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Incidence of Naturally-healed Fractures in the Pectoral Bones of North American Accipiters

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The theory of skeletal strength proposed by Alexander (1981, 1984) suggests that optimal bone strength evolved to minimize risk of fracture. Alexander theorized that a balance between risk of bone failure and energy cost of growth and utilization of heavier skeletons should be achieved through natural selection. He further suggested that fracture incidence should increase as the cost of injury falls. Studies of fractures in wild populations are potentially useful in testing this theory. Few such studies have been published.

In this study, we focused on healed fractures to the pectoral girdle in three species of *Accipiter*. Members of this genus are specialized forest predators that primarily use a series of perch and scan periods from the concealment of tree branches and bushes before chasing prey (Bent 1937). The Sharp-shinned Hawk (*Accipiter striatus*), primarily a small-bird predator, Cooper's Hawk (*A. cooperii*), and Northern Goshawk (*A. gentilis*), both more generalized small-mammal and bird predators, hunt in this manner (Reynolds and Meslow 1984). This type of hunting behavior may lead to collisions with branches and other such obstacles. Therefore, evidence of fractures should be present in these species, given that the cost of such injury is low enough to enable individuals to recover.

Methods

Skeletal specimens ($N = 339$) of accipiters were visually inspected for evidence of healed fractures to the pectoral girdle (furcula, scapula, and coracoid). The pectoral girdle was chosen due to its importance to flight and its potentially higher susceptibility to breakage from head-on impact. Healed fractures were identified by the presence of bone callus associated with fracture lines. Species examined were *A. cooperii* ($N = 115$: 37 males, 64 females, 14 unknown sex), *A. gentilis* ($N = 52$: 26 males, 22 females, 4 unknown sex) and *A. striatus* ($N = 172$: 65 males, 90 females, 17 unknown sex). Birds that were known to have been captive for any period of time were not included.

Specimens were collected between 1921 and 1998. The frequencies of birds with healed fractures collected from each decade were compared to determine if rates increased with time. Due to smaller sampler sizes it was not possible to compare frequencies from the 1920s, 1940s, and 1960s

Results

Evidence of healed fractures was found in 18.6% (63 hawks with 67 fractures) of the individuals ($N = 339$) There was no significant difference among the species ($\chi^2 = 1.78$, df = 2, $P > 0.25$; Table 1). There was also no significant difference between the combined sexes (sexes were combined to increase sample size) ($\chi^2 = 0.96$, df = 1, $P > 0.25$; Table 1). The majority of fractures occurred in the furcula (16%, $N = 54$), 12 fractures were found in the scapula (4%); and only one healed fracture was found in the coracoid (0.3%). Fractures occurred in varying locations in both the furcula and scapula. Fractures at the center of the furcula (i.e., point of fusion of the clavicles) were common as well as fractures near or at the midpoint of each clavicle shaft. Fractures of the scapula were most often at either the extreme distal end or near the center. Scapular fractures sometimes healed at an angle (e.g., one scapula healed at the midpoint of the bone at an angle of about 45°). There was no significant difference between the frequencies of healed fractures in birds collected during the 1930s, 1950s, 1970s, 1980s, and 1990s ($\chi^2 = 2.01$, df = 4, $P > 0.50$).

Discussion

The incidence of healed pectoral fractures confirms that impact injuries occur in accipiters and that some are able to recover. The cause of fractures could not be determined from museum specimens. There were no biases in fracture incidences with respect to species and sex (Table 1). We suggest that both natural and anthropogenic causes were involved in fractures. If anthropogenic causes were more significant than natural causes, than fracture incidence would be expected to increase through time due to increased urbanization. However, this was not the case.

Raptor rehabilitation efforts have increased since 1960 (T. French pers. comm.). This could affect healed fracture incidence for birds collected in subsequent years. Our data showed no significant change in the fracture

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Table 1. Incidence of healed pectoral-bone fractures in each of the three North American *Accipiter* species.

	Number of Fractures	Fracture Incidence
Cooper's Hawk (N = 115)	26	23%
Northern Goshawk (N = 52)	10	19%
Sharp-shinned Hawk (N = 172)	27	16%
Total male (N = 128)	29	23%
Total female (N = 176)	31	18%
Unknown sex (N = 35)	3	9%

rates for years before and after 1960, suggesting that rehabilitation is not a factor.

Healed fracture incidence represents only birds that survive injury. Therefore, the incidence of impact injury to the pectoral girdle in accipiters may be higher than that found in this study, especially in urban habitats. Boal and Mannan (1999) found that collision with man-made objects were responsible for 69.8 percent of mortalities of Cooper's Hawks in an urban environment. Many of the specimens used for this study were collected during migration, making it impossible to know if they frequented rural or urbanized habitats during the breeding and winter seasons. The fact that fracture incidence did not increase through time with increased urbanization suggests that either anthropogenic causes of fracture are not more significant than natural causes or that birds are less likely to survive collision with man-made structures. Further studies of fracture incidence among urban versus rural birds are needed. Also, the scarcity of healed coracoid fractures could be the result of less frequent injury to this bone, or birds are less likely to survive coracoid injury. Peregrine Falcons (*Falco peregrinus*) with broken coracoids are unable to fly well enough to catch prey and, therefore, are unable to recover (T. French pers. observ.).

Previous studies have focused on healed fractures in the long bones of wild birds. Brandwood et al. (1986) examined wild-caught individuals from three avian families for incidence of long-bone fractures. They found a fracture incidence of 0.4% for total bones examined in anatids, 0.4% and 0.5% in two larid samples and 0.2% in columbids. It was theorized from these data that most birds would be either unlikely to suffer fractures or would not survive them (Brandwood et al. 1986). Accipiters represent an exception to this hypothesis as do members of the genus *Gyps*. In a small sample of White-backed Vultures (*G. africanus*) and Rueppell's Griffons (*G. rueppellii*), Houston (1993) found a 20% incidence of healed ulnar fracture. Unlike accipiters, these vultures do not engage in high-risk behavior. Houston theorized that the high fracture incidence in *Gyps* is due to skeletal fragility related to extreme weight reduction.

Considering the importance of flight to accipitrine hunting style, it is significant that these birds are able to recover from a pectoral-bone fracture. This suggests the cost of such an injury is sufficiently low as to balance the risk of collision inherent in the behavior of this genus. In addition, the susceptibility to fracture of the furcula and scapula in accipiters may be compensated by the lower energy cost of a light skeleton.

RESUMEN.—Especimenes de Museo (N = 339) de *Accipiter striatus, A. cooperii y Accipiter gentilis* fueron examinados debido a la evidencia de fracturas soldadas naturalmente en el hueso pectoral. La incidencia general de las fracturas fue del 19%. No hubo diferencia en la frecuencia de fracturas entre las tres especies o entre sexos. La mayoría de las fracturas ocurrieron en la "furcula." La frecuencia de las fracturas soldadas sugieren que las heridas causadas por impacto son comunes en los accipiters, y que algunos individuos son capaces de recuperarse.

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