

Preliminary Notes on the Pelvic Floor Musculature of *Macaca ira* in Relation to the Assumption of Upright Posture¹

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With the advent of the fixation of the body for extensive use of the hands and of true upright posture, the bony pelvis and the muscles of the pelvic floor have undergone certain morphological changes for the support of the pelvic viscera. The form of the pelvis and the arrangement of its muscles in most pronograde mammals would offer little support for the abdominal viscera were the animal to take the upright position for brachiation or extensive hand use, not to mention bipedal progression.

In the primates there are obvious differences in posture and in the morphology of the pelvic bones and pelvic floor musculature. Although they are end products in their own evolutionary sequences, the individual primates at their different levels of developmental sophistication suggest factors present at various stages in the phylogeny of the primates as a group. Because of these indications, Sir Arthur Keith (4) and others have suggested that a comparative study of the pelvic floor musculature of the primates may give us more knowledge of the evolution of this muscular diaphragm which is so important in the assumption of upright posture.

Following this premise, H. O. Eggeling in 1896 (1), outlined a general evolutionary pattern for the pelvic floor in the higher mammals. In turn H. O. Elftman in 1932 (2), synthesized Eggeling's comprehensive work and suggested a more specific scheme of evolution for the pelvic floor muscles in primates from data obtained from dissections of the following species: *Lemur rufifrons*, *Tarsius*, *Papio*, *Lasiopyga*, *Cebus*, *Hylobates*, *Pongo*, *Pan*, *Gorilla gorilla*, and *Homo sapiens*.

To summarize Elftman's theories, it is necessary to point out that the posture of the primates ranges from the pronograde lemur to the true upright bipedal gait of man. The stages in between are represented by the sitting of the Old-World monkeys and the brachiating and sometime bipedal progression of the Great Apes. In none of the postures illustrated is there as much pressure and strain induced by the viscera on the pelvic floor outlet as there is in the fully erect walking of man. For here, the shock of each step is transmitted by the jarring of the abdominal contents toward the pelvic floor.

To sustain this strain, the shape of the pelvis has come to play more and more of a role in visceral support by becoming more "basin" shaped—i.e., the pelvis is flattened downward and expanded laterally and antero-posteriorly. Further bony support in man is provided by an inward curving sacrum placed at the level and below the symphysis pubis—thus differing from the highly placed and rather straight sacrum

1. The author expresses his appreciation to Dr. Riggins of the Pitman-Moore Biological Laboratories who donated the specimens used.

of the other primates. These changes in the pelvic bones are correlated with upright posture.

Although the bones of the pelvis in man offer relatively more support, there are still many areas of the floor and diaphragm that are totally unprotected and unsupported by bone. The muscles that are found in these areas are: the tail muscles—the coccygeus, pubococcygeus, and iliococcygeus; the muscles of the urogenital triangle—the bulbocavernosus, ischiocavernosus, and the transversus perinei; and the anal triangle muscle—the sphincter ani externus.

In the lemurs and Old-World monkeys—the first mentioned group, the pubo-iliococcygeus muscles—exhibit considerable development because of extensive tail use. In addition the pubococcygeus becomes more closely related to the rectum—progressing from the lemurs to man. In the anthropoid apes and man the absence of a tail sees the iliococcygeus becoming tendinous with only the pubococcygeus retaining a muscular form and supporting function. In modern man the iliococcygeus and coccygeus tends to be even more tendinous and fascia-like. Elftman concludes that with upright posture the increased resiliency and resistance to fatigue of fascia structures facilitates a withstanding of long periods of stress.

In the urogenital area from the lemurs to the anthropoid apes the fibers of the bulbocavernosus muscle strengthen the diaphragm by inserting on the ischial bones. In man, on the other hand, a separate muscle—the transversus perinei profundus joins the ischial bones and is separated from the bulbocavernosus by fascia.

In all non-human primates the anal triangle muscle, the sphincter ani externus, is much heavier than in man. Furthermore, in the anthropoid apes this muscle has migrated and spread from the anus to the pubic symphysis, adding support to the urogenital diaphragm. In man the sphincter ani externus is located around the anus, and the transversus perinei profundus, in turn, adds support to the urogenital area of the perineum.

Elftman's general conclusions from his study on the evolution of the pelvic floor muscles are: [1] that the supporting function of the tail muscles (iliococcygeus, pubococcygeus, coccygeus) is already present in the Old-World monkeys, as is a more active support of the viscera by a slight funneling of the bony pelvis; [2] that the muscles which cease to be for tail movement become tendinous and fascia-like; [3] that the shape of the human ilium is correlated with erect posture; [4] and that the "new" muscle, the transversus perinei profundus in man replaces the fibers of the bulbocavernosus which go to the ischia in the Old-World monkeys and replaces the spread-out sphincter ani externus in the Great Apes.

Elftman's postulates suggested the present study of an Old-World monkey. The dissection of *Papio* (the baboon) and *Lasiopyga* (the Mona monkey) make up the totality of the data on his study of the Old-World monkey. From this work he concluded that a common ancestor of the Great Apes and Man could have been in many aspects, as far as the muscles of the pelvis are concerned, similar to a typical Old-World monkey. In other words, he believes that the state of the pelvic floor

muscles in the monkeys is such that it could easily serve either a "primitive brachiator" or an "incipient biped".

His theory thus suggests that variation studies on a genus of unspecialized Old-World monkey would shed further light on pelvic floor evolution in the primates—for Elftman based his conclusions on data from two relatively specialized forms: *Papio*, the predominantly terrestrial baboon and *Lasiopyga*, the arboreal Mona monkey. Since two extreme types of Old-World monkey have already been investigated, it seems that a study of a more generalized specimen of this group would be more profitable.

The choice of *Macaca ira* (*Cynamolgus Irus*) fulfilled most of the prerequisites. *Irus* is a hardy, rather small, monkey from South-East Asia and India (5). Furthermore, this species was selected for study because of its availability, extensive use as a laboratory animal (3), and for the important fact that hardly any morphological investigation had been previously carried out on it.

The general purpose, then, of this investigation of *Irus* was to carry out a morphological study of the muscles, and to obtain a sufficient sample of variation to contribute to our knowledge on the evolution of pelvic floor musculature in primates.

In *Irus* the upright position is maintained mostly while sitting during fixation for extensive hand-use and for climbing, with more extensive progression accomplished in a modified pronograde position—i.e. with the body inclined to the rear because the arms are longer than the legs. *Macaca ira* has a long, narrow pelvis in relation to its width with relatively flat, vertical ilia; in addition the sacrum is placed much higher relative to the pubic symphysis. As is the case in most Old-World monkeys, this species has ischial callosities for protection of the pelvic floor outlet while sitting. As one would expect, because of the relatively little bony support to the abdominal contents, the strongly developed tail muscles also serve a supporting function. The ventral part of these muscles (the pubo-iliococcygeus group) have some insertion into the viscera, notably, the pubococcygeus sends fibers to insert into the rectum. Like most species of primates there is some sexual dimorphism present in the form of the muscles of the perineum. In the male the bulbocavernosus and ischiocavernosus are well developed with the converse being true in the female of the species. The female shows the most interesting variation in this area and in the associated sphincter cloacae.

In addition to a more complete morphological study the following is observed in the variation investigation: [1] the degree of association and insertion of the pubococcygeus muscle into the rectum; [2] the degree of tendonization and fascia formation of the three large and important tail muscles—the iliococcygeus, pubococcygeus, and coccygeus; [3] the problem as to whether the bulbocavernosus inserts fibers to the ischial bones and how such an insertion is arranged; and finally, [4] the degree of migration of the sphincter ani externus.

In conclusion, the research has progressed to the point that a general morphology of this area of *Irus* can soon be completely drawn up; and all that remains is for a greater sample to be taken in the

variation study. However, the pilot study has revealed certain trends; and the following results can be expected: In all the specimens of the sample varying degrees of muscular insertion of the pubococcygeus into the rectum was found. Secondly, the largest percentage shows strong muscularity for the pubo-coccygeus group. If tendonization is present, it is usually in the iliococcygeus and coccygeus, rather than in the pubococcygeus. Next, the degree of variation of the bulbocavernosus may suggest whether the transversus perinei profundus in man can be considered its homologue. Only a large sample can give significant data for consideration of this problem, however. Finally, the sphincter ani externus doesn't seem to have a wide-spread migration in *Inus*.

Preliminary studies of the migrations of the bulbocavernosus and sphincter ani externus would tend to indicate that man and the Great Apes developed from a common Old-World monkey-like ancestor with the development of the transversus perinei profundus coming from the migratory bulbocavernosus. This, plus the increased tendonization of the great tail muscles seems more sensible than to postulate a loss of an ape-like sphincter ani externus in the forms leading to man.

The fairly good size sample of thirty specimens should yield, when fully investigated and processed, sufficient data for support or rejection of the postulates thus presented on the evolution of the pelvic floor musculature in primates.

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