematic for the bird since this is a pneumatic bone and may result in air sac disruption [19,24,25]. If the air sac system is disrupted, air leakage may occur at the fracture site, possibly causing contamination [24]. Also, infected material may be transferred into the bone or air sac during irrigation [27]. In the present study, humeral fractures were encountered in the middle third (66.66%). This agrees with previous findings that the majority of humeral occur midshaft or at the junction of the middle and lower thirds of the bone, which are the least protected areas by surrounding muscles [28].

Regarding radius and/or ulna fractures, one occurred in the red-legged seriema and four in birds of the family Falconidae, two included both bones, one was concomitant with a humeral fracture and another was only in the ulna. Some authors report that in most cases both radius and ulna bones are fractured together [25,26]. However, other authors report that in approximately 50% of the cases, one of the bones is fractured, but not both [28], and concurs with the findings of the present study. Only one bird in the family Falconidae had fractures in both carpal and metacarpal bones. Fractures involving carpal bones, or metacarpal and digits are considered an uncommon, or rare occurrence in birds [26].

Radiographs of the axial skeleton showeda red-legged seriema (Cariamidae family) with a lesion above the synsacrum, suggestive of a fracture or luxation. Although spinal fractures are considered uncommon in birds, those that collide with closed windows may present fractures cranial to the synsacrum [19].

Urbanization interference in wild bird populations could be observed in the present study since only seven birds were treated surgically and managed to be released (red-legged seriemas n=6; *F. femoralis* n=1). The percentage of successfully treated fractures in the Falconidae (6.25%) in this study is different from the 20% reported in griffon vultures, which survived despite the fractured wing [29].

Conclusion

In both families, the highest prevalence of fractures was in the appendicular skeleton. In the family Cariamidae the fractures occurred mainly in pelvic limbs, with the tibiotarsus most frequently affected. In contrast, in the family Falconidae, the fractures were found more frequently in the thoracic limbs, specifically, the humerus was the most commonly affected bone. The differences between fracture sites can be related to the behavioural and structural peculiarities of each family.

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Declaration of Competing Interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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