The urethral support system during pregnancy and after childbirth

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CHAPTER 2

Anatomical and functional changes in the lower urinary tract during pregnancy

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ABSTRACT

Objective To assess the prevalence and the development of urinary incontinence in nulliparous pregnant women, both subjectively and objectively, and to investigate the relation of incontinence with the mobility of the urethro-vesical junction measured by perineal ultrasound.

Design A prospective longitudinal study.

Setting University Hospital and Martini Hospital Groningen, the Netherlands.

Population A cohort of 117 nulliparous pregnant women and 27 nulliparous non-pregnant controls.

Methods Urinary incontinence was measured by a questionnaire and by a 24-hour pad test. The position of the urethro-vesical junction and its mobility were measured by perineal ultrasound.

Main outcome measure Prevalence of urinary incontinence; mobility of the urethro-vesical junction, indicated by the displacement/pressure coefficient.

Results Up to 35% of the women reported urinary incontinence in pregnancy, and 20% of the women had a positive pad test. The angle of the urethro-vesical junction angle at rest and the displacement/pressure coefficient during coughing showed a significant increasing trend during pregnancy, but no changes were seen during the Valsalva manoeuvre. No relationship was found between subjective and objective incontinence data and the position and mobility of the urethro-vesical junction.

Conclusion The prevalence of incontinence in nulliparous women as found by the pad test was significantly higher in pregnancy (20%) than in the non-pregnant control group (4%). Perineal ultrasound of the urethro-vesical junction showed lowering of the pelvic floor occurring as early as 12-16 weeks of pregnancy. Serial measurements of the displacement/pressure coefficient suggest that the dynamic characteristics of the connective tissues of the pelvic floor remain unaltered, whereas a significant decrease in pelvic floor muscle contraction occurs. Since no relation was found between measurements of the urethro-vesical junction and incontinence, urinary incontinence in pregnancy is most likely explained by other factors.
INTRODUCTION

It is generally accepted that as pregnancy proceeds a growing number of women complain of urinary incontinence. Accidental loss of urine is reported in 17-25% of women in early pregnancy \(^1, 2\) and in up to 36-67% in late pregnancy \(^1, 3\). Moreover, the degree of incontinence worsens as pregnancy advances \(^3\). The prevalence of incontinence during pregnancy is usually calculated from self-reporting of symptoms without objective measurements. Urinary incontinence during pregnancy is ascribed to detrusor instability resulting from changes in hormone levels \(^4\) and to anatomical changes due to the growing uterus and the engagement of the fetal head in the pelvis \(^5\). Others \(^6\) have suggested that reduced fascial strength and subsequent weakness of the pelvic supports might contribute to urinary incontinence during pregnancy.

The scarcity of information on urinary incontinence during pregnancy, the wide variation of the reported prevalence and the uncertainty concerning the underlying mechanism prompted us to investigate these issues in a prospective longitudinal study. In a homogeneous cohort of nulliparous pregnant women, urinary incontinence was assessed by questionnaire, and by a 24-hour pad test. Changes in pelvic floor function during the course of pregnancy were dynamically investigated by perineal ultrasound measurements of the position and the mobility of the urethro-vesical junction.

METHODS

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 this study the women were investigated three times, at 12-16 weeks, at 28-32 weeks and at 36-38 weeks of pregnancy. During the study six women withdrew because of matters of inconvenience, and three had their delivery
preceding the third visit. To investigate changes early in pregnancy an age-matched control group of 27 nulliparous non-pregnant continent women from the infertility outpatient clinic was included. These non-pregnant controls were subjected to the same protocol, including the pad test, but only once.

At each visit all women completed a questionnaire on symptoms of incontinence. Stress incontinence was defined as the loss of urine on physical effort and urge incontinence as the loss of urine associated with a strong desire to void. If incontinence was reported women tried to classify it as stress or urge incontinence.

At the first visit pads were given to all women, to be worn for 24 hours preceding the second and third visit. Three pads were packed in a plastic bag and weighed by the investigators before and after use. The women received a written instruction and were free to wear one, two or three pads. It was emphasised that the bag should be closed carefully every time a pad was changed to prevent evaporation. If the bag was returned open or contained less than 3 pads the test was excluded from evaluation. The outcome of the 24-hour pad test was recorded as the weight gain at every visit of the pads. In accordance with the literature a cut-off level of 9 g was used to classify a woman as incontinent.

Perineal ultrasound was performed with an Aloka 600 machine with a 3.5 MHz convex scanner and the woman in the lithotomy position. Bladder volume varied from 100-300 ml. The position of the urethro-vesical junction was recorded continuously during coughing and during the Valsalva manoeuvre. The central part of the curved array probe was placed at the same level as the inferior border of the symphysis, with the radial line kept horizontally. Care was taken to prevent rotation of the convex ultrasound probe in the sagittal plane and to place the probe only lightly against the perineum during the various procedures. Simultaneous abdominal pressure changes were recorded by the insertion of a microtip pressure transducer (Gaeltec) inserted high in the posterior fornix of the vagina. At a frequency of 8 Hz ultrasound images and pressure measurements were recorded on line and stored on a hard disk during each exercise after the pre-set trigger pressure level of the system had been met by the participant. During coughing this level was 70 cm H2O and during Valsalva 50 cm H2O. Off line, the displacement of the urethro-vesical junction was measured with respect to the fixed lower edge of the symphysis and was expressed in degrees, as shown in Figure 1. Like others we defined the position of the bladder neck as the angle $\beta_{1,2}$ between the line going from the urethro-vesical junction to the inferior border of the pubic bone and a reference line.
As a reference line we used the radial line from the curved array probe through the horizontal plane that goes through the inferior border of the pubic bone. The effect of possible changes in the position of the ultrasound probe relative to the pelvis as a result from unintended rotational movements during coughing and during the Valsalva manoeuvre was investigated in ten women (nos. 10, 20…100). For this purpose, a line from the inferior border of the pubic bone through the center of the pubic bone was added. In this way in each participant a fixed line was obtained. The variation of the angle between this fixed line and our reference line is an index of rotational artefacts. The standard deviation for this angle during a session (24 samples), measured in 10 women, was 1.6 degrees on average for coughing and 2.4 degrees for the Valsalva manoeuvre. Comparison of the values of this angle at the consecutive measurements during the course of pregnancy revealed no significant differences. Also, the distance between the urethro-vesical junction and the inferior pubic bone showed no significant changes during a session, the average distance being 46.5 mm (SD 3.0 mm) during coughing and during the Valsalva manoeuvre.

**Figure 1:** Schematic representation of measurement of the angle of the urethro-vesical junction.

During the Valsalva manoeuvre and during coughing a set of time related data of displacement of the urethro-vesical junction and the change in abdominal pressure was obtained, as shown in Figure 2a and 2b. From these two simultaneously
recorded variables an X-Y graph was plotted, showing the relationship between
displacement of the urethro-vesical junction and abdominal pressure (Figure 2c). The
slope of the line connecting the starting point and the point at maximum pressure
was considered as a characteristic index of pelvic floor function. We called this
the displacement/pressure coefficient, which is expressed as displacement of the
urethro-vesical junction in degrees per abdominal pressure change in cm H₂O.

Measurements of angles and pressures in each session were done in duplicate.
Since the results were not available in real time, flaws were not detected until the
data were analysed. To remove outliers from the data we excluded from further
analysis those sessions with duplicates outside the 95% confidence interval 13. The
coefficient of variation within each session was < 4% for angles (A₀ and A_max) and the
 corresponding pressures (P₀ and P_max). For the displacement/pressure coefficient
the variation coefficient was 14% in the Valsalva and 17% in the cough experiments.

Figure 2a-2c: Simultaneous perineal ultrasound and vaginal pressure measurements. Figure 2a shows the time series for pressure changes during the Valsalva manoeuvre, at a frequency of 8 Hz. Figure 2b shows the simultaneous recorded time series for the rotation angle and figure 2c is the cross plot of figure 2a and 2b.

A₀ is the resting angle, the rotation angle at rest, pressure is minimal. A_max is the maximal angle, the rotation angle at maximal pressure during Valsalva. The lower part of the curve reflects the angle with increasing vaginal pressure whereas the upper part of the curve reflects the angle with decreasing vaginal pressure. The slope of the line connecting the starting point and the point at maximum pressure is defined as a characteristic parameter of the pelvic floor, the displacement/pressure coefficient, expressed as the displacement of the urethro-vesical junction in degrees per abdominal pressure change in cm H₂O.
**STATISTICAL ANALYSIS**

The Kolmogorov-Smirnov test was used to assess if the data had a Gaussian distribution. The progressive increase in incontinence during pregnancy was verified with the chi-squared test for trend. For the weight gain in the pad test the Mann-Whitney test was used and for 2 * 2 frequency tables Fisher’s exact test. Friedman’s two-way analysis of variance by ranks was used for the longitudinal ultrasound and pressure measurements, and the Mann-Whitney test for comparison between these measurements in non-pregnant and early pregnant women.

**RESULTS**

*Incontinence during pregnancy*

During pregnancy the number of women reporting urinary incontinence increased significantly from 16% at 12-16 weeks, to 30% at 28-30 weeks and to 35% at 36-38 weeks (p=0.002). Of the women reporting urinary incontinence, stress incontinence occurred in 45, 49 and 59% respectively, at the first, the second and the third visit. The remaining women reported urge incontinence. Pads were returned according to the protocol by 98% and 86% of the women at the second and third visit respectively. The mean weight gain of the pads was 5.7 gram, at 28-32 weeks and at 36-38 weeks gestation. Using a definition of stress incontinence of weight gain of 9 grams, a significant association (p=0.03) was found between self-reported incontinence and the results of the pad test. In the early pregnant group the pad test revealed significantly more weight gain than was found in the non-pregnant control group (5.7g vs. 3.1g, p<0.001). Comparison of the women with stress and urge incontinence showed no significant differences in results of the pad tests.

*Measurements of the urethro-vesical junction in pregnancy*

The resting angle of the urethro-vesical junction ($A_0$) widened significantly during pregnancy, from 51.5 degrees at 12-16 weeks to 62.0 degrees at term (p<0.001). At 12-16 weeks the resting angle was already significantly increased as compared to that in the non-pregnant control group, where a resting angle of the urethro-vesical junction of 44.5 degrees was found (p=0.01). The effects of coughing and of the Valsalva manoeuvre on the mobility of the urethro-vesical junction were investigated.
by using the displacement /pressure coefficient. During coughing and during the
Valsalva manoeuvre, the mean peak pressures that were reached were 88 and 75
cm H$_2$O, respectively. During coughing there was a significant increasing trend in the
displacement/pressure coefficient during of pregnancy (p=0.03), although at 12-
16 weeks the difference was not significant from the non-pregnant control group.
For the Valsalva manoeuvre no significant change in the displacement/pressure
coefficient was found at 12-16 weeks compared with the control group, 0.32 vs.
0.30, and throughout pregnancy no significant difference was observed (Tables 1
and 2).

No relationship was found between measurements of the urethro-vesical junction
and the women’s perception of urinary incontinence. This applied to all variables
studied during coughing as well as during the Valsalva manoeuvre: the angle of the
urethro-vesical junction at rest, the angle of the urethro-vesical junction at maximum
pressure and the displacement/pressure coefficient. Also, no statistically significant
relationship could be demonstrated between these variables and the results of the
pad tests.

Table 1: Relationship between the angle of the urethro-vesical junction and pressure during coughing at
consecutive visits in pregnancy, and in the controls

<table>
<thead>
<tr>
<th></th>
<th>Rest resting angle (A$_0$)</th>
<th>Cough maximal angle (A$_{max}$)</th>
<th>Pressure change (ΔP)</th>
<th>displacement/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>median</td>
<td>Σ ranks*</td>
<td>median</td>
<td>Σ ranks*</td>
</tr>
<tr>
<td>12-16 weeks</td>
<td>51.5</td>
<td>146.5</td>
<td>65.0</td>
<td>150.0</td>
</tr>
<tr>
<td>28-32 weeks</td>
<td>58.5</td>
<td>206.5</td>
<td>74.5</td>
<td>212.0</td>
</tr>
<tr>
<td>36-38 weeks</td>
<td>62.0</td>
<td>241.0</td>
<td>79.0</td>
<td>238.0</td>
</tr>
<tr>
<td>controls</td>
<td>44.5</td>
<td>62.5</td>
<td>94.0</td>
<td></td>
</tr>
</tbody>
</table>

Angles in degrees, pressure in cm H$_2$O and displacement/pressure coefficient in degrees/cm H$_2$O, medians
and sum of ranks, * significant trend, p< 0.01, two way analysis of variance in ranks, † ns.

Table 2: Relationship between the angle of the urethro-vesical junction and pressure during the Valsalva
manoeuvre at consecutive visits in pregnancy, and in controls

<table>
<thead>
<tr>
<th></th>
<th>Rest resting angle (A$_0$)</th>
<th>Valsalva maximal angle (A$_{max}$)</th>
<th>Pressure change (ΔP)</th>
<th>displacement/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>median</td>
<td>Σ ranks*</td>
<td>median</td>
<td>Σ ranks*</td>
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<tr>
<td>12-16 weeks</td>
<td>49.5</td>
<td>122</td>
<td>76.6</td>
<td>135</td>
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<tr>
<td>28-32 weeks</td>
<td>57.1</td>
<td>173</td>
<td>83.6</td>
<td>179</td>
</tr>
<tr>
<td>36-38 weeks</td>
<td>61.5</td>
<td>203</td>
<td>84.9</td>
<td>184</td>
</tr>
<tr>
<td>controls</td>
<td>43.5</td>
<td>73.5</td>
<td>77.0</td>
<td></td>
</tr>
</tbody>
</table>

Angles in degrees, pressure changes in cm and displacement/pressure coefficient in degrees/cm H$_2$O,
medians and sum of ranks, * significant trend, p< 0.01, two way analysis of variance in ranks, † ns.
**DISCUSSION**

The prevalence of incontinence reported by the pregnant women in our study is in agreement with data from the literature, and so is the increase observed during the course of pregnancy. However, the reliability of figures on the prevalence of incontinence in pregnancy, based on self-reporting of urinary incontinence, has been questioned. Burgio et al. found that the self-reported prevalence of incontinence in pregnancy was associated among other things with the level of education and attendance at childbirth classes. Therefore they recommended self-reporting of symptoms should be supplemented by objective measures, such as the pad test. Ryhammer et al., in a study in menopausal women found no relation between self-reported incontinence and objective measures such as the 24-hour home pad test.

If we use a cut-off point of 9 grams weight gain in the 24-hour pad test to define urinary incontinence, a significant relation was found between the results of the pad test and the self-reporting of symptoms. Thus our findings indicate that there is a relation between objective and subjective measurements of incontinence in pregnancy.

By using the 9 gram cut-off of the 24-hour pad test to define urinary incontinence the frequency of incontinence in our study was 24% and 16% at 12-16 and 36-38 weeks respectively. These figures are still significantly higher than in the non-pregnant control group where only one out of 27 women (4%) had a pad test result of 9 grams or more. Pregnancy itself therefore seems to be the causal factor for incontinence, although the mechanism is not clear.

The function of the pelvic floor is thought to play an important part in the mechanism of continence in women, and so we investigated the changes in pelvic floor function during pregnancy and its relation to incontinence. We used simultaneous recording of abdominal pressure and the consequent changes in the position of the urethro-vesical junction. The method of perineal ultrasound to study vesical neck mobility has been evaluated by Schaer et al. who found it to be valid. Like most other investigators, we have applied perineal ultrasound in the lithotomy position. From the study of Vierhout and Jansen it is evident that there is a small but consistent change in the localisation of the bladder neck when moving from the lithotomy position to the vertical position. Although there is a difference in the starting-point of the localisation of the urethro-vesical junction, the direction and the magnitude...
of the displacement during Valsalva and coughing is not essentially different whether the woman is standing or in the lithotomy position. In practice, it appears more difficult to obtain accurate measurements in the vertical position. Moreover, Vierhout and Jansen found that women experience more discomfort during such measurements in the standing position than in the lithotomy position.

The proximal urethra and the anterior vaginal wall are intimately connected and attached to the muscles of the pelvic diaphragm and to the arcus tendineus fasciae pelvis. Support of the urethra at rest comes from both its attachments to the arcus tendineus fasciae pelvis and the resting tone of the muscles of the pelvic diaphragm\textsuperscript{18}. Therefore, the mobility of the urethro-vesical junction can be used as an index of the mobility of these pelvic floor structures. Already in early pregnancy we found a significant widening of the resting angle compared with the non-pregnant control group. This finding is interpreted as lowering of the pelvic floor, a phenomenon previously described in late pregnancy by Peschers et al.\textsuperscript{5}. They explain it by the pressure of the growing uterus and the engagement of the fetus and by the hormonal changes of pregnancy. As we observed the widening already early in pregnancy, it seems unlikely that pressure by the growing uterus and the engaging fetus are the only factors responsible for the observed widening of the angle of the urethro-vesical junction. We therefore believe that the effects of pregnancy hormones on the connective tissues of the pelvic floor are much more important in this respect. This is supported by a study of Landon et al\textsuperscript{16}. They showed intrinsic tissue changes due to the hormonal state of pregnancy itself, resulting in an increased stretching of fascial tissue. Versi et al found that the collagen content of skin is associated with several characteristics of the urethral pressure profile, both at rest and during coughing. They state that urethral collagen might well be under similar hormonal and genetic control mechanisms as skin collagen\textsuperscript{19}. The exact way in which pregnancy and its hormones affect the mechanical properties of the supporting connective tissue and fascia of the urogenital tract in the human is unknown. In dogs elevated levels of progesterone in pregnancy decrease urethral pressure by facilitating β-adrenergic responses\textsuperscript{20}. In the human progesterone receptors have been demonstrated and quantified in the female pelvic floor muscles, the urogenital ligaments and in the myometrium by monoclonal antibody assay techniques\textsuperscript{21}. It is likely that in pregnancy high levels of progesterone lead to hypotonicity of the pelvic floor structures.

The relationship between the position of the urethro-vesical junction and abdominal pressure, the displacement/pressure coefficient, provides quantitative insight into
the functional dynamic state of the supportive structures of the urethro-vesical junction, i.e. the pelvic floor muscles and adjacent connective tissue. We found that the displacement /pressure gradient remained virtually constant with the Valsalva manoeuvre during the course of pregnancy. This observation suggests that the dynamic connective tissue qualities of the pelvic floor are not progressively influenced by pregnancy. Unlike the Valsalva manoeuvre, coughing is accompanied by a reflex contraction of pelvic floor muscles, which makes the pelvic floor more resistant to deformation during coughing than during the Valsalva manoeuvre. This explains why with coughing the displacement/pressure coefficient is only half the value of this coefficient with the Valsalva manoeuvre. During the course of pregnancy the increase of the displacement/pressure coefficient during coughing indicates a decreasing effect of contraction of the pelvic floor muscles. This may be a direct consequence of impaired muscle contraction due to muscular or nerve fibre tissue changes. However, it is also possible that we measured an altered effect of normal muscle contraction, primarily resulting from connective tissue changes. A combination of these factors is possible. Much electrophysiological research has been done in incontinent women and in women with genital prolapse. In nerve conduction studies nerve damage, possibly as a result of delivery, with resultant pelvic floor muscle weakness is a common finding in women with stress incontinence of urine. However, it seems unlikely that during pregnancy, prior to labour and delivery, that nerve damage and denervation plays an important role. Some investigators suggest that altered innervation does not play an important part in the aetiology of stress incontinence. The reason for this may be that minor alterations in the innervation of striated muscle are not related to a reduction in muscle power, and are therefore not of clinical or aetiological significance in incontinence. Electromyography of pelvic floor muscles during pregnancy would be required to clarify this issue. Recently, King et al, also using perineal ultrasound, reported that primigravid women with postpartum urinary stress incontinence had greater mobility of the bladder neck antenatally than women who were continent postpartum. Although they found a high incidence of reported urinary incontinence antenatally, they do not mention a possible relationship between antenatal incontinence and mobility of the bladder neck antenatally. They suggest a constitutional susceptibility to stress incontinence brought about by a pre-existing collagen deficiency, exacerbated by increased collagen remodelling during pregnancy. The results of the present study indicate that the changes in the quality of the
connective tissue or muscle of the pelvic floor are not responsible for the higher prevalence of urine incontinence in pregnancy. Our study focussed on the changes in the extrinsic mechanism of continence, pelvic floor muscle and fascia. Changes in the intrinsic mechanism of continence, the urethral tissues including the urethral sphincter, during pregnancy were studied by van Geelen\textsuperscript{25} and Iosif\textsuperscript{26}. They concluded that an inherent weakness of the urethral sphincter mechanism could largely explain the occurrence of incontinence in pregnancy. Their conclusion is indirectly supported by the results of this present study which revealed that changes in the extrinsic continence mechanism are not related to urinary incontinence in the course of pregnancy. We are currently investigating the possible relationship between the antenatal findings and the effects of labour and delivery on the mobility of the urethro-vesical junction postnatally and urinary incontinence.

**Reference List**


