New research finds deep evolutionary origins of a unique mammalian anatomical pattern

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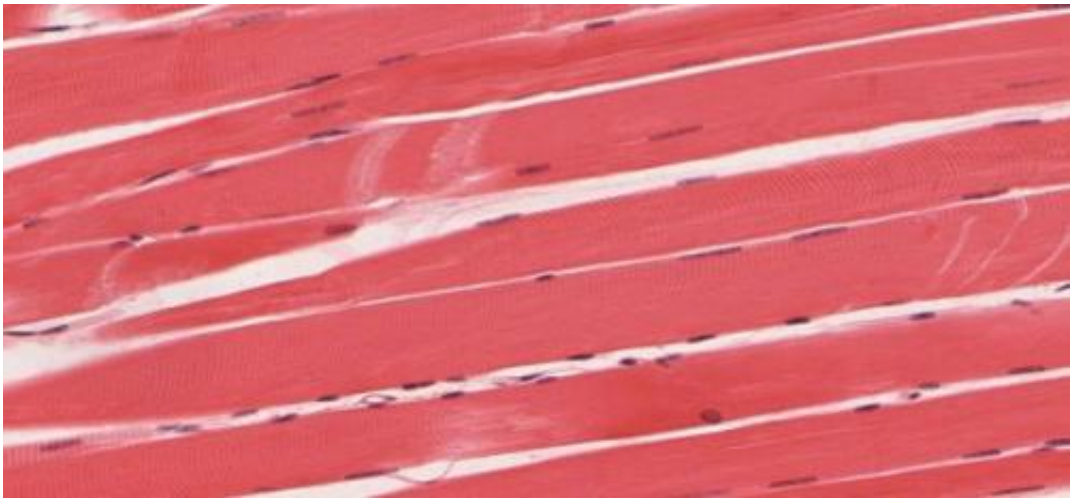

Skeletal muscle tissue. Credit: University of Michigan Medical School

By performing detailed dissections and corresponding examinations of embryological development, researchers at Midwestern University, led by Margaret Hall, Ph.D. and Jeffrey Plochocki, Ph.D., show that the muscles that control the unique mammalian perineal structures follow a surprisingly ancient pattern.

Mammalian perineal structure derived from septation of the cloaca is an important evolutionary innovation that allows myriad anatomical configurations, diverse reproductive strategies, and precise excretory control available only to mammals. The researchers were surprised to

discover that, despite the perineum's structural complexity, the muscles of the mammalian perineum show a reemergence of a simple pattern of body wall layering that dates back more than 360 million years ago—during the origin of tetrapods, the first vertebrates to move out of the water onto land. Basal vertebrates, such as fish, organize their body wall into two muscular layers that are important for swimming. However, with the transition from water to land, the body wall of most tetrapods expanded to four muscles layers in order to stabilize their trunks against gravity and facilitate the more complex movements of the limbs during terrestrial locomotion. Amniotes, vertebrates who can reproduce on land and away from water, have four muscle layers in the thorax and the abdomen, but still retain the original two muscle layers in the pelvis and perineum. Mammals, like other amniotes, have four muscle layers in the thoracic and abdominal body wall. Unlike other amniotes, mammals extended the four muscle layers to the perineum. This allows mammals to control their newly derived structures associated with the external genitalia and the anus.

What defines placental mammals as a group?

Mammals are a very successful group of vertebrates traditionally defined by the presence of hair, the ability to produce milk using mammary glands, and specialized hearing enhanced by dedicated middle ear bones. Among mammals, Placentalia, the group that includes humans, is the only group of vertebrates to evolve the specialized suite of perineal characteristics that includes the erectile tissues of the penis and the clitoris, the urethra, the distal rectum, the anus, as well as the voluntary muscles that control these structures. Most vertebrates have only a single orifice that serves both reproduction and excretion called the cloaca. The cloaca requires relatively simple muscular control, which is probably why most vertebrates have only two perineal muscle layers. Separation of the cloaca into distinct and more complex perineal structures required mammals to develop correspondingly more complex and precise

mechanisms of muscular control for these structures.

Researchers often use embryological development to find important clues about how evolutionary processes may have occurred. Modern mammals develop a cloaca embryologically, which subsequently divides into a urogenital half- that continues to form the urethra and the erectile tissues of the penis and clitoris, and an anorectal half- that develops into the distal rectum and the anal canal. The authors discovered evidence for restructuring of the body wall muscle layers during fetal development that support cloacal separation into distinct structures and is retained into adulthood.

This study, conducted by a team at Midwestern University, is the first time that the four serially homologous trunk body wall layers in the mammalian perineum are defined. These muscle layers support a unique mammalian perineal structure derived from separation of the cloaca, an important evolutionary innovation that allows diverse reproductive strategies and precise excretory control available only to mammals.

More information: Margaret I. Hall et al, Reorganization of mammalian body wall patterning with cloacal septation, *Scientific Reports* (2017). DOI: 10.1038/s41598-017-09359-y

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