CHAPTER 5

VARIATION IN THE DIAMETER OF THE MUSCLE FIBRES IN THE PECTORALIS MAJOR AND ITS RELATION TO MUSCLE SIZE AND MODE OF FLIGHT

Variation in the diameter of the muscle fibres in different muscles has been of considerable interest to muscle biologists. Fibres of muscles differing in function have been studied to correlate the size of the fibre with function. But, this approach has however not met with much success. George and Jyoti in their paper (1955a), cited in the first chapter of this thesis, made some interesting comments on the great variation in the diameter of the muscle fibres in the pectoralis major muscle of a few birds and suggested the possibility of some relation between the fibre diameter and the mode of flight. The present investigation is an attempt to explore further, the dark corners of this most complex problem.

Material and Methods

All the birds used in the present work, except the fowl and partridge, were either trapped or shot with an air-rifle. The pectoralis of one side in each bird was used exclusively for studying the structure of the muscle, the full account of which will be presented in the next chapter. The pectoralis of the other side was removed short while after the death of the animal and weighed immediately. Small pieces cut from it were used for obtaining the fresh frozen sections. The sections were mounted in 50 % glycerol solution on microslides and under a magnification of eight hundred, the diameter of several hundreds of fibres from each preparation were measured using the ocular scale and the micrometer slide. In most of the birds the fibres in the superficial region of the muscle were somewhat bigger in diameter than those in the interior. So, to obtain a correct mean value in such a muscle, measurement of the fibre diameter was done from areas selected at random from different depths of the muscle.

Results

The results obtained are presented in table ~~no.~~ 1, where the birds studied are grouped differently according to their mode of flight. It must, however, be stated that the grouping of the birds is by no means definite and absolute. For example, many of the birds grouped under A, often exhibit shooting type of flight; Shikra (a hawk), though listed as a soarer (group B), while moving from tree to tree or while flying at low altitudes, does flap its wings constantly with ease. This grouping only suggests the mode of flight commonly and most frequently indulged in by a particular bird. The weight of bird, wherever recorded, is mentioned so as to give some idea ~~about the~~ size. ~~of the animal~~. The values of the diameter of the fibres are the mean of several hundreds of fibres measured. Wherever, more than one specimen of one type were used, the mean of values obtained from different

Table 1 – needs title

Name of birds	Fibre diameter ± S.D.	Body wt.	muscle wt.
A Birds exhibiting shooting (gliding) flight			
Indian Robin (*Saxicoloides fulicata*)	33.8 ± 8		1.0
House Sparrow (*Passer domesticus*)	34.5 ± 11		2.0
Green Bee-eater (*Merops orientalis*)	38.0 ± 10	15	1.5
Red-vented Bulbul (*Molpastes hoemorrhous*)	38.3 ± 10	33	2.3
Mahratta Woodpecker (*Liopicus mahrattensis*)	40.2 ± 6	37	2.5
Blue-tailed Bee-eater (*Merops superciliosus*)	42.5 ± 10	36	3.6
White-breasted Kingfisher (*Halcyon smyrnensis*)	49.8 ± 11	80	6.1
B Birds exhibiting flapping flight			
Re-rumped Swallow (*Hirundo daurica*)	35.5 ± 5		1.3
Common Babbler (*Argya caudata*)	40.2 ± 9	59	4.0
Pied-crested Cuckoo (*Clamator jacobinus*)	37.0 ± 6	80	4.2
Common Myna (*Aeridotheres tristis*)	37.7 ± 10	112	7.0
Crow Pheasant (*Centropus sinensis*)	44.0 ± 8	233	9.0
Green Parakeet (*Psittacula krameri*)	36.6 ± 7	118	10.25
Blue Jay (*Coracias benghalensis*)	41.5 ± 8		10.0
Koel (*Eudynamis scolopaceus*)	41.9 ± 9		12.0
Common House Crow (*Corvus splendens*)	42.3±11		17.0
Red-wattled Lapwing (*Sarcogrammus indicus*)	40.7±11		17.0
Paddy Bird (*Ardeola grayi*)	42.7±10		18.0
Cattle Egret (*Bubulcus ibis*)	43.2±10	347	21.0
Owl	48.5±11		50.0
Spotted Dove (*Streptopelia chinensis*)	40.0±16		9.0
C Birds exhibiting soaring flight			
Shikra (*Astur badius*).	41.2±13	148	11.3
Common Pariah Kite (*Milvus migrans*)	26.6 ± 9		39.0
White-backed Vulture (*Pseudogyps bengalensis*)	66.2±13	2509	341.0
D Nonflying birds			
Partridge – Sc. name? (Pandiy?)	60.8±15		12.0
Fowl (*Gallus domesticus*)	64.0±16		47.0

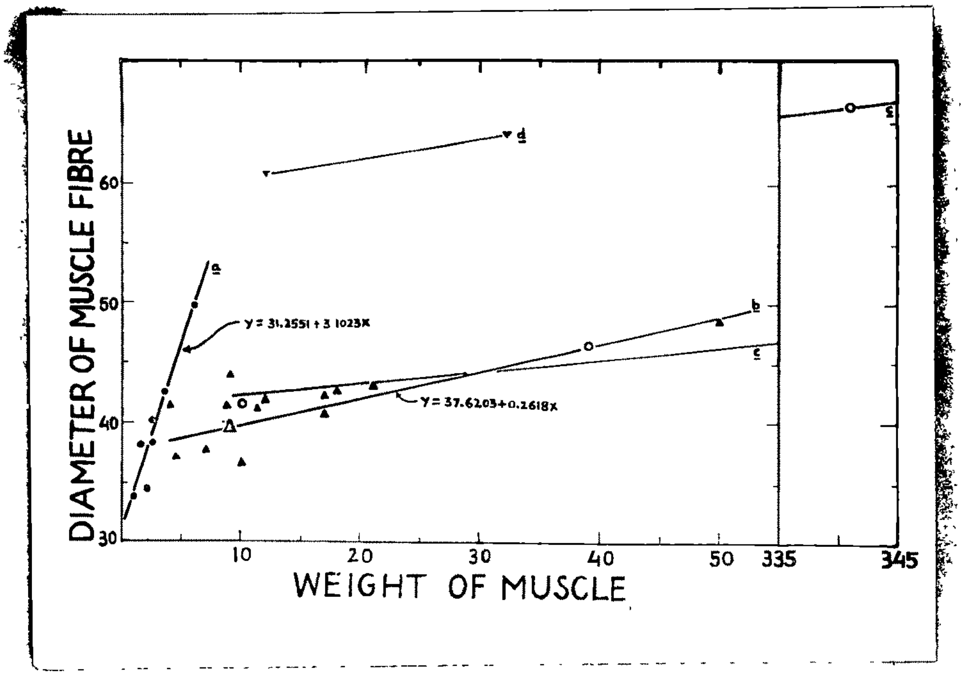

Fig. 5.1 Relation between the diameter of the muscle fibres and the weight of the pectoralis major of the birds exhibiting shooting type of flight (line a), flapping type of flight (line b) and soaring type of flight (line c) and the birds which are non-fliers.(line d).

Shooting type of flier ●
Flapping type of flier ▲
Soaring type of flier o
Non-flying type ▼
Platted after drawing the regression line △

specimens is given. However, in no case were individual variations ~~were~~ found to be large. It appears that the mean fibre diameter of the pectoralis is fairly constant for a bird, provided it is fully grown, normal and active.

Taking birds of any single group, it can be observed that the diameter of fibres increases with the weight of the muscle. Figure 5.1 is a graphical representation of the relation between the fibre diameter and muscle weight. It can be observed that all the birds in group A fall along the line a; the formula for the regression line is $y = 31.2551 + 3.1023x$ ($r = 0.96$). Similarly, the birds of the group B fall along the line b, where $y = 37.6203 + 0.2618x$ ($r = 0.58$). It will be observed that the slope of ~~the~~ line a is much steeper than that of ~~the~~ line b. Since the ~~number of~~ birds observed in group C and D are fewer in number, no accurate relationship for line c and d can be derived. But it appears that the birds of ~~the~~ group C do not differ significantly from ~~the~~ group B as far as the relation between the diameter of the fibres and the muscle weight is concerned.

Discussion

The size of a cell in any tissue is considered to be a fixed entity. In a larger animal, it does not become larger, though cells may increase in number to form a bigger structure. An individual muscle fibre, though multinucleated, since is derived from a single myoblast, may be regarded as a cell. In that case, the present work shows that the muscular tissue is an exception to the above stated general rule. It appears that in homologous muscles with identical functions, diameter of the fibres varies with the size of the muscle.

With increase in fibre diameter the distance between the centre of the cell and the blood capillaries lining its border increases. Hill (1956) pointed out that, " In objects of similar shape, the time taken for diffusion to operate varies directly as a square of the linear size, the rate of supply of disolved substances to the interior of the cell decreases with the increase in the fibre diameter", Under these circumstances, unless the inherent requirement of oxygen in bigger muscles is less, the muscle cannot function effectively.

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Again, according to Hill (1956), " The total power output of similar animals increases about as the square of their linear size, so the maximum oxygen requirement per gram weight diminishes inversely as the linear size". This deduction, derived from the principles of thermodynamics, for an entire animal, can as well apply to an entire muscle. Larger muscles should have higher total power output and consequently less oxygen requirement per gram weight. Moreover, comparing the diameter of fibres with the muscle weight, has several advantages. The size of the animal may be expressed in terms of body weight or the surface area. A look at the table no. 1

will show that the diameter of the muscle fibres shows a closer relation with muscle weight than with the body weight. The surface area is a better index for size, but its accurate direct measurement is in no way simple. The square of the animal length is often taken as an index of the surface area, but it is no longer comparable in animals with different shapes, as in birds, where great modifications in the length of the appendages and neck are a common feature.

In group A and B relation between the weight of the animal and fibre diameter essentially remains the same. Birds exhibiting shooting type of flight form (altogether) another line with very steep slope, thus differing sharply from the birds grouped under A and B. The fibre diameter in the pectoralis of these birds is comparatively bigger. Since with the increase in the size of the muscle, the increase in the diameter of the fibres is considerable, the decrease in the rate of diffusion of dissolved substances should be appreciable. Possibly, the mode of flight of these birds, in which every quick succession of wing flaps is followed by a short period of rest, might be the underlying reason. It is quite significant that this mode of flight is confined ~~only~~ to smaller birds.

Average fibre diameter of birds in group D is highest among the birds studied and the limitations it enforces on tissue respiration is well correlated with the non-flying habit of these birds. The babbler and crow pheasant (included in group A) with broad and short wings are poor fliers, in that, their wing beats are fast but of very short duration and it is not surprising that they have fibres with a greater diameter (when compared to other birds) in group A. Probably, they may go to form altogether a separate line of poor fliers.

Among the birds studied, the parakeet and pigeon have pectoralis with smallest average diameter. Only thing common among them is that both are very good fliers. Parakeet is too well known for its flight with uninterrupted rapid succession of wing beats. The pigeon seems to have faced the problem of fibre diameter in an unique manner, the full significance of which is still obscure.

Many more birds, especially (of the bigger) size, should be examined before the functional differences in flying birds, as revealed by this work, is firmly established. Nevertheless, the present observations have opened up some new avenues in the study of the functional anatomy of muscles.

Summary

1. In birds with similar flying habits, the mean diameter of the fibres in the pectoralis major muscle varies with the size of the muscle.

2. The rate of increase in the diameter of the fibres per gram weight of the muscle varies in birds with different flying habits.