Does vaginal closure force differ in the supine and standing positions?

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Objective: This study was undertaken to quantify resting vaginal closure force (VCFREST), maximum vaginal closure force (VCFMAX), and augmentation of vaginal closure force augmentation (VCFAUG) when supine and standing and to determine whether the change in intra-abdominal pressure associated with change in posture accounts for differences in VCF.

Study design: Thirty-nine asymptomatic, continent women were recruited to determine, when supine and standing, the vaginal closure force (eg, the force closing the vagina in the mid-sagittal plane) and bladder pressures at rest and at maximal voluntary contraction. VCF was measured with an instrumented vaginal speculum and bladder pressure was determined with a microtip catheter. VCFREST was the resting pelvic floor tone, and VCFMAX was the peak pelvic floor force during a maximal voluntary contraction. VCFAUG was the difference between VCFMAX and VCFREST. T tests and Pearson correlation coefficients were used for analysis.

Results: VCFREST when supine was 3.6 ± 0.8 N and when standing was 6.9 ± 1.5 N—a 92% difference (P < .001). The VCFMAX when supine was 7.5 ± 2.9 N and when standing was 10.1 ± 2.4 N—a 35% difference (P < .001). Bladder pressure when supine (10.5 ± 4.7 cm H2O) was significantly less (P < .001) than when standing (31.0 ± 6.4 cm H2O). The differences in bladder pressure when either supine or standing did not correlate with the corresponding differences in VCF at rest or at maximal voluntary contraction. The supine VCFAUG of 3.9 ± 2.7 N, was significantly greater than the standing VCFAUG of 3.3 ± 1.9 N.

Conclusion: With change in posture, vaginal closure force increases because of higher intra-abdominal pressure and greater resistance in the pelvic floor muscles.

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Stress urinary incontinence and pelvic organ prolapse can be highly morbid conditions with a significant impact on quality of life. The pathophysiology of symptomatic disease is not well understood, but the upright posture of humans is generally considered a contributing factor. The pelvic floor soft tissues close the genital hiatus (GH), support the pelvic viscera, and play an important role in bladder and bowel continence.

KEY WORDS
Pelvic floor
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Levator ani
Vaginal closure force

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The levator ani muscles, which are an important component of this soft tissue, exhibit constant activity and have evolved to meet the increased support needed with upright posture. To visualize the perineum and vagina optimally, examinations are usually performed with patients in lithotomy position. Although this approach is understandable, it may not adequately reflect the physiologic function of the pelvic floor soft tissues.

Vaginal closure force (VCF), which is the force exerted by the pelvic floor soft tissues to close the vaginal opening, can be quantified using an instrumented speculum. In previous work, our research group has shown that the VCF is correlated with levator ani muscle damage seen on magnetic resonance imaging scans. The relationship between posture and vaginal closure pressures has been studied by other investigators who used a balloon device, but with this methodology, it has not been possible to differentiate intra-abdominal from vaginal pressure. The objectives of this study were to determine posture-related differences in resting vaginal closure force (VCFREST), maximum vaginal closure force (VCFMAX), and augmentation of vaginal closure force (VCFAUG) and to explore whether the change in intra-abdominal pressure is related to differences in VCF.

Methods

Recruitment and protocol

A convenience sample of 39 asymptomatic, continent women was recruited through 3 Institutional Review Board–approved projects. Information on age, body mass index (BMI), and obstetric history were collected. A pelvic examination, a cystometrogram, and a full bladder stress test were performed. GH was measured from the mid-urethra to perineal body. Women were excluded if the vaginal wall descended below the hymen with valsalva or if they experienced incontinence caused by a detrusor contraction, a cough, or a valsalva effort.

An 8F micro-tip dual sensor (Gaeltec Ltd, Isle of Skye, Scotland) was placed in the bladder to monitor pressure during filling with 300 mL of normal saline solution and was used throughout testing as a surrogate for intra-abdominal pressure. The subject was instructed in pelvic floor muscle contraction until satisfactory performance of a contraction was demonstrable. The upward motion of the perineum and vaginal palpation of the levator ani muscle were used by the examiner to confirm proper technique. If pelvic floor muscle contraction caused the bladder pressure to rise above its baseline, patients were re instructed on technique and advised to avoid use of the abdominal and gluteal muscles.

Statistics

Two-sided paired t-tests were performed to compare the means of VCF and bladder pressure when supine and standing. Pearson correlation coefficients were used to evaluate the relationship of age, BMI, parity, most dependent point of vaginal wall support, and GH with VCFREST, VCFMAX, and VCFAUG when supine and standing. A level of P < .05 was considered significant.

Results

Subjects

Mean age (±SD) was 45.8 ± 9.5 years, BMI 28.7 ± 4.9 kg/m², and parity 2.2 ± 1.3. Mean GH was 2.7 ± 0.8 cm. Thirty-two women had delivered by vaginal delivery only, 3 women had delivered by cesarean section only, and 3 women had delivered by both vaginal and cesarean delivery. One woman was nulliparous. There
was a trend, which was not statistically significant, between increasing parity and GH.

**VCFs and bladder pressures**

Standing VCF\textsuperscript{REST} was 92% greater than supine VCF\textsuperscript{REST} and standing VCF\textsuperscript{MAX} was 35% greater than supine VCF\textsuperscript{MAX} (Table and Figure 3). Bladder pressure when standing (31.0 ± 6.4 cm H\textsubscript{2}O) was significantly greater (P < .001) than when supine (10.5 ± 4.7 cm H\textsubscript{2}O). The difference in resting bladder pressure when standing and supine did not correlate with the corresponding difference in VCF (r = 0.1, P = .58, Figure 4). The difference in bladder pressure at maximal voluntary contraction when supine and standing also did not correlate with the corresponding difference in VCF (r = 0.01, P = 0.93). The mean difference in bladder pressure during a voluntary pelvic floor muscle contraction was 1.7 ± 2.5 cm H\textsubscript{2}O when supine and 7.5 ± 5.1 cm H\textsubscript{2}O when standing. Figure 5 illustrates that almost all subjects when standing had more difficulty contracting the pelvic floor muscles without a concomitant increase in intra-abdominal pressure. VCF\textsuperscript{AUG} when supine was 18% greater (P = .009) than when standing (Table).

**Factors possibly influencing VCF**

Factors that could influence VCF were evaluated. Supine VCF\textsuperscript{REST} was inversely correlated with genital hiatus (r = –0.36, P = .02) but not with age, BMI, parity, or most dependent point of vaginal wall support. Standing VCF\textsuperscript{REST} was positively correlated with BMI (r = 0.36, P = .02) but not with age, parity, most dependent point of vaginal wall support, or GH. There were no statistically significant correlations between supine VCF\textsuperscript{MAX}, standing VCF\textsuperscript{MAX}, supine VCF\textsuperscript{AUG}, or standing VCF\textsuperscript{AUG} and age, BMI, parity, most dependent point of vaginal wall support, or GH.

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<tr>
<th>Table</th>
<th>Mean VCF when supine and standing</th>
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<td>VCF\textsuperscript{REST}</td>
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<tr>
<td>Supine</td>
<td>3.6 ± 0.8</td>
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<tr>
<td>Standing</td>
<td>6.9 ± 1.5</td>
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<td>Arithmetic difference (N)</td>
<td>3.3</td>
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<td>Percent difference (%)</td>
<td>92</td>
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<td>Statistical significance</td>
<td>P &lt; .0001</td>
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Figure 2 Example of a vaginal closure force tracing. A trial in the supine and standing position is shown to illustrate how a tracing is analyzed to determine VCF\textsuperscript{REST}, VCF\textsuperscript{MAX}, and VCF\textsuperscript{AUG}. Bolded vertical lines before pelvic muscle contraction indicate when the computer is available for data capture and do not indicate the latency between instruction to contract and time of contraction.

Figure 3 Mean VCF\textsuperscript{REST} and mean VCF\textsuperscript{MAX} in the supine and standing positions. There was a 92% difference (P < .001) between supine and standing VCF\textsuperscript{REST} and a 35% difference (P < .001) between supine and standing VCF\textsuperscript{MAX}.
**Comment**

This study revealed a 92% increase in $VCF^{\text{REST}}$ when a woman moves from the supine to the standing position. What might have caused this? An increase in intra-abdominal pressure or greater resistance from the pelvic floor muscles are 2 potential factors. The simultaneous measurement of these 2 measures allows the relative contribution of increased intra-abdominal pressure on $VCF$ to be explored. The lack of a significant correlation between the differences of them when supine and standing suggests that an increase in intra-abdominal pressure does not entirely account for the increase in $VCF$.

The design of the instrumented vaginal specula and the definition of the term $VCF$ have implications regarding what is measured. $VCF$ is an assessment of the resultant force acting normal to the vaginal axis in the midsagittal plane. $VCF^{\text{REST}}$ consists of 3 components:

1. The passive force on both the anterior and posterior bills from the circumferential stretch of the fibromuscular tissue of the vagina and pelvic floor muscles on insertion of the speculum;
2. The superiorly directed force on the posterior bill of the levator ani muscle resisting intra-abdominal pressure; and
3. The inferiorly directed force on the anterior bill from the intra-abdominal pressure acting perpendicular to the speculum’s longitudinal axis on the cross-sectional area and from the presence of the pubic symphysis.

The force related to intra-abdominal pressure on the anterior bill results from the hydrostatic pressure caused...
by the weight of the superincumbent intra-abdominal contents and intra-abdominal pressurization caused by abdominal muscle contraction. Unlike the balloon pressure devices, the speculum is insensitive to pressures acting in the mediolateral direction or craniocaudally along the axis of the vagina.

Our findings of increased intra-abdominal pressure with change in posture are consistent with previous studies. The mean resting intra-abdominal pressure we reported was 31 cm H₂O, which is similar to the findings of Henriksson et al⁹ and Iosif et al.¹⁰ When standing, higher intravesical pressures occur for 2 reasons: (1) the height of the superincumbent intra-abdominal contents (eg, the height of the column of water) above the bladder is increased and (2) in comparison to supine positioning, abdominal muscle tone increases,¹¹ leading to additional intra-abdominal pressurization.

It is instructive to estimate the contributions to VCF when supine and standing. The force that is due to supine intra-abdominal pressure can be calculated by converting the measured intravesical pressure to units of N/cm² and then multiplying the result by the cross-sectional area of the anterior bill of the speculum:

\[ 10 \text{ cm H}_2\text{O} = (0.1 \text{ N/cm}^2)(18.8 \text{ cm}^2) = 1.9 \text{ N} \]

This suggests that 1.9 N of the 3.6 N of supine \( \text{VCF}^{\text{REST}} \) is an inferiorly directed force on the anterior bill caused by intra-abdominal pressure and the remaining 1.7 N is due to the passive tissue stretch and the presence of the pubic symphysis. Because the speculum is in equilibrium, the sum of the forces on the 2 bills must be equal. Therefore, the pelvic floor muscles provide a superiorly directed force on the posterior bill of 3.6 N as they hold the speculum against the pubic symphysis and resist the action of intra-abdominal pressure. Now, what happens when standing? We can again estimate the

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Figure 5  Change in bladder pressure with maximal voluntary contraction when (A) supine and (B) standing. When supine, subjects were able to isolate the pelvic floor muscles and avoid increasing intra-abdominal pressure. When standing, they had difficulty contracting the pelvic floor muscles without increasing intra-abdominal pressure.
contribution of intra-abdominal pressure to the standing VCF$_{\text{REST}}$ if we multiply the intra-abdominal pressure by the area of the anterior blade:

$$31 \text{ cm H}_2\text{O} = (0.31 \text{ N/cm}^2)(18.8 \text{ cm}^2) = 5.6 \text{ N}$$

This means that 5.6 N of the 6.9 N of average standing VCF$_{\text{REST}}$ is the inferiorly directed force of intra-abdominal pressure on the anterior blade. The remaining 1.3 N is due to the passive forces of tissue stretch and the presence of the pubic symphysis. The superiorly directly force from the pelvic floor muscles is now 6.9 N. The weak correlation between the difference in supine and standing VCF$_{\text{REST}}$ and bladder pressure can be explained by interindividual variability in the recruitment and tone of the abdominal and pelvic floor muscles. However, the fact that VCF$_{\text{AUG}}$ was 3 to 4 N in the supine and standing positions suggests that the maximal volitional increase in the pelvic muscle force elevating the speculum is independent of body orientation and that the instrumented speculum captures the increase of VCF in the sagittal plane.

The closure of the vagina with change in posture has been evaluated by previous investigators. By using vaginal pressure transducers, both Bö and Finkenhagen$^7$ and Miller$^8$ found differences between resting supine and standing measures. However, their findings at maximum voluntary contraction with respect to vaginal closure pressure were not consistent. With change in posture, Bö and Finkenhagen$^7$ found a difference in intravaginal pressure at maximum voluntary contraction but Miller$^8$ did not. It is not clear if this discrepancy could be due to the methodology used or differences in the population of women studied (eg, Bö and Finkenhagen$^7$ only studied women who were stress incontinent and Miller$^8$ studied both asymptomatic and stress incontinent women).

The associations of clinical factors with standing VCF$_{\text{REST}}$ and supine VCF$_{\text{REST}}$ deserve further investigation. It was not possible to determine how parity and route of delivery affected VCF with this sample size and the distribution of obstetric events. The importance of the correlation between higher BMI and standing VCF$_{\text{REST}}$ is interesting given the known influence of obesity on symptoms of urinary incontinence. The clinical significance of each of these findings will need further examination.

This study has certain limitations. The number of neuromuscular units recruited, the presence/absence of neurologic damage, and the role of muscle fatigue cannot be quantified with this technique. Supplemental studies with electromyography may help clarify these issues but this technique too has limitations. Electromyography can only be used to study intact muscle and it has been shown that pelvic floor muscle can be missing.$^{12,13}$ Multiple techniques of examination may be needed to better understand pelvic floor structure and function. Second, the most effective technique of pelvic floor contraction may involve coactivation of the abdominal muscles.$^{14}$ When standing, women tended to tighten their abdominal muscles during contraction, even if they had demonstrated excellent technique when supine. Third, the sample of subjects should be considered. Although this cohort was asymptomatic and continent, they were also parous and may have some underlying, subclinical neuromuscular damage.$^{15}$ The BMI is also high and may not be generalized to all populations.

The levator ani muscles close the urogenital hiatus and supports the abdominopelvic organs. Injury to them can result in increased risk for pelvic organ prolapse and stress urinary incontinence.$^{16,17}$ Physiologic differences in levator ani function may have broad implications for patients. They may explain differences in symptom control and account for many of the successes and failures of both conservative and surgical treatments. Although it will always be more convenient to study pelvic floor muscle action when supine, data taken in the upright posture captures the natural action of the muscle in the position in which it must function daily. Investigations of pelvic floor muscle in upright postures may bring new insights to pelvic floor function.

References


