

Computational Model of Levator Ani Muscle Stretch During Vaginal Delivery

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Introduction. Childbirth-induced damage to the pelvic floor is considered a major cause of female pelvic floor dysfunction, including urinary incontinence and pelvic organ prolapse. The mechanism of injury is unknown but may be dependent on pelvic anatomy and birth conditions. This project aims to create a computer model of the female pelvic floor and use it to study the effects of delivery on pelvic floor muscles, particularly the levator ani (LA) muscle.

Methods. A 21 year old nulliparous woman underwent supine pelvic MRI to evaluate a double cervix/vagina. There was no MR evidence of pelvic muscle abnormalities. Pelvic organs, muscles, and bones were segmented, decimated, smoothed, and populated with tetrahedral cells to create both coarse (594 nodes) and refined (2696 nodes) models. A rigid ball (90mm diameter) was passed through the vagina to simulate childbirth. Constitutive muscle properties were approximated using modified St. Venant-Kirchhoff large strain isotropic, homogeneous hyper-elastic potential, with small-strain Young's modulus and Poisson's ratio chosen as values typical of unstressed saturated striated muscles. Galerkin discretization of the equations of motion was carried out on the tetrahedral mesh using the element free Galerkin method, with dynamic relaxation over 44 quasi-static equilibria deformation stages. Results were assessed at the initial stress-free state, two intermediate states, and the final configuration.

Results. The largest simulated principal stretch ratio in the LA was 3.5 and was sensitive to stiffness of elastic ties between the LA and obturator internus but not to the contact penalty stiffness or mesh density. The refined model enabled the muscle to spread wider and thinner in the final configuration.

Conclusions. This model and simulation produces large stretch in the LA during childbirth, demonstrating its vulnerability to damage during delivery. Future study is aimed at testing the effects of anatomic and birth parameter variations on the LA muscles.