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STRESSES IN LEG TENDONS OF BIRDS

by

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SUMMARY

In several species of birds, leg tendons were dissected and the stresses which could be applied by muscles in life, in isometric conditions, were calculated by means of several anatomical parameters. Ultimate tensile stresses were measured with an Instron testing machine. Using both of these stresses, the safety factors of some tendons were calculated. These safety factors agree with the few values previously published on bird tendons, but are lower than the values known for mammalian tendons. Considering the relationship between the cross-sectional area of the muscle and the cross-sectional area of the tendon, bird tendons are relatively thinner than those of mammals. Finally, the possibility that the bird tendons studied work as springs and the supposed evidence of a different mechanical behaviour of some tendons, because of particular adaptative reasons, are discussed.

KEY WORDS: tendons, legs, birds, stresses, safety factors, scaling, adaptation.

INTRODUCTION

In the last few years, a good deal of literature has been produced about tendon properties, mainly elastic properties. See, for example, KER (1981), ALEXANDER (1984, 1988), BENNETT & STAFFORD (1988) and OLMOS *et al.* (1989). Other tendon particularities, such as fracture stresses, have been less well described. OLMOS *et al.* (1993) recently studied the scaling of the tensile fracture loads in bird tendons. The most comprehensive paper on fracture stress in mammalian tendon questions is possibly that of KER *et al.* (1988). In this article the authors show that most of the mammalian tendons are much thicker than necessary. Therefore, the safety factor is generally high, except in tendons which store energy during locomotion. In view of these results, we wondered about the properties of tendons of other vertebrate groups.

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Here, we present our results on both the stresses which could be applied by muscles in life in isometric conditions, and the ultimate tendon stresses, from leg tendons belonging to several species of birds.

MATERIAL AND METHODS

We used seven tendons from bird legs, belonging to one extensor and six flexor muscles. The material studied, 158 tendons, is summarized in table I. Tendons were dissected by one of us (M.O.) for a parallel research (Olmos *et al.*, 1993). They were placed in Ringer's solution and frozen until used. This procedure has no effect on the mechanical properties (Olmos *et al.*, 1989). They were weighed and their length was measured. Normally, measurements were taken on the whole tendon, but in some cases only fragments of tendons were used, *e.g.*, when there were bifurcations or aponeurotic fragments.

During dissection, the wet mass of the muscles from which the tendons originated and the mean fibre length of the muscle were also measured.

For the calculations, the formulae proposed by Ker *et al.* (1988) were used. That means, the tendon stresses to which its muscle is exerting the maximum isometric force (σ_t) should be

TABLE I

List of the species and muscles of the tendons studied. Abreviations: *d.l.*, Extensor digitorum longus; *p.d. II*, Flexor perforatus digiti II; *p.d. IV*, Flexor perforatus digiti IV; *p.p.d. II*, Flexor perforans et perforatus digiti III; *f.l.*, Fibularis longus-Flexor perforatus digiti III; *h.l.*, Flexor hallucis longus-Flexor digitorum longus.

Species	*d.l.*	*p.d.II*	*p.d.IV*	*p.p.d.II*	*p.p.d.III*	*f.l.*	*h.l.*
Accipiter nisus	–	–	2	2	2	–	–
Alectoris rufa	–	2	2	–	1	2	–
Anas clypeata	3		4	2	4	1	–
Anas platyrhynchos	3	–	4	2	3	–	–
Anas strepera	3	–	2	–	2	–	–
Bubulcus ibis	4	1	3	2	3	1	2
Corvus corax	1	–	–	–	–	–	–
Gallinago gallinago	1	2	2	2	2	–	–
Gallinula chloropus	–	1	–	–			–
Haematopus ostralegus	2	3	2	2	2	–	2
Larus ridibundus	2	–	1	2	2	–	–
Netta rufina	1	–	2	–	2	–	–
Podiceps cristatus	6	–	5	7	7	5	6
Rallus aquaticus	1	–	1	2	1	–	–
Vanellus vanellus	3	2	3	2	3	3	3
Total = 158	30	11	33	25	34	12	13