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ANAL SPHINCTER ANATOMY PRE-PREGNANCY TO POST-DELIVERY AMONG THE SAME PRIMIPAROUS WOMEN ON DYNAMIC MAGNETIC RESONANCE IMAGING

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Structured Abstract

Objectives—We utilized 2D images from pelvic 3Tesla magnetic resonance imaging (MRI) to characterize changes in the internal (IAS) and external (EAS) anal sphincter from pre-pregnancy to post-delivery in the same cohort.

Methods—This secondary analysis studied a prospective cohort of women undergoing 3TMRI before their first pregnancy and 6 months after delivery. Radial thickness was measured at 12, 3, 9, and 6 o'clock from axial proximal and mid views and oblique distal views of the IAS, and at 3 and 9 o'clock from oblique views of the EAS. Measurements were compared pre-pregnancy to post-delivery; 10 women had 80% power ($\alpha=0.05$) to detect a 0.85 mm change.

Results—19 women completed initial 3TMRI, 15 achieved pregnancy and birth, and 10 completed post-delivery MRI (4 vaginal birth and 6 Cesarean delivery). Mean change in measurement from pre-pregnancy to post-delivery was $-0.01 \text{ mm} \pm 1.03 \text{ mm}$ for the distal 12 o'clock IAS ($p=0.98$) and $+0.19 \pm 0.64 \text{ mm}$ for the lateral EAS ($p=0.32$). All pre-pregnancy and post-delivery women had discontinuous EA sphincters at 6 and 12 o'clock. There were no statistically significant changes from pre-pregnancy to post-delivery in any IAS or EAS location (all >0.05) for the entire cohort, those with vaginal birth, or following Cesarean.

Conclusions—Anal sphincter measurements on MRI imaging did not change significantly in nulliparous women pre-pregnancy to post-delivery at any location, and the EAS was not measurable at 12 o'clock in any women at either time point, challenging classic concepts of EAS anatomy.

Keywords

Anal sphincter; anatomy; pre-pregnancy; post-delivery; MRI

Introduction

Vaginal birth (VB) is a well-known risk factor of pelvic floor injury, and is associated with the devastating condition of fecal/anal incontinence both immediately following birth and later in life. Unfortunately, this association between vaginal birth and fecal/anal incontinence occurs even in the absence of overt obstetrical anal sphincter injury (OASI) at the time of the VB.¹⁻⁴ In imaging studies utilizing both magnetic resonance imaging (MRI) and ultrasound (US) technologies, nulliparous women and women who have had only one Cesarean birth have less bulky anal sphincters in the anterior segment compared to either male anatomy or female anal sphincters in non-anterior locations.^{5,6} Large prospective studies have demonstrated that women following normal vaginal delivery, in the absence of severe perineal laceration or operative delivery, have similar fecal incontinence symptom prevalence compared to women post Cesarean delivery.^{3,7} Due to these data, it has been hypothesized that women may be predisposed to functional anal sphincter weakness even without overt OASI due to vaginal birth.

Despite these theories, relatively little data exists characterizing the anatomy of the anal sphincter changes from pre-pregnancy to post-delivery in the same group of nulliparous women. Data from a large, prospective cohort study utilizing ultrasound imaging demonstrated that women with a vaginal birth do not have substantially different anal sphincter anatomy than those who had a Cesarean section, but this study contains no data on the pre-pregnancy anal sphincter complex (ASC).⁸ Despite the fact that both MRI and US technology has been found reliable in imaging the ASC,^{9,10} few data sets from either imaging modality characterize the same women before pregnancy and after their first delivery.

The aim of this study was to describe anal sphincter anatomy in women pre-pregnancy and 6 months after a first birth, and investigate changes between these time points in the same cohort of women utilizing modern MRI imaging techniques. We hypothesized that the anterior, distal aspect of the internal anal sphincter (IAS) and the anterior external anal sphincter (EAS) would decrease in thickness from pre-pregnancy to postpartum.

Materials and Methods

This was a secondary analysis of a prospective cohort study where nulliparous women were recruited at the University of Alabama at Birmingham when they presented for assisted reproductive technology (ART) assessment prior to pregnancy. Participants were consented at that time and underwent baseline health and pelvic floor assessment as well as dynamic pelvic 3T MRI.¹¹ Women who achieved pregnancy, had a term birth (by either vaginal or Cesarean delivery), and had both pre-pregnancy and post-delivery MRI were included in this analysis. Women were excluded from this secondary analysis if they did not go on to have post-delivery MRI imaging or did not have a documented pregnancy and term delivery. Labor and maternal characteristics were gathered prior to pregnancy and at delivery. As described in the primary paper,¹¹ women underwent pre-pregnancy and post-delivery assessment with the pelvic organ prolapse quantification exam (POP-Q)¹² and assessment of

fecal and urinary incontinence symptoms using the Pelvic Floor Distress Inventory (PFDI-20), a validated measure of pelvic floor symptom severity.¹³

Patient characteristics including age, BMI pre-pregnancy, medical conditions such as hypertension requiring medication, diabetes, tobacco use within the last 24 months, and regular exercise were collected. Data regarding labor and delivery, including obstetrical lacerations, delivery type, use of forceps, and birth weight of the infant were also recorded. These characteristics were described for all women in this analysis and compared between women having a vaginal birth or a Cesarean delivery using the Fisher's exact test for categorical data (as all comparisons included at least one field with a value <5) and a non-paired t-test for continuous data.

Both pre-pregnancy and 6 months post-delivery, patients underwent dynamic pelvic 3 Tesla MRI without gaps. After an MRI safety questionnaire and pregnancy test were performed, the subject was placed upon the MRI table after voiding and asked to roll onto her side (usually left side down). Using two catheter tip syringes, approximately 120 mL of inert ultrasound gel was placed into the rectum. The subject was then positioned supine, and a phased-array coil was centered over the low pelvis. The subject was moved into the center of the MRI and instructed to lie still for approximately 15–30 minutes as the images were obtained. Static images were initially obtained during quiet breathing. Breath-hold sagittal baseline images were centered on the urethra, vagina, rectum, and coccyx. After these images, each subject was asked to “bear down” for strain images as described in the primary paper;¹¹ images for the anal sphincter complex (ASC) in this analysis were taken from resting 3 mm thick images prior to strain.

The MRI study utilized the multiplanar localizer, axial and coronal T2 Fast Spin Echo (FSE) at rest (3mm thick/0mm gap; Field of View (FOV) 25cm), sagittal T2 FSE images (10mm/0mm), and angled transverse high resolution anal T2 FSE (1.5mm/0mm)(FOV 15cm). Single ultrafast sagittal T2 Half-Fourier Acquisition Single-Short Turbo Spin Echo (HASTE) (10mm thick) image centered on the anal canal were obtained at rest and during maximum strain.

The MRI data sets from resting (non-strain) images were analyzed to find the static axial 2D image that allowed for the best view of the internal and external anal sphincter together, or the level of the distal anal sphincter complex (ASC) according to the anatomical description by DeLancey et al.¹⁴ The static 2D axial image of that exhibited the best and most symmetrical axial view of the IAS just distal to the anal angle (the proximal level) and at the level of the pubovisceralis muscle's closest proximity to the rectum (the mid-level) were also determined.¹⁴ Measurements were obtained of the axial sphincter thickness in millimeters (from medial to lateral or from anterior to posterior) at 3, 6, 9, and 12 o'clock at the proximal, mid, and distal levels for the IAS. For the distal IAS and the EAS (which only resided at the distal level by definition) the best 2D image which offered the best view of the EAS and IAS together was determined. For this population of images, this was the oblique view (35 degrees to the long axis of the rectum), as the 2D images perpendicular to the rectum were not of sufficient resolution to determine intersphincteric fat and clearly delineate the sphincter borders. On this image, the medial to lateral axial thickness at 3

o'clock and 6 o'clock were measured. Planned measurement of the axial thickness at 12 o'clock and 6 o'clock for the EAS was also intended, although review of images revealed that true sphincter muscle was not visible at these locations (see Results).

A paired t-test was used to compare the change in a given measurement from pre-pregnancy to 6 months after delivery in the same women, which was the primary outcome in this secondary analysis. This analysis was repeated within the subgroups including only those women who had a vaginal delivery or only those women who had a Cesarean section.

The parent study was powered for the relation of pelvic floor anatomy to postpartum pelvic floor outcomes, and not for the primary outcome in this study, which was change in the anal sphincter thickness from pre-pregnancy to post-delivery. However, a post-hoc power analysis indicated that, based on past translabial ultrasound findings determining where the axial EAS thickness had a standard deviation (SD) of 0.85 mm,⁸ our population of 10 women allowed us to detect a change of 0.85 ± 0.85 mm (a change of one SD where it is assumed that the SD of the change would not be greater than the SD of the original measurement) from pre-pregnancy to post-delivery with a power of 80%, with a two-sided alpha level of 0.05.

Results

Nineteen nulliparous women who desired pregnancy and were planning assisted reproductive technology in this cohort underwent pre-pregnancy dynamic pelvic 3T MRI. Of these, 4 did not become pregnant and 10/15 (67%) of eligible women who became pregnant went on to have postpartum MRI 6 months. The 10 women who had both pre-pregnancy MRI and underwent repeat, post-delivery MRI imaging 6 months after their first birth were the population of interest in this study. The characteristics of these patients are demonstrated in Table 1; four of these women had a vaginal birth and six had Cesarean delivery. Two of the women who had a vaginal birth (and none of the women who went on to have a Cesarean section) sustained an episiotomy or a second degree spontaneous laceration. None of the women in this cohort (with a vaginal or Cesarean delivery) had attempted or completed forceps or vacuum delivery, or had a recognized laceration to the anal sphincter complex (third or fourth degree laceration).

An example of an axial MRI image utilized in the study and an example of IAS and EAS measurements at the distal level is seen in Figure 1. The mean measurements of the IAS at all three levels and EAS at the distal level for these women are shown in Table 2. Although the distal level of the anal sphincters was well visualized on the MRI images for all women, the 12 o'clock or 6 o'clock segment of the EAS was seen to be discontinuous at these locations in our distal oblique views for all of the women in the cohort, both pre-pregnancy or 6 months after delivery. For this reason, only results for 3 o'clock and 9 o'clock measurements of the EAS are described. An example of a pre-pregnancy distal anal sphincter complex MRI image, which was representative of the type of image seen in all the women in this study prior to pregnancy, is shown in Figure 2. This image exemplifies that no 12 o'clock or 6 o'clock EAS sphincter muscle is visualized; indicating that the muscle is not clearly continuous at these locations.

Changes from pre-pregnancy to post-delivery were minimal throughout the anal sphincter complex. We hypothesized that the distal level IAS (specifically at the anterior) would be significantly altered post-delivery, but the mean change in measurement from pre-pregnancy to post-delivery was merely $0.01 \text{ mm} \pm 1.03 \text{ mm}$ (0.98). Also, despite our hypothesis about the anterior EAS, we found that no 12 o'clock EAS was truly visualized as discussed above. However, the lateral EAS compartments (3 o'clock and 9 o'clock), which were consistently demonstrated, showed a small and non-significant increase in thickness ($+0.19 \pm 0.64 \text{ mm}$, $p=0.32$). In fact, when sphincter measurements were compared for these women from pre-pregnancy to post-delivery, there were no significant changes for any level or quadrant of the IAS (all $p>0.05$). The largest magnitude of change was seen at the proximal level of the IAS at 9 o'clock, with a $+0.52 \pm 1.05 \text{ mm}$ change from pre-pregnancy to post-delivery, but was not statistically significant ($p=0.15$). There were no significant changes in either the 3 o'clock or the 9 o'clock EAS from pre-pregnancy to after delivery (Table 2).

When analysis was repeated for subgroups by mode of delivery (women who had a vaginal birth and who had a Cesarean section), there were also no significant changes from before pregnancy to post-delivery for any quadrant or level of the IAS or either side of the EAS. There were no significant differences between the two modes of delivery in the mean magnitude of change in sphincter anatomy from pre-pregnancy to after birth (Table 3). The change from pre-pregnancy to post-delivery in vaginal birth women that was most notable was at the 12 o'clock mid-level IAS (pre-pregnancy mean $3.08 \pm 1.38 \text{ mm}$ and post-delivery mean $2.70 \pm 1.14 \text{ mm}$, mean change $-0.38 \pm 0.48 \text{ mm}$, $p=0.22$). For Cesarean delivery participants, the change that most closely approached significance was at the 9 o'clock proximal IAS (pre-pregnancy mean $4.1 \pm 1.18 \text{ mm}$ and post-pregnancy mean $4.97 \pm 0.98 \text{ mm}$, mean change $+0.87 \pm 1.16 \text{ mm}$, $p=0.13$). Of note, although these were not the locations with the greatest mean magnitude of change (Table 3), they were the locations where the change from pre-pregnancy to post-delivery most closely approached significance due to variability in measurements.

Discussion

In this secondary analysis of a prospective cohort of healthy, continent women having MRI imaging of their ASC anatomy both pre-pregnancy and after a first delivery, there were no significant changes in ASC anatomy pre-pregnancy to post-delivery. Despite our hypothesis that the anterior aspect of both sphincters would change substantially in these participants, neither nulliparous nor primiparous women had a measurable anterior external anal sphincter (EAS) on high-resolution oblique views 35 degrees to the long axis of the rectum, which was where the EAS and internal sphincter (IAS) were most clearly visualized together.

These findings are limited by the fact that the best view to clearly delineate the EAS and IAS together at the distal level were oblique views, as opposed to those views completely perpendicular to the long axis of the rectum. Due to this, we cannot completely rule out that measurable anterior or 12 o'clock EAS may exist in the pre-pregnancy or the post-delivery women. However, the fact that no measurable anterior EAS was seen in any of the pre-pregnancy women challenges the classic anatomical philosophy of the EAS. Historically, the

EAS is thought to be a continuous cylinder that is continuous at 12 o'clock, and that this cylinder can be interrupted, particularly at 12 o'clock, during vaginal birth. Based on this thinking, there would be measurable anterior EAS in the midline, in either perpendicular or oblique views, but our imaging did not confirm this. Ultrasound imaging studies have described the "anterior" EAS to be substantially thinner than lateral parts of the sphincter complex even in nulliparous women.^{15,16} Similarly, while our imaging cannot completely exclude the presence of a contiguous EAS across the anterior midline, it also indicates that the EAS is not a symmetrical, concentric structure around the anal opening. The EAS, in fact, may be physiologically have a "natural gap" at the 12 o'clock position, as described by the ultrasound study by Bollard et al in 2002.¹⁷ While our findings cannot discard the long-standing hypotheses that the EAS is contiguous across the anterior midline, we must consider that 12 o'clock position on the anterior EAS may be anatomically different than the rest of the sphincter in women who have never been pregnant. It may be a thinner band of muscle, may be fibrous or connective tissue as opposed to contiguous muscle. If we accept the idea that a non-contiguous or thinner anterior EAS may be a normal variant, non-contiguity on post-delivery imaging (or at any time point) may not always constitute an "interrupted" sphincter or evidence of trauma.

This new EAS hypothesis is further supported by a large, prospective ultrasound study of women who had had only Cesarean delivery were not free of anal sphincter damage, and that anal sphincter interruption, defined as total non-contiguity of the EAS anteriorly, was not significantly different between Cesarean and vaginal birth.⁸ An elegant diagram by Netter et al¹⁸ is consistent with this philosophy, and corresponds with the anatomy seen in our pre-pregnancy and postpartum images of the EAS (Figure 2). If 12 o'clock contiguity or symmetry with the rest of the EAS is not normal anatomy, it should be no surprise to the specialty that surgeries to create anterior contiguity or bulk (sphincteroplasty) have never enjoyed great success in fecal incontinence outcomes.^{19,20}

Even for those portions of the ASC that have clear, measurable muscle fibers, we found that the anatomy does not change substantively from pre-pregnancy to after delivery. A current study by Karcaaltincaba et al measured the sphincter thickness in the same group of women immediately before and after delivery, and demonstrated significant change in the 12 o'clock IAS and EAS from antepartum to postpartum in vaginal birth women, although the magnitude of these changes were small (0.5 mm).²¹ As this ultrasound study was a larger population (n=60) than our present study, it was powered to detect subtler changes. However, this larger cohort utilized a different imaging modality, measured the sphincter at only one level (not three), and measured the sphincter thickness pre-delivery (not pre-pregnancy) and merely 48 hours after birth. The present study sought to investigate all levels of the IAS and also performed MRI imaging, which can distinguish fibrotic tissue or reorganization, after tissue healing had already occurred 6 months later.

This study also calls to attention a possible discrepancy in the image of the anterior EAS seen between imaging modalities. Ultrasound studies, such as Karcaaltincaba et al and another large sonographic investigation in postpartum women,⁸ have images that espouse a contiguous anterior sphincter. This may be due to the fact that ultrasound technology visualizes even non-muscular tissue, such as connective tissue seen in the perineal body, as

hyperechoic. For this reason, sonographic imaging may not pick up the natural thinning or discontinuity in the 12 o'clock EAS that is suspected on this MRI study. Interestingly, we also visualized a lack of EAS fiber continuity at 6 o'clock as well. While this posterior position is not as relevant to the perineal anatomy from a clinical standpoint, it still may play a role in re-examining the concept of the circular sphincter that many fields have long assumed to be true.

These data force us to consider that "birth injury" to the ASC may be something that only occurs if the sphincter or its connective tissue are completely transected, or that the damage occurring is not visible on current imaging. This concept of the distinction between the "normal gap" or "normal thinning" at 12 o'clock and true sphincter interruption has been described in the past by Bollard et al.¹⁷ Although past studies describe high rates of "sphincter injury" after a primiparous birth,^{22–24} these studies typically investigate the sphincter after the birth has already taken place, without analysis of pre-birth or pre-pregnancy anatomy. As was suspected in this study, non-visible width or non-contiguity of the EAS at 12 o'clock may be a normal state in some nulliparous women, so normal non-contiguity may be labelled falsely as sphincter laceration. It is known that women with higher parity and sphincter interruption have a higher prevalence of anal incontinence,^{25,26} so there is no doubt that pregnancy and birth are damaging to the continence mechanism, and certainly the true muscle of the anterior anal sphincter may be disrupted in locations lateral to 12 o'clock. However, disruption and partial volume loss of the puborectalis muscles at their insertion onto the pubic symphysis have shown association with pelvic floor dysfunction and would not be visible by imaging the sphincter alone.²⁷ Furthermore, it is more likely that a large part of obstetrical injury damage is neurological or microscopic in nature, a type of damage that is often not radiologically detectable. In support of this theory, investigations on the treatment of fecal incontinence indicate that anterior sphincter construction (sphincteroplasty) is not as effective for restoring continence as nerve stimulation therapy.²⁸ In fact, a publication on ultrasound imaging data found no correlation between anal sphincter measurements postpartum and functional outcomes such as anal incontinence.²⁹ Given these past and present findings, we can no longer assume that obstetrical anterior external anal sphincter damage is straightforward or can be easily visualized.

Strengths of the study include the ability to compare measurements of the anal sphincter complex in the same cohort of women both before pregnancy and after birth. We also performed imaging pre-pregnancy (as opposed to during pregnancy) and 6 months postpartum, therefore avoiding bias from sphincter changes that may occur either during pregnancy but before birth, or after birth but before healing has occurred. Although a small population, there was high power to detect a very small (<1 mm) change in the anal sphincter thickness pre-pregnancy to post-delivery. Modern 3Tesla MRI technology without gaps was used for imaging, which enabled us to identify the 2D image that allowed for the best measurement of ASC anatomy. MRI imaging has been found to be highly accurate and reproducible in measuring the ASC, so the use of this technology is a substantive strength of the study. Finally, this cohort included no women with sphincter interruptions, and no women had anal incontinence pre-pregnancy on validated questionnaires,¹¹ so this cohort represents is presumably a set of functionally normal women.

Limitations of this study include the smaller population size from a single center, which was powered for the primary aim of the parent study. Also, while analysis within each delivery mode (vaginal birth and Cesarean section) did not reveal any significant changes in the ASC anatomy pre-pregnancy to after delivery, the power of this study to detect subtle changes in anatomy within 4–6 women is limited. Lastly, although our MRI protocol was high-quality and MRI is widely considered an excellent manner of ASC imaging that is comparable or even superior to ultrasound,^{9,10} there may still be issues with our imaging protocol. Asymmetry due to our protocol selection of the oblique as the optimal distal ASC view, non-protocol rotation of the patient, or natural asymmetry of the EAS may have created, in this small sample size, spurious findings or exacerbated the appearance of non-contiguity of the anal sphincter at 12 and 6 o'clock in all women at both time points. In other words, we cannot definitively rule out that the EAS continuous across the midline in pre-pregnancy women based on these results alone. Lastly, there was no objective functional assessment of the anal sphincter in these women (such as manometry or squeeze strength), but validated questionnaires applied to these women for other study aims indicated none of these women had pre-pregnancy or post-birth FI or AI, so this was a cohort of functionally continent women.¹¹ For these reasons, our findings may not be generalizable to other imaging modalities or other populations (such as those at higher obstetric risk), and our findings require validation on other imaging investigations.

The current study is part of a growing body of evidence demonstrating that sphincter measurements do not change substantially from pre-pregnancy to after a first birth, regardless of mode of delivery, and anal sphincter compromise during pregnancy and birth is not always visible with imaging technology. Therefore, the medical field should consider that description and correction of anal sphincter anatomy may not be entirely understood, and our conceptions must be altered to help women achieve anal function.

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Figure 1.

Images of the distal anal sphincter complex, with the internal (IAS) and external (EAS) sphincters indicated on the images on the left. The images on the right, with a closer views of the sphincter complex, exhibit how axial measurements of sphincter thickness were taken for the IAS and EAS at 9 o'clock.

Figure 2.

Example of distal MRI sphincter pre-pregnancy and corresponding diagram displaying how external sphincter is not anatomically contiguous across the midline at 12 o'clock or 6 o'clock, but sends fibers to other structures.

Table 1

Patient characteristics of the population of interest in this study: women who had a term birth and both antepartum and postpartum MRI sphincter measurements, also described for those women who had a vaginal birth or a Cesarean delivery.

	Women in entire cohort (vaginal birth or Cesarean) both pre- pregnancy and post- delivery MRI N=10 number (%) or mean $\pm$ SD	Women with vaginal birth who had both pre- pregnancy and post- delivery MRI N=4 number (%) or mean $\pm$ SD	Women with Cesarean birth who had both pre- pregnancy and post- delivery MRI N=6 number (%) or mean $\pm$ SD	p-value
Age (years)	31.9 $\pm$ 2.8	32.8 $\pm$ 3.5	30.5 $\pm$ 2.9	0.24
Race				
Caucasian	7 (70)	4 (100)	3 (50)	0.20
African American	3 (30)	0	3 (50)	0.20
Tobacco use last 24 months	1 (10)	0	1 (16.7)	1.0
Body mass index (kg/m ²)	25.4 $\pm$ 3.5	23.7 $\pm$ 2.4	26.5 $\pm$ 3.9	0.21
Infant weight at birth (grams)	2123.4 $\pm$ 309.3	3289.7 $\pm$ 329.9	3012.6 $\pm$ 264.6	0.21
Episiotomy or laceration				
2 nd degree	2	2	0	0.13
3 rd or 4 th degree	0	0	0	1.0
Hypertension requiring medication or diabetes	0	0	0	1.0
Exercise at least 3 days a week	6 (60)	3 (75)	3 (50)	0.57
Operative vaginal delivery (forceps or vacuum)	0	0	0	1.0
Length of labor (hours)	9.4 $\pm$ 8.5	12.1 $\pm$ 10.4	1.8 $\pm$ 4.0	0.22

Table 2

Mean measurements of the external anal sphincter (EAS) and internal anal sphincter (IAS) and the change in measurement and comparison of measurement (paired t-test) between pre-pregnancy and post-delivery.

Location of ASC Measurement	Pre-Pregnancy Mean Measurement (mm) mean $\pm$ SD	Post-Delivery Mean Measurement (mm) mean $\pm$ SD	Mean Change in Measurement from Pre-Delivery to Post-Delivery (mm) mean $\pm$ SD	p-value (paired t-test)
Mean EAS Thickness				
At 3 o'clock	1.95 $\pm$ 0.50	2.17 $\pm$ 1.00	+0.22 $\pm$ 0.66	0.32
At 9 o'clock	1.93 $\pm$ 0.73	2.08 $\pm$ 1.10	+0.15 $\pm$ 0.63	0.47
Mean IAS Thickness				
Proximal IAS				
At 12 o'clock	3.86 $\pm$ 1.00	3.77 $\pm$ 1.21	-0.09 $\pm$ 1.04	0.79
At 3 o'clock	4.29 $\pm$ 1.03	4.04 $\pm$ 0.92	-0.24 $\pm$ 1.35	0.59
At 6 o'clock	3.99 $\pm$ 1.35	3.76 $\pm$ 1.26	-0.23 $\pm$ 1.42	0.62
At 9 o'clock	3.77 $\pm$ 1.04	4.29 $\pm$ 1.15	+0.52 $\pm$ 1.05	0.15
Mid IAS				
At 12 o'clock	4.01 $\pm$ 1.37	3.68 $\pm$ 1.33	-0.33 $\pm$ 0.97	0.31
At 3 o'clock	3.93 $\pm$ 0.91	4.32 $\pm$ 0.87	+0.39 $\pm$ 1.11	0.30
At 6 o'clock	4.17 $\pm$ 0.82	4.23 $\pm$ 1.10	+0.06 $\pm$ 1.19	0.88
At 9 o'clock	3.97 $\pm$ 0.99	4.08 $\pm$ 0.99	+0.11 $\pm$ 1.27	0.79
Distal IAS				
At 12 o'clock	3.90 $\pm$ 1.05	3.89 $\pm$ 1.22	-0.01 $\pm$ 1.03	0.98
At 3 o'clock	4.33 $\pm$ 1.12	3.97 $\pm$ 0.66	-0.36 $\pm$ 1.14	0.34
At 6 o'clock	3.69 $\pm$ 0.67	4.12 $\pm$ 0.89	0.43 $\pm$ 1.19	0.28
At 9 o'clock	4.10 $\pm$ 1.22	4.32 $\pm$ 0.86	0.22 $\pm$ 1.05	0.52

Table 3

Mean changes in measurements of the external anal sphincter (EAS) and internal anal sphincter (IAS) from pre-pregnancy to after delivery for each mode of delivery (vaginal birth and Cesarean delivery), with comparison in the magnitude of sphincter change between delivery modes

Location of ASC Measurement	Vaginal Birth Mean Change in Measurement from Pre-pregnancy to 6 mo After Delivery (mm) mean $\pm$ SD	Cesarean Delivery Mean Change in Measurement from Pre-pregnancy to 6 mo After Delivery (mm) mean $\pm$ SD	p-value (unpaired t-test comparing delivery modes)
Mean EAS Thickness			
At 3 o'clock	+0.13 $\pm$ 0.25	+0.28 $\pm$ 0.86	0.68
At 9 o'clock	0	+0.25 $\pm$ 0.82	0.49
Mean IAS Thickness			
Proximal IAS			
At 12 o'clock	-0.50 $\pm$ 0.71	+0.18 $\pm$ 1.19	0.29
At 3 o'clock	-0.75 $\pm$ 1.55	+0.10 $\pm$ 1.22	0.40
At 6 o'clock	-0.58 $\pm$ 1.66	0 $\pm$ 1.34	0.59
At 9 o'clock	0 $\pm$ 0.71	+0.87 $\pm$ 1.16	0.18
Mid IAS			
At 12 o'clock	-0.38 $\pm$ 0.48	-0.30 $\pm$ 1.25	0.90
At 3 o'clock	+0.13 $\pm$ 1.11	+0.57 $\pm$ 1.18	0.57
At 6 o'clock	+0.50 $\pm$ 1.08	-0.23 $\pm$ 1.26	0.36
At 9 o'clock	-0.13 $\pm$ 1.11	+0.27 $\pm$ 1.44	0.64
Distal IAS			
At 12 o'clock	-0.13 $\pm$ 1.48	+0.07 $\pm$ 1.33	0.76
At 3 o'clock	-0.60 $\pm$ 1.85	-0.20 $\pm$ 0.47	0.70
At 6 o'clock	+0.50 $\pm$ 0.91	+0.38 $\pm$ 1.42	0.88
At 9 o'clock	-0.60 $\pm$ 0.99	+0.77 $\pm$ 0.71	0.06