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PELVIC FLOOR SOFT TISSUE STRETCH INDUCED BY VAGINAL BIRTH

Aims of Study

Vaginal birth is known to increase the risk for pelvic organ prolapse (for example, Mant 1997) and urinary incontinence (for example, Hunskaar 2003). We hypothesize that maternal soft tissue injury may be implicated. Soft tissue injury can occur, for example, when tissue stretch exceeds an ultimate permissible value or similarly, when tissue shear or compression exceeds given limits. The values of maternal tissue stretch engendered by human vaginal birth are presently unknown. It therefore seems worthwhile to estimate soft tissue stretch during vaginal birth in order to identify the structures most at risk for stretch injury. We had two aims: Aim 1 was to develop a computer model of the soft tissues comprising the female human pelvic floor; Aim 2 was to use this model to simulate soft tissue stretch during the second stage of vaginal birth. We tested the null hypothesis that pelvic muscle tissue stretch is uniform during vaginal birth.

Methods

Thirty consecutive 5 mm-thick axial MR scans were obtained using a 1.5 T scanner from a healthy 34 year-old nulliparous woman who gave informed consent. The outlines of the bony pelvis, pelvic floor muscles and organs were digitized and imported into an engineering graphics program (IDEAS™). The outlines were lofted to yield a 3-D model of the female pelvis and pelvic floor. Twenty four 1 – 5 mm-thick and 5 - 10 mm-wide parallel-fibered muscle bands were used to represent the iliococcygeus, pubococcygeus, and puborectalis muscles on the left and right sides. Muscle fiber directions were taken from the literature. The arcus tendineii, perineal membrane and midline anococcygeal raphe were also represented.
The fetal head was represented by a sphere of equivalent diameter that of a 50th percentile fetal head at 42 weeks of gestation. Using data from the literature, fetal head molding was simulated by considering that diameter to be reduced by 20% during the second stage of labor. Fetal head descent during the second stage of labor was then simulated by the incremental progression of the head along the Curve of Carus, as it descended around the pubic symphysis and progressively engaged and stretched the pelvic floor muscles. The maximum stretch ratio, defined as maximum stretched length divided by initial length, of each muscle band was then calculated at the end of the second stage of labor.

Results

The nulliparous pelvic floor computer model is shown in Figure 1 in a left-ventral (and slightly caudad) three-quarter exterior view. In that figure the upper view shows the intact model, while the lower view shows the detailed soft tissue anatomy of the pelvic floor with the pubic rami in outline. The "U-shaped" pubovisceral muscles are shown as they originate from the inner surface of the pubic bone on either side of the midline and insert into the perineal membrane, perineal body, and anal sphincter complex, as well as forming a sling behind the rectum. In the lower figure the muscle bands are numbered sequentially from 1 (puborectalis), 2 (ventral-most pubococcygeus band), to 24 (dorsal-most iliococcygeus band) in a ventrodorsal direction. The arcus tendinei appear as white bands, as does the midline anococcygeal raphe.
The results for Aim 2 led us to reject the hypothesis that pelvic floor tissue is uniform during the second stage of labor. The maximum soft tissue stretch, 3.26, was found to occur in the medial-most band of pubococcygeus (marked as "2" in the lower illustration in Figure 1, see also Figure 2). This stretch ratio exceeds by 217% the largest non-injurious stretch ratio (1.5 stretch ratio) tolerated by passive striated muscles of the torso or extremities in non-gravid mammals (for example, Brooks 1995). The initial and final lengths of each numbered muscle band are shown in the upper half of Figure 2, while the resulting stretch ratio for each muscle band stretch ratio is shown in the lower half of that figure. Because of its short initial and long final length, the most ventral and medial pubococcygeal muscle band exhibited the greatest stretch ratio.

Despite some limitations, this graphical analysis circumvents the limitations of current analytical approaches to structural simulation, which are limited to stretch ratios of about 1.3. Partial validation for the model predictions comes from MR scans of the pelvic floor of women nine months post-partum. These images show atrophic pelvic floor muscle in the region corresponding to the model muscle bands placed under greatest stretch.

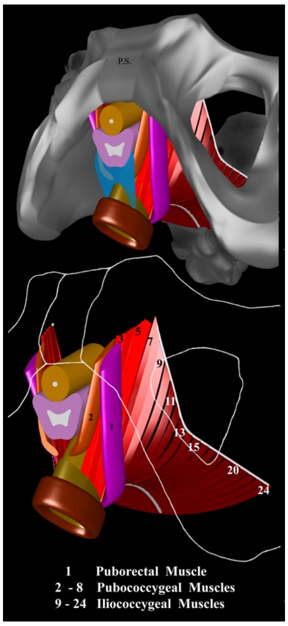

Figure 1: Views of the Nulliparous Pelvic Floor Model.

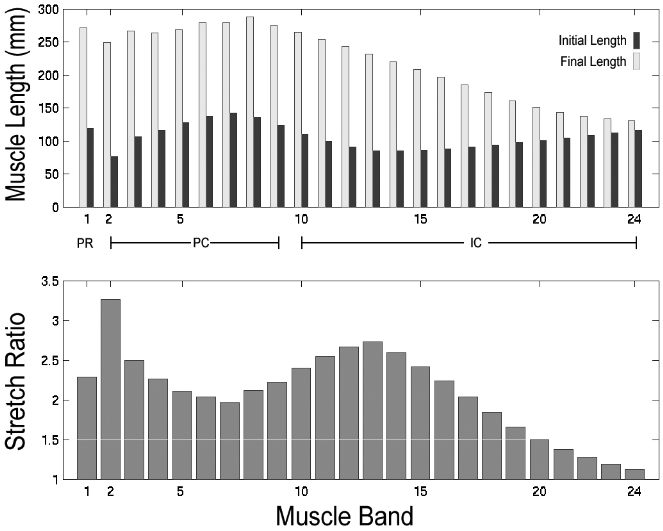

Figure 2: Initial and final muscle lengths (top), and stretch ratios (bottom) by muscle band (see Fig. 1).

<u>Conclusions</u>

We conclude that the left and right most ventral and medial parts of the pubococcygeal muscles undergo the largest pelvic floor tissue strains during vaginal birth. They may therefore be placed at the greatest risk for stretch-related injury during the second stage of labor.