The urethral support system during pregnancy and after childbirth
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CHAPTER 5

Displacement and recovery of the vesical neck position during pregnancy and after childbirth

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ABSTRACT

The aim of this study is (i) to describe the displacement and recovery of the vesical neck position during pregnancy and after childbirth and (ii) to discriminate between compliance of the vesical neck supporting structures with and without pelvic floor contraction.

In the present study we focussed on the biomechanical properties of the vesical neck supporting structures during pregnancy and after childbirth by calculating the compliance and the hysteresis as a result from of abdominal pressure measurements and simultaneous perineal ultrasound.

This study shows that compliance of the supporting structures remains relatively constant during pregnancy and returns to normal values 6 months after child birth. Hysteresis however showed an increase after child birth, persisting at least until 6 months post partum.

Vaginal delivery may stretch and or load beyond the physiological properties of the pelvic floor tissue and in this way may lead to irreversible changes in tissue properties which play an important role in the urethral support continence mechanism.

Key words Urethral support, pelvic floor, vaginal delivery, compliance and hysteresis.
INTRODUCTION

In an overview article Gregory and Nygaard about childbirth and pelvic floor disorders the describe the urinary continence mechanism depends among other factors on urethral support of both endopelvic fascia and muscles of the pelvic floor. In this respect the biomechanical properties of the pelvic floor are of great importance, since the pelvic floor must be capable in providing sufficient back pressure for urethral closure.

The pelvic floor mainly consists of connective tissue and muscles. De Lancey discusses the normal structure of the pelvic floor and its basic function in relation to its structural biomechanics. He stresses the important role of the endopelvic fascia which attaches the pelvic organs to the pelvic wall, in this way suspending and supporting the pelvic organs. Connective tissue undergoes significant remodelling of its components in response to a variety of factors or mechanical stresses. Pregnancy and childbirth may be among these factors.

In a review article on the muscles of the pelvic floor, Wall gives a description of muscle contribution to urethro-vesical support. Declined muscle function due to impaired muscle integrity and neural control mechanisms directly influence this supportive mechanism. Moreover the pelvic floor muscles exhibit a constant baseline tone. By maintaining closure of the pelvic floor, the viscera can rest on this muscular shelf, keeping the ligaments from stretching. Reduction of muscle function due to pregnancy and or delivery may therefore be indirectly responsible for stretching the pelvic floor connective tissues.

In the present study we focussed on the biomechanical properties of the vesical neck supporting structures during pregnancy and after childbirth. Generally, tissue distensibility is determined not only by the elasticity of the constituent muscle and connective fibers itself but also by the geometrical arrangement of those fibers. Two parameters are in use to describe the mechanical properties of tissue: Young’s modulus, or its reciprocal (the compliance), to quantify the pure elastic behaviour of tissue in which the geometrical structure of the fibers remain unaltered, and hysteresis: the failure of tissue to follow the same course during relaxation as it did during distension. The latter parameter is thought to be the result of shifts in the geometrical structure of the fibers with respect to each other, and can be
interpreted as a form of internal friction within the tissue. Also, inertial effects involved may effect the return of the tissues to a normal position.

By the use of perineal ultrasound and simultaneous abdominal pressure measurement we were able to measure the displacement and the recovery of the vesical neck in relation to the increase of abdominal pressure during coughing and during Valsalva manoeuvre, in this way measuring its compliance during cough and during Valsalva. Also the course of the displacement could be followed during increase and decrease of the abdominal pressure, from which hysteresis could be calculated. These measurements were made throughout pregnancy and after childbirth resulting in serial measurement of the biomechanical properties of the vesical neck supporting structures during pregnancy and after childbirth.

The aim of this study is (i) to describe the displacement and recovery of the vesical neck position during pregnancy and after childbirth and (ii) to discriminate between the compliance with and without pelvic floor contraction of the levator muscles.

**METHODS**

The present study is part of a prospective study on the effect of pregnancy and delivery on changes in pelvic floor mobility and urinary incontinence. One hundred and seventeen women who attended the outpatient clinics of the University Hospital Groningen and the Martini Hospital Groningen enrolled for the study. The women ranged in age from 17 to 41 years (mean and median 30 years). All women were of Caucasian origin, except three who were of Mediterranean origin. All women were nulliparous and had no history of incontinence, pelvic operations or neurological disease. Written informed consent was obtained from all participating women. The study was approved by the medical ethical committees of both hospitals. For the study women were investigated three times during pregnancy, at 12-16 weeks, at 28-32 weeks and at 36-38 weeks of pregnancy. After childbirth women were investigated twice, at 6 weeks and 6 months post partum. During the study six women withdrew because of matters of inconvenience, and three had their delivery preceding the third visit. Numbers of women with available data were 98, 80 and
Perineal ultrasound was performed with Aloka 600 equipment with a 3.5 MHz convex transducer and the woman in the lithotomy position. Bladder volumes as calculated by scan at the three subsequent measurements varied from 100-300 ml, the mean (sd) being 238 (51), 254 (60) and 222 (54). No significant differences at the subsequent measurements. The position of the urethro-vesical junction was recorded continuously during coughing and during the Valsalva maneuver (figure 1), standardized as described before⁴, for coughing over 70 cm H₂O and for Valsalva over 50 cm H₂O was needed before measurements were made. Simultaneous abdominal pressure changes were recorded by the insertion of a microtip pressure transducer (Gaeltec) high in the posterior fornix of the vagina. All scans were made by the first and second author. Inter and intra observer variability was less than 5%. A more extensive description of the methods can be found in a previous article⁴.

During the Valsalva manoeuvre and during coughing a set of data of displacement of the urethro-vesical junction and the change in abdominal pressure was obtained, as shown in figure 2, showing the relationship between displacement of the urethro-vesical junction and abdominal pressure, i.e. the stiffness of the vesical neck supporting structures. In physiology often the reciprocal of the stiffness is used, the compliance: the increase in length per unit force applied. In more dimensional structures compliance is also defined as the increase in extension per unit pressure. As a parameter directly related to extension of the pelvic floor we used the change in the urethro-vesical junction angle under application of pressure. Pressure was generated by both letting the subjects perform a Valsalva manoeuvre and during voluntary coughing. Since the change in urethro-vesical junction angle is independent of the anatomical dimensions, the resulting parameter, change in angle divided by the pressure generated, can be considered as the specific compliance with as
dimension the change of angle in degrees per pressure in Cm H$_2$O. On base of a theoretical approach as described in the section discussion the effect of contraction of the pelvic floor muscles to the pelvic floor stiffness is then calculated. Hysteresis, the failure of tissue to follow the same course during relaxation as it did during distension, is expressed as the area of the curve, estimated as area of an the standardized ellipse, $\pi * 1 * c/b$, figure 2.

**Figure 1:** Measurement of the angle of the urethro vesical junction at rest, $\beta_1$, (left) and during Valsalva $\beta_2$ (right) (B = bladder, S = symphysis, uvj = urethro vesical junction).

**Statistical Analysis**

Using SPSS for windows, all continuous variables were tested for normal distribution using the Kolmogorov-Smirnov test; no continuous variables were assigned to differ from the normal distribution. For comparison between groups of continuous variables the t-test for equality of means was used.
**Figure 2:** Calculation of compliance and hysteresis

Compliance, the displacement/pressure coefficient, expressed as the displacement of the urethro-vesical junction in degrees per abdominal pressure change in cm H₂O, ΔA/ΔP. Hysteresis, the failure of tissue to follow the same course during relaxation as it did during distension, expressed as the area of the curve, estimated as area of a standardized ellipse π*c/b.

### RESULTS

During pregnancy the compliance during coughing remains practically unchanged. After childbirth the compliance during coughing increases significantly. At 6 months post partum the compliance during coughing differs no longer from coughing compliance in the control group, figure 3.

For the compliance during Valsalva there is the same trend during pregnancy, no significant changes. After childbirth, compliance during Valsalva increases significantly. After 6 months the compliance during Valsalva has returned to the value of the control group, figure 4.

The “muscle compliance”, as calculated from compliance during coughing and during Valsalva is not influenced by pregnancy. After childbirth “muscle compliance” significantly increases. 6 Months after childbirth “muscle compliance” is comparable to the value as found in the control group, figure 5.

Hysteresis as calculated during the Valsalva manoeuvre (figure 6) and during coughing (figure 7) is not influenced by pregnancy. After childbirth there is a significant rise, persisting at least until 6 months post partum.
DISCUSSION

This study shows that compliance of the vesical neck supporting structures remains relatively constant during pregnancy and returns to normal values 6 months after childbirth. Hysteresis however showed an increase after childbirth, persisting at least until 6 months post partum.

Stiffness, or its more mechanical denomination elasticity, of the pelvic floor is an important biomechanical property. It is usually defined as the force to be applied necessary to achieve a predetermined percentage or fraction increase in length. In physiology often the reciprocal of the elasticity is used, the compliance: the increase in length per unit force applied. In more dimensional structures compliance is also defined as the increase in extension per unit pressure.

Figure 3: Compliance during coughing
In general, deformation under load for tissue is seldomly linear. To quantify such deformation we decomposed deformation into elasticity, approximated by a linear model and hysteresis, estimated by a non linear model as shown in figure 1. The compliance of the vesical neck supporting structures seems to be significantly affected by childbirth as measured by the increased compliance 6 weeks after delivery. 6 Months after delivery compliance has normal values, comparable with an age matched nulliparous non pregnant control group. Our data suggest that childbirth in primiparous women only affects this dynamic pelvic floor tissue properties temporary. This holds for the pelvic floor tissue during Valsalva manoeuvre as well as during coughing.
**Figure 5:** Muscle compliance

**Figure 6:** Hysteresis during Valsalva
The increase in hysteresis however seems to be permanent. Since hysteresis, the phenomenon that tissue does not follow the same course during distention as during relaxation, depends on shifts of the constituent fibers with respect to each other, an increase in hysteresis means that the geometrical structure becomes looser. Both compliance and hysteresis contribute to the stiffness of the pelvic floor and our data suggest that a decrease in stiffness of the pelvic floor after child birth is mainly due to a more loosely coupling of the various fibers in the pelvic floor tissue to each other. Reduced fascial strength and decreased muscle tone tend to make the pelvic floor more flaccid so that the necessary back pressure cannot be produced leading to hypermobility of the Urethro Vesical Junction, significantly related with genuine urinary stress incontinence\(^6\).

Figure 7: Hysteresis during coughing

The compliance of the pelvic floor in vivo is determined by both muscle tone and the properties of the fascia. During the Valsalva manoeuvre no additional muscle tone originating from the pelvic floor muscles was supposed to be present. Little contraction of the pelvic floor muscles cannot be ruled out because straining induces levator ani muscle contraction, more pronounced in sudden straining than in slow sustained straining\(^7\). Moreover women do not always find it possible to relax their muscles during Valsalva’s maneuver, especially if they are concerned about
loosing gas. Therefore we instructed patients emphatic to avoid pelvic floor muscle contraction. This is described to be effective to relax pelvic floor muscles as measured by reduced EMG activity. During coughing a reflex contraction of the suburethral pelvic floor muscles occurs. In this way we have two measurements of compliance under different muscle tone, which allow us to focus on the contribution of muscle activity to the pelvic floor compliance.

Increased post partum Valsalva compliance means less resistance to abdominal pressure rises and hypermobility of the viscera and its supported organs in the post partum period. In our study Valsalva compliance returns to normal values after 6 months, indicating normal dynamic function of the fascia at least during slow abdominal pressure rises, such as Valsalva.

Norton reviews on the role of fascia and ligaments. Connective tissue of the pelvic floor mainly consists of type 3 collagen. The collagen fibres are randomly layered and give the pelvic viscera its elastic properties. Fascia are resistant to great forces. It is thought that as the tissue is stretched the crimp gradually disappears by straightening the collagen fibres. Stretching or loading beyond this point may lead to irreversible damage. Stress relaxation is thought to be an accommodation effect of fascia to pregnancy and as a preparation to childbirth. Cervical ripening after prostaglandins is associated with collagen fiber re-arrangement and increase of ground substance. It is likely that these alterations take place in all collagen tissue. This may contribute to lack of urethrovesical support during pregnancy, thus leading to (temporary) hypermobility, a well known risk factor for urinary incontinence.

Tissue consisting of structures each having different elastic properties has a total elasticity which can be calculated as the sum of the elasticity's of the components. By converting the measured compliances to elasticity (the reciprocal value) and subtracting the values obtained during coughing and those obtained at the Valsalva manoeuvre we calculated the effect of contraction of the pelvic floor muscles to the pelvic floor stiffness, using the following estimate:

\[
\frac{1}{\text{compliance (contracted muscles)}} = \frac{1}{\text{compliance Cough}} - \frac{1}{\text{compliance Valsalva}}
\]

The method we used to estimate the compliance of the contracted pelvic floor muscles may have its limitations. Undoubtedly there exists a remaining muscle tone
during the Valsalva manoeuvre. It should be kept in mind that the compliance values measured during the Valsalva manoeuvre cannot be completely ascribed to the mechanical properties of endopelvic fascia alone, but also reflect some muscle tone, thus effecting the outcome in our estimation. In conclusion the separation of compliance between fascia and relaxed muscle on one hand and fascia and contracted muscle on the other hand may not be complete. However, a complete separation cannot be realized in in vivo measurements. Moreover other effects may explain these differences, such as muscle integrity and neural control mechanisms. To obtain quantitative insight in the course of the mechanical properties of the pelvic floor during pregnancy and after childbirth in vivo measurements are necessary and the method used in this study may therefore be a good approximation. For convenience the estimated compliance of the contracted muscles is referred to as “Muscular compliance”.

“Muscular compliance” is, similar to fascial compliance during Valsalva, only temporary affected. Pelvic muscle groups support structures which penetrate the urogenital hernia. During stressful periods of increased intra abdominal pressure, such as coughing these muscle groups provide support by reflex contraction. The passing fetal head may lead to direct muscular or indirect neurological injury due to (over)stretching. This may lead to hypermobility of the urethro vesical junction and to urinary incontinence. From our results we conclude that muscular function itself during coughing is not permanently significantly affected by pregnancy and childbirth.

Barbic described increased compliance of the pelvic floor during coughing as a distinguishing mark in women with stress urinary incontinence. He found a greater compliance in his study group of parous women with stress urinary incontinence (SUI) as compared to a control group without SUI. Measurements were done during coughing in non pregnant parous women, no Valsalva measurements are reported. Howard reported on stiffness of the pelvic floor both during coughing and during Valsalva. For coughing he found a decrease of stiffness in stress incontinent primiparous women as compared to nulliparous continent women. For Valsalva no difference between these groups was found. Our results do not indicate permanent increase of compliance due to childbirth for the study group, nor for coughing, nor for Valsalva. The fact that we have not found significant differences, does not mean
that there were not individual women who lost support. It should be emphasized that these women may have permanent increased compliance and may be the ones who develop SUI directly or later in lifetime.

Calculation of pelvic muscle compliance is not described before. The pelvic floor muscular impact on urinary stress incontinence is qualitatively studied by measuring the cough leak point pressure (CLPP) and Valsalva leak point pressure (VLPP)\(^7\)\(^\;\)\(^{16}\). A greater CLPP than VLPP in an incontinent woman indicates the presence of an effective contraction of the suburethral tissue during coughing. Women with grade III SUI had lower VLPP than CLPP, indicating more intrinsic sphincter deficiency (ISD). In these women less hypermobility of the urethra vesical junction was found than in women with a lower CLPP. From their study on CLPP and VLPP Pescher et al. \(^17\) conclude that these provocations result in a different reaction of the pelvic floor, possibly due to an involuntary isotonic or isometric contraction of the pelvic floor muscles stabilising the pelvic floor. Another way of measuring the pelvic floor muscular continence component is imaging of voluntary pelvic floor contractions\(^18\). The latter gives information on voluntary contraction but does not measure the function of the pelvic floor during the provocative moment of coughing, therefore the clinical use of it is probably limited.

In our study we described changes in the dynamics of urethral support structures during coughing and during Valsalva throughout pregnancy and up to 6 months after childbirth. We found that the compliance and of the pelvic floor is only temporary affected by the process of childbirth, both during coughing as well as during Valsalva. We described a theoretical approximation of muscular and fascia contribution to compliance of the pelvic floor. Both muscular tissue and connective tissue seem to be resistant to the process of childbirth as concluded from the values for both compliances after six months, being not different from the measurements in non pregnant controls. Hysteresis however showed an increase after child birth at least persisting until six months post partum, showing that delivery may stretch and or load beyond the physiological properties of the pelvic floor tissue and in this way may lead to irreversible changes in tissue properties which play an important role in the urethral support continence mechanism.
REFERENCE LIST


