W36: What is a vaginal pressure profile and how might this be useful?

Workshop Chair: Jennifer Kruger, New Zealand
06 September 2019 09:00 - 10:30

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Aims of Workshop
The aim of the workshop is to provide a basic understanding of the biomechanics associated with the development of a vaginal pressure profile. It will explore how changes in the pelvic anatomy (usually due to pelvic organ prolapse or urinary incontinence) are likely to impact on vaginal pressures and how this may influence the pressure differential along the length of the vagina. Participants will have an up to date review of instrumentation development used to measure pressure to assess pelvic floor muscle function/dysfunction. Recent advances in instrumentation development, data interpretation and the potential application of the profile (intra-abdominal pressure vs pelvic floor muscle pressure) will also be discussed.

Learning Objectives
1. Understanding the basic biomechanics that are involved the development of pressure and how these changes can be measured in the vagina.
2. Awareness of the instrumentation that has been developed to measure pressure/force in this area: the pro’s and con’s
3. Application of the profile to a clinical condition

Target Audience
Urology, Urogynaecology, Basic Science, Conservative Management

Advanced/Basic
Basic
Pressure is a measure of force over a defined surface area. The SI unit for pressure is Pascal, representing 1 Newton over 1 square metre. Pressure has historically been measured by its ability to displace a column of liquid in a manometer, hence the units of millimeters of mercury (mmHg) or centimetres of water (cmH2O) have become commonly adopted. Today solid-state sensors, electronic circuits and microprocessors support reporting pressure in any familiar unit of pressure. Unlike force, pressure is a scalar such that any point in the body will have a pressure that is independent of direction. The pressure in a static fluid (e.g. in the bladder) is a single value and the pressure value is the same everywhere in the bolus of fluid. So what does it mean when we talk about a pressure profile along the vagina?

To start this workshop, we will clarify what can realistically be measured by typical pressure sensing devices, used to assess pelvic floor muscle function. We will discuss these measurements in relation to other types of physiological pressures that are routinely measured in the body i.e. intra-cranial pressure, or blood pressure. Finally, the potential value of measuring pressures along the length of the vagina, which requires an understanding of absolute pressure values which are generated at rest, and differences in pressure generated from intentional muscle exercising.

Review of instrumentation developed to measure vaginal pressures: how do they work, assumption, advantage and disadvantages and recent updates

Dr Jennifer Kruger
Principal Investigator Pelvic Floor Research Group. Auckland Bioengineering Institute. The University of Auckland New Zealand.

A review of the literature will provide a historical perspective of the use of instruments to measure pressure/force in a clinical context, and a critique on the current, more commonly used instruments used for research and clinically. Discussion will focus on instrumentation that includes either force transducer(s) or pressure sensor(s) The advantages and disadvantages of the various systems will be presented. This will include myometers, elastometers, and pressure sensing devices. Commercially available devices, in which the measurement system is public knowledge will be included as part of the discussion and a brief look at the use of mobile technology linked to devices, as a means for encouraging pelvic floor muscle training. We will discuss any evidence of reliability or validity for these products.

The development of a vaginal pressure profile and the association between the features of the anatomy that are thought to contribute to this profile in relation to pelvic floor function/dysfunction will be presented.

Measurement of any physiological parameter (muscle force/pressure/) is dependent on how the data is collected and analysed. Each instrument will collect data differently dependent on the characteristics of that instrument. How this data is analysed, presented, interpreted, and any potential clinical implications will be part of the discussion.

Repeatability and validity of intravaginal pressure measurements.

Conservative management of urinary incontinence and POP: is it important to control abdominal pressure in addition to train the pelvic floor muscle?

Update on therapies aiming to reduce intra-abdominal pressures

Professor Chantale Dumoulin
Chercheure et directrice de laboratoire. Titulaire de la Chaire de Recherche du Canada Santé Urogynécologique et vieillissement
Centre de recherche, Institut Universitaire de Gériatrie de Montréal, University of Montreal, Canada

Intra-vaginal pressure measurements have been used since Kegel’s first perineometer to evaluate and document PFM function in women. Originally intra-vaginal pressure was measured with one large intra-vaginal pressure sensor. Recent intra-vaginal pressure measurement units use multiple pressure sensors to document pressure profile throughout the vaginal cavity. In this section of the workshop, we will present the psychometric properties (repeatability, validity and sensitivity) of both types of intravaginal pressure measurements. Further, we will discuss advantages and disadvantages of these measuring instruments in clinical practice.

Conservative management of urinary incontinence and POP aims to increase pelvic floor muscle strength and tone (making it resistant to stretching) in order to limit downward movement during effort and exertion, thereby preventing urine leakage and symptoms of POP. Up until now the conservative management has mainly focussed on the PFM. Recent studies have documented the impact of certain sports, exercise and activities on intra-vaginal pressure and indirectly on the PFMs. The impact of these new data and their impact on choice of exercises will be discussed. We will further discuss the importance of controlling or reducing intra-abdominal pressure in addition to train the PFM as a conservative management for urinary incontinence and POP.
Finally, therapies aiming to reduce intra-abdominal pressures and thereby improve PFM tone (hypopressive technics) have become more popular in the last decade. We will present and discuss the evidence on the impact of these approaches on PFM function and on urinary incontinence and POP.

**Pressure during exercise. Its relevance and current research. How is this information helpful?**

Dr Margaret Sherburn: Coordinator, Women’s Health Programs; Physiotherapy, School of Health Sciences. The University of Melbourne

Clinicians have long understood that raised intra-abdominal pressures during exercise may have deleterious effects on the pelvic floor heightening the risk of pelvic floor dysfunctions. Measuring the pressures developed during different exercises has now become possible with wireless technologies. Initially intra-abdominal and pelvic floor pressures were able only to be measured separately, giving clinicians some information on which to base their rehabilitation of women at risk of PFD, but many questions remain unanswered.

The Pelvic Floor First program of the Continence Foundation of Australia (http://www.pelvicfloorfirst.org.au/) was set up to assist clinicians make decisions on the use of pelvic floor ‘safe’ exercises for women at risk of pelvic floor dysfunction. Decisions as to what constituted a pelvic floor ‘safe’ exercise was based on best knowledge at the time. The development of a vaginal pressure profile device now means that both intra-abdominal and pelvic floor pressures can be measured simultaneously during an exercise, giving us more information about safe exercise for the pelvic floor.

A recent study undertaken by this group investigated nine exercises, using a vaginal pressure profile device, and compared the pelvic floor ‘safe’ version versus the conventional form of the same exercise. We will present the results from this study and open it up for discussion.

**References:**

Biomechanics of pressures and how we measure them

David Budgett (PhD)
Auckland Bioengineering Institute
University of Auckland
New Zealand

Quantifying pelvic floor muscle performance

Tricky because:
• Access is restricted
• Visualisation is poor

Vagina provides a window to the pelvic floor (and beyond)

What might a pressure profile tell us?

Some pressures are easy to understand

• Stephen Hales measured the blood pressure of a horse in 1733.
  Glass tube ~ 9 feet of blood.

• Easy to extend concept to column of mercury or water.

• Brain pressure (ICP) another example

Height of sensor

Cystometry and pressure-flow study requires fluid-filled catheters with external pressure transducers to be leveled at the height of the upper edge of symphysis pubis.

ICS Good Uro Practices and Terms 2016

• How much does the level change?
• How often does the patient move?
Solid state pressure sensors

Sensors have a tiny window
They measure a deflection over this window
Usually with respect to atmospheric pressure

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Absolute pressure sensors – not vented

Rigid sections linked with bendy fibre

Fibre Bragg Grating:
Paul Hodges and John Arkwright: 72 sensors 10mm spacing
Cost: about $20,000. Can be fragile.

Absolut pressure sensors

LPS22 from ST

- Accuracy 0.375 mmHg
- Temperature sensitivity 0.005 mmHg per degree
- Range 195 to 945 mmHg (Absolute)
- Cost: about $2
- These can be used to measure pressure in a balloon

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Easy corrections to pressure readings

- Weather in Gothenburg this week: 750 to 776 mmHg
- Altitude of Madrid: 667m
Pressure drop 58 mmHg compared to Gothenburg

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Pressure not related to pelvic floor activity

Posture

- Obvious anatomical differences
- Might be valuable to study these differences
- When trying to compare profiles, check like with like

Need to set a baseline

- What will be the zero point?
- When a patient is relaxed in correct posture?

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Size of pressure zone (balloon)

- Too few (e.g. one) no differentiation of regions
- Too many - small micro regions

---

Conclusions

- Pressure has clinical history and makes sense in a fluid
- Vaginal pressure in an empty collapsed vessel?
- Can make sense if introduce a series of mini-balloons and report pressure in each balloon
- Need to define (regularly) what zero pressure means
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Measuring vaginal pressure

Jennifer Kruger (PhD)
Auckland Bioengineering Institute
University of Auckland
New Zealand

Outline

• The origin of measuring pressure - urethral/bladder pressures – urinary incontinence
• Vaginal pressure vs abdominal pressure
• Vaginal pressure profile
• New instruments and application (FemFit and prolapse study)

Why measure pressure?

Stress urinary incontinence
• Urethral pressure
• Supporting anatomical structures of the urethra
• Barnes (1940) suggested that the UI results from
  • ‘primary damage to the urethra and/or sphincter
  • ‘damage to the peri-urethral and supporting tissue’
• Regardless: ‘when the force of urinary expulsion higher power of urethral resistance = SUI’

Measuring urinary pressures

Enhorning (1961) first solid state urethral catheter 2 pressure transducers
• Simultaneously measure urethral pressure and bladder pressure
• Unequal pressure transmission from bladder and urethra during increases in intra-abdominal pressure in incontinent patients.
• Urethral pressure profile extensively used to determine integrity of the urinary tract system:
• Aid for diagnosis type/severity treatment options.

Urodynamics

• Includes IAP measurement (via vagina/rectum)
  Bladder, urethral pressure.
• Artefacts, dampening of signal, low frequency
Measuring Abdominal pressure

• Measurement of abdominal pressure

• Risk for women developing PFD?

• Assess abdominal pressure during activity

Exercise Activities and pressure

Devices used to measure IAP

<table>
<thead>
<tr>
<th>Reference</th>
<th>Participants</th>
<th>Method</th>
<th>Activities</th>
<th>(maximal mean/mean peak)</th>
</tr>
</thead>
<tbody>
<tr>
<td>de Gennaro et al (2019)</td>
<td>25 women</td>
<td>IVP and accelerometer</td>
<td>13 types</td>
<td>4.2 (lying)-188 (jumping)</td>
</tr>
<tr>
<td>Tsimaz et al (2015)</td>
<td>20 women</td>
<td>IVP</td>
<td>Pilates (11 exercises)</td>
<td>~40</td>
</tr>
<tr>
<td>Tian (2017)</td>
<td>52 women</td>
<td>IVP</td>
<td>10 types/pelvis floor safe vs conventional</td>
<td>3.5</td>
</tr>
<tr>
<td>Cobb et al (2005)</td>
<td>8 men/6 women</td>
<td>Intravesical</td>
<td>Cross-fit</td>
<td>108 (benzyl)-236 (jumping)</td>
</tr>
<tr>
<td>Weir (2006)</td>
<td>30 women</td>
<td>Rectal</td>
<td>6 types</td>
<td>10 (crunches)-188 (jumping)</td>
</tr>
<tr>
<td>Iqbal et al (2008)</td>
<td>10 participants</td>
<td>Nasogastric</td>
<td>17 (lifting)</td>
<td></td>
</tr>
</tbody>
</table>

1 kPa ≈ 7.5 mmHg ≈ 10.2 cm H2O

Measuring and interpreting pressure

• Consider peak?; mean?; rate of change?; AUC?

• Remove a baseline?

• Units: kPa; mmHg or cmH2O?

• More complicated than it looks:
  • (Hamad et al 2013)
  • (Tian et al 2016)

Vaginal pressure profile

• Guaderrama (2005)

• Vaginal pressure profile using similar technique to the urethral pressure profile

• Identified an area 'high pressure zone'
Bo (1990) identified the contribution of abdominal/other pressure on any ‘balloon’ shaped device – air filled.

- High pressure zone = ~ 35mm from vaginal opening
- Need to discriminate between abdominal pressure, pressure produced by the pfm and atmospheric pressure.
- Vaginal pressure profile....

Measuring the pressure profile?

<table>
<thead>
<tr>
<th>Pressure zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The vaginal canal, to a lesser or greater extend, becomes occupied by: the uterus and cervix or vaginal vault (apical compartment) prolapsed front wall of vagina with bladder (anterior compartment) prolapse back wall of vagina with rectum (posterior compartment)</td>
</tr>
</tbody>
</table>

Utility of the vaginal pressure profile

1. Correct and incorrect pelvic floor muscle contractions
2. The change in the profile during exercise
3. The change in profile due to pathology – pelvic organ prolapse

Pelvic Organ Prolapse

• Re-establish normal pelvic organ anatomy (removes vaginal bulge and restores bladder/bowel control)
• Repair and reinforce para-vaginal fascia using suture plication (not mesh) for anterior and posterior compartments
• Various strategies for apical compartment- removal of uterus, reinforce pelvic ligaments (uterosacral plication), vault suspension

<table>
<thead>
<tr>
<th>Aims of pelvic floor surgery</th>
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Vaginal pressure profile...
Vaginal pressure profiles in POP

- Vaginal pressure profile will capture distinct pressure zones
- Changes in vaginal pressure profiles pre and post-surgery are anticipated due to anatomical restoration of pelvic organs
- Objective measurement of vaginal pressure profiles pre and post-surgery may assist in understanding changes in pelvic floor strength

Intra-Vaginal Pressure Sensor Device (FemFit®)

Approx. 8 cm long, 2.5 cm wide, 0.5 cm thick
Tail is approx. 25 cm long
Medical grade silicone
Eight pressure sensors
Bluetooth telemetry module

Vaginal placement of Femfit®

Closest to abdomen
Closest to pelvis
Closest to introitus

Protocol for Femfit® testing

Supine
Standing upright

Data Analysis

3 x Pelvic Floor Muscle Contraction

Results

Mid-Contraction Vaginal Pressure Profile for n = 5
Results

- n= 20 women
- 17 sets of pre-post vaginal pressure profiles for analysis
- Age:
  - Mean: 64 (SD 10.7) years
  - Range: 40 – 75 years
- BMI:
  - Mean: 24.3 (SD 1.8) kg/m²
  - Range: 20.8 – 28.1
- Majority of POPQ scores (Aa, Ba, C, D, Ap, Bp, and pb) significantly different after surgery
- No significant correlation between VPP and questionnaire symptoms or Oxford score grades

Summary results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre Mean (SD)</th>
<th>Post Mean (SD)</th>
<th>Mean diff (95% CI)</th>
<th>t stats (df)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICIQ–UI</td>
<td>7.06 (5.57)</td>
<td>2 (2.37)</td>
<td>5.06 (2.92 Inf)</td>
<td>4.13 (16)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Bowel pattern</td>
<td>5 (2.52)</td>
<td>4.12 (1.11)</td>
<td>0.88 (-0.06 Inf)</td>
<td>1.63 (16)</td>
<td>0.06</td>
</tr>
<tr>
<td>Bowel control</td>
<td>5.88 (5.8)</td>
<td>3.35 (3.22)</td>
<td>2.53 (-0.02 Inf)</td>
<td>1.73 (16)</td>
<td>0.05</td>
</tr>
<tr>
<td>Bowel: Quality of life</td>
<td>5.71 (7.36)</td>
<td>4.12 (4.73)</td>
<td>1.59 (0.5 Inf)</td>
<td>1.33 (16)</td>
<td>0.10</td>
</tr>
<tr>
<td>Vaginal symptoms</td>
<td>23.62 (9.18)</td>
<td>5.12 (3.96)</td>
<td>18.5 (14.14 Inf)</td>
<td>7.43 (15)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Supine peak vaginal pressure</td>
<td>10.49 (7.18)</td>
<td>16.8 (12.45)</td>
<td>-6.31 (- Inf -2.75)</td>
<td>-3.1 (16)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Upright peak vaginal pressure</td>
<td>16.03 (12.79)</td>
<td>21.49 (10.22)</td>
<td>-5.46 (- Inf -1.77)</td>
<td>-2.61 (14)</td>
<td>0.01</td>
</tr>
<tr>
<td>Supine abdominal pressure</td>
<td>4.08 (4.52)</td>
<td>5.95 (13.15)</td>
<td>-1.87 (- Inf 4.01)</td>
<td>-0.55 (16)</td>
<td>0.29</td>
</tr>
<tr>
<td>Upright abdominal pressure</td>
<td>7.89 (8.71)</td>
<td>12.59 (9.99)</td>
<td>-4.7 (- Inf 0.23)</td>
<td>-1.68 (14)</td>
<td>0.06</td>
</tr>
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</table>

Where to from here

- Understanding the vaginal pressure profile may be a useful metric post surgery.
- Vaginal pressure measurements could serve as a baseline for women to encourage adherence in pelvic floor muscle training
- Pressure profile useful in determining which exercises create abdominal pressures may be provocative in women with PFM compromise
- Important that the pressure can be measured during functional activities. i.e. not only supine and standing during activity

Confident that the measurements are a true reflection of the pressures in the vagina.

thank you

Tack
Affiliations to disclose:

Funding for speaker to attend:
- Self-funded
- Institution (non-industry) funded
- Sponsored by:

Measuring intra-vaginal pressure to inform physiotherapy interventions for pelvic floor muscle dysfunction

Chantale Dumoulin, Ph.D., Physiotherapist
Professor, School of Rehabilitation, Faculty of Medicine, University of Montreal
Canadian Research Chair in Urogynecological Health and Aging,
Research Center, Institut Universitaire de Gériatrie de Montréal, Canada

PFM manometry

“Perineometer” (1948)
First intra-vaginal pressure device proposed to assess PFM

“The term perineometer is somewhat misleading as the pressure-sensitive region of the manometer probe is not placed at the perineum, but inside the vagina”

Pelvic floor manometers
Vaginal resting pressure or pressure rise generated during contraction of the PFM
- "air balloon type" (pliable material)
- average pressure of a large area

New PFM manometry devices

Pliance®
- cylinder: 23.2mm Ø; 8cm length
- sensing area: 70.7x70.7mm
- each transducer 5.5x5.5mm; 0.6mm thick
- with 1.6mm gap between them
- protective layer: 0.3 mm
- measurement range: 0.5–100kPa
- resolution: 0.42kPa, unidirectional measurements along the vaginal canal

Pliance®
- FemFit®
Reliability and validity

Reliability Results:

- **Design**: cross-sectional study
- **Population**: 26 healthy women
- **Exclusion**: BMI > 30; history of pregnancy within the past year; condition, medication or risk factors likely to interfere with study

<table>
<thead>
<tr>
<th>Task</th>
<th>Pressure profile compared to Oxford scale</th>
<th>Differentiation between tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFM contraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valsalva</td>
<td></td>
<td></td>
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</tbody>
</table>

Statistics: Reliability → ICC; validity → Spearman's correlation, ANOVA

Reliability Results:

- Intra and Inter-raters reliability (n=26)
- Inter-session repeatability (n=15)

Validity (n=26):

- Pressure profile compared to Oxford scale
- Differentiation between tasks

Reliability and validity

Reliability Results:

- Two observers and two task (PFM contraction and Valsalva)
- Two tasks repeated 2 week after

Validity Results:

- Significant moderate correlation between digital palpation assessment and biomechanical assessment (peak pressure) [Spearman's coefficient of $r = 0.5477$ (p < 0.001)] (Cacciari, 2017)

Reliability and validity

Reliability and validity

Reliability Results:

- Two observers and two task (PFM contraction and Valsalva)
- Two tasks repeated 2 week after

Validity Results:

- Significant moderate correlation between digital palpation assessment and biomechanical assessment (peak pressure) [Spearman's coefficient of $r = 0.5477$ (p < 0.001)] (Cacciari, 2017)
Reliability and validity

Reliability: the piance® demonstrate excellent reliability and repeatability in mid vaginal canal

Validity of the piance®:
- is moderately associated with PFM digital assessment,
- provides a high-resolution map of the dynamic and spatiotemporal pressure profile throughout the vaginal canal
- differentiating the action of PFMs from intra-abdominal pressure increases

Validity, Reliability and Usability study

Design: prospective test-retest cohort study
Population: 20 healthy women
Exclusion: pregnancy and pathologies/medications likely to interfere with PFM function

Outcomes:
- Displacement: Observed after every exercise set (lying/standing)
- Comfort: Reported during exercises insertion and removal
- Reliability: Within and between sessions
  - PFMC & Valsalva
  - standing & lying


Sensor preparation: disinfected, covered with a condom and lubricated
Insertion: by the physiotherapist, always in the antero-posterior axis

Validity, Reliability and Usability study

Sensor preparation: disinfected, covered with a condom and lubricated
Insertion: by the physiotherapist, always in the antero-posterior axis

Validity, Reliability and Usability study

Demographics

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<th>Characteristics</th>
<th>N (%)</th>
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<tr>
<td>Age (mean ± SD)</td>
<td>51.5 ± 19.7 years</td>
</tr>
<tr>
<td>Parity (%)</td>
<td></td>
</tr>
<tr>
<td>Nulliparas</td>
<td>45%</td>
</tr>
<tr>
<td>Primiparas</td>
<td>5%</td>
</tr>
<tr>
<td>Multiparas</td>
<td>50%</td>
</tr>
<tr>
<td>PFM function (median [range])</td>
<td>4 (1-5)</td>
</tr>
</tbody>
</table>

Excluded: 1 participant (unable to follow instructions)

Displacement
- FemFit® repositioned 5/96 (6%) during Valsalva trials
- 2/48 lying down (4%)
- 4/48 standing up (8%)

Comfort
- No discomfort reported
Validity, Reliability and Usability study

**Intravaginal pressure reliability**

<table>
<thead>
<tr>
<th>Session</th>
<th>T1 Mean ± SD</th>
<th>T2 Mean ± SD</th>
<th>ICC 95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PFMC lying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>within session</td>
<td>12.59 ± 8.76</td>
<td>12.14 ± 7.39</td>
<td>0.98 (0.93 to 0.99)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>between sessions</td>
<td>12.59 ± 8.76</td>
<td>14.06 ± 8.67</td>
<td>0.78 (0.30 to 0.93)</td>
<td>0.006</td>
</tr>
<tr>
<td><strong>PFMC standing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>within session</td>
<td>11.51 ± 4.52</td>
<td>14.21 ± 7.03</td>
<td>0.78 (0.35 to 0.93)</td>
<td>0.001</td>
</tr>
<tr>
<td>between sessions</td>
<td>11.51 ± 4.52</td>
<td>10.31 ± 5.78</td>
<td>0.82 (0.50 to 0.94)</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Valsalva lying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>within session</td>
<td>16.52 ± 10.75</td>
<td>13.48 ± 9.26</td>
<td>0.86 (0.57 to 0.95)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>between sessions</td>
<td>16.52 ± 10.75</td>
<td>17.58 ± 10.39</td>
<td>0.83 (0.52 to 0.94)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Valsalva standing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>within session</td>
<td>23.05 ± 13.83</td>
<td>22.64 ± 9.92</td>
<td>0.88 (0.65 to 0.96)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>between sessions</td>
<td>23.05 ± 13.83</td>
<td>20.09 ± 12.06</td>
<td>0.79 (0.38 to 0.93)</td>
<td>0.003</td>
</tr>
</tbody>
</table>

PFMC: pelvic floor muscle contraction; SD: standard deviation; limits of agreement = mean difference ± 1.96*SD

Validity, Reliability and Usability study

**Displacement**: Device remained in position during contraction, and most of the time during Valsalva (condom?)

**Comfort**: No discomfort reported

**Reliability**: Excellent reliability for most intravaginal pressure measurements → High variability within and between sessions for the Valsalva task in standing position

Further studies needed:
- Reliability for Valsalva task, for standing task
- Validity of measurements when compared to other measuring instruments

Studying Mechanisms of Action Example 1

**Diaphragmatic aspiration**

Defined as a breathing technic aiming to:

- Decrease intra-abdominal pressure (IAP) (Caufriez et al., 2007)
- Produce a reflex PFMC contraction and transverse muscles of the abdomen (Rial and Pinsach, 2012)
- Can be associated with a specific posture

**Population**

Inclusion:
- Women 18 years +
- SUI (QUID), 3 UI/week

Exclusion:
- U1 or M1
- Any conditions, medications likely to bias study results

**Material**

Source: yogamrita.com
Studying Mechanism of action

5 min. training video with expert PT (JV) (N=17)

Evaluation session:
- 3 maximal pelvic floor muscle contraction (PFMC)
- 3 diaphragmatic aspiration (DA)
- 3 diaphragmatic aspiration + posture (DAP)

Data analysis:
- Pressure profile at max amplitude (mmHg)
- Complete (n=2)
- Partial (n=4)
- Exclusions (n=6)

Pressure at rest and during the 3 tasks

Conclusion:
- Diaphragmatic aspiration (as a task) appears to reduce intra-abdominal pressure but the magnitude is low (Caufriez et al, 2007)
- Diaphragmatic aspiration (as a task) does not appear to produce a significant PF muscle contraction
- Posture does not appear to affect results
- More studies are needed to better understand intra-vaginal pressure distribution produced by this technic

Studying mechanisms of action exemple 2

The Pompoir technique is:
- A millenary practice from India, Japan or Thailand.
- Consists of using several exercises to coordinate the contraction and relaxation of various portions and layers of PF muscles along the entire vaginal canal, aiming at contributing to sexual pleasure and function.

Population
Inclusion:
- 40 women 20 to 45 years
- Premenopausal
- Normal BMI

Exclusion:
- Not virgin
- Not currently pregnant or in past year
- No present PF muscles dysfunctions
- No medications, conditions likely to influence PF function

Matériel
Studying Mechanism of action

Design: Cross sectional study

Methodology: Task 1 endurance: contraction of PFM sustained 10 s, while breathing normally.

Task 2 wave: waveform contractions in a caudal-cranial direction for 2 s, then relaxation in a cranial-caudal direction for 2 s. Cadence was controlled by a digital metronome.

Results:

Endurance task:
Pompoir group was able to sustain the pressure levels achieved for a longer period (40% longer, moderate effect, P=0.04).

“Waveform” task:
Pompoir group achieved lower, earlier peak pressures (moderate effect, P=0.05) and decreased rates of contraction (small effect, P=0.04) and relaxation (large effect, P=0.01). However, there was no evidence of a wave contraction going up and down the vaginal canal.

Specific coordination training of the PFM alters the pressure distribution profile. It is interesting to have new instruments able to evaluate pressure profiles of different regions in the vaginal canal to study specific approach that have been proposed to train the PP.
Vaginal Pressure during Exercise: Relevance and Current Research

Margaret Sherburn
The University of Melbourne
Australia

How is this information helpful?

- Intra-abdominal (IAP) and pelvic floor (PF) muscle pressure measurement has been in use clinically for decades
  - But measurements of IAP & PF pressure separately
- Technology now being developed
  - For simultaneous measurement
  - With the aim to measure IAP & Vaginal pressures more accurately

How does IAP affect the pelvic floor?

- It’s all in the physics
  - The trunk is a sealed pressurised elastic cavity
  - Pressure equal throughout (Pascal)
  - Capsule wall tension varies according to the radius of the capsule (LaPlace)
  - PFM could be overpowered by the abdominals?
  - Or all work in synchrony & wall tension similar around capsule

Understanding the mechanisms

Diaphragm, trunk and pelvic floor muscles all have postural & dynamic roles

Compromise:

Eg. When respiratory demands increase
(or contract the PFM voluntarily with a cough):
  - Postural activity of diaphragm, TrA and PFM decrease

Application of this theory:

Exercise modification and limits

(Continence Foundation of Australia 2011)

pelvic floor first

PF Safe Exercises vs Exercises to avoid

**Modified plank: knees & hands - slight bend at hips**
Wall push ups

**Plank position on hands and feet - “hovers”**
Full push ups

**Ball bridge (feet or back on ball on ball, +/- single leg lift)**
All fours, arm and leg lift

**Sit ups, curl ups, crunches**
Medicine ball rotations

**Shallow and narrow leg squats**
Shallow forward lunges
Low bench step up/down

**Deep lunges or side lunges**
Wide leg or deep squats
High bench step up/down

**Walking**
Swimming
Seated cycling

**Running**
Jumping

---

**But is that the full story?**

- New insights with wireless research technology to measure IAP during exercise
  - IAP: intravaginal pressure sensor, non distorting
- Measured IAP in:
  - reference activities
  - a series of PF safe and conventional exercises

---

**What’s the difference in abdominal pressures?**

- No difference found between recommended and discouraged versions in 5 of the 10 exercises (ball rotations, lunges, core, push-ups and squats).
  - Cough & Valsalva are different from all PF safe exercises

**Conclusion:**
- PF safe exercises may not necessarily protect the pelvic floor

(Kruger et al. 2013)

---

**Results**

- No difference found between recommended and discouraged versions in 5 of the 10 exercises (ball rotations, lunges, core, push-ups and squats).
  - Cough & Valsalva are different from all PF safe exercises

**Conclusion:**
- PF safe exercises may not necessarily protect the pelvic floor

(Kruger et al. 2013)
New study: Comparison between ...

Cycling:
- Sitting vs. Standing

Planks:
- Modified vs. Full

Pushups:
- Wall vs. Full

Lunges:
- Narrow vs. Weighted

Step ups:
- 20cm bench vs. 40cm bench

All fours lifting arms and legs vs. Curlups

Floor ball rotations: Feet seated vs. Feet raised

Treadmill:
- Walking vs. Running

With simultaneous measurement of IAP and PF

Exploratory study

N = 30

Women with no or mild PFD

Comfortable exercising

Typical traces during exercises

Examples of raw traces (baseline removed)

Some examples of the results

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Median % Difference (95% CI)</th>
<th>P value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycling: Sitting vs. Standing</td>
<td>PF: -34% (-63%, 17%) AB: -56% (-75%, 17%)</td>
<td>0.51</td>
<td>The median max pressure recorded on the PF sensor is on average 45% smaller than the median max pressure recorded on the PF sensor for modified vs full plank</td>
</tr>
<tr>
<td>Planks: Modified vs. Full</td>
<td>PF: -45% (-69%, 0%) AB: -40% (-67%, 8%)</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Pushups: Wall vs. Full</td>
<td>PF: -58% (-77%, 22%) AB: -65% (-83%, 36%)</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Lunges: Narrow vs. Weighted</td>
<td>PF: -10% (52%, 66%) AB: -10% (52%, 66%)</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Squats: Narrow vs. Wide</td>
<td>PF: -38% (-78%, 12%) AB: -7% (-95%, 75%)</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Step ups: 20cm bench vs. 40cm</td>
<td>PF: -54% (-75%, 18%) AB: -54% (-72%, 10%)</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>All fours lifting arms and legs vs. Curlups</td>
<td>PF: 38% (-24%, 153%) AB: 8% (-45%, 34%)</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Floor ball rotations: Feet seated vs. Feet raised</td>
<td>PF: -19% (-67%, 17%) AB: -18% (50%, 50%)</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>Treadmill: Walking vs. Running</td>
<td>PF: -32% (-63%, 35%)</td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

Extracted data from same participant (n=1).

Main outcome was individual variability in performing exercises
- Subjects allowed to do each exercise unconstrained.
- With the same instructions, but used own motor control

- Surprisingly few exercises showed significant difference between recommended and discouraged exercises
- Small cohort size?
- Tighter instructions needed?
And finally, to wrap up ...

- This is the beginning
- More research & development needed to fully understand the implications of these pressure measurements.
- Modifications have been made to the FemFit – more likely to be retained during exercise.

Thank you
ENTER YOUR WORKSHOP TITLE HERE!!

Affiliations to disclose:

Funding for speaker to attend:
- Self-funded
- Institution (non-industry) funded
- Sponsored by:

Please complete the in-app evaluation in the workshop before leaving.

- Handout for all workshops is available via the ICS app, USB stick and website.
- Please silence all mobile phones
- PDF versions of the slides (where approved) will be made available after the meeting via the ICS website so please keep taking photos and video to a minimum.
W36: What is a vaginal pressure profile and how might this be useful?

Workshop Chair: Jennifer Kruger, New Zealand
06 September 2019 09:00 - 10:30

<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>Topic</th>
<th>Speakers</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>09:20</td>
<td>Biomechanics of pressures and how we measure them</td>
<td>David Budgett</td>
</tr>
<tr>
<td>09:20</td>
<td>09:40</td>
<td>Review of instrumentation developed to measure vaginal pressures: how do they work, assumption, advantage and disadvantages and recent updates</td>
<td>Jennifer Kruger</td>
</tr>
<tr>
<td>09:40</td>
<td>10:00</td>
<td>Repeatability and validity of intravaginal pressure measurements. Conservative management of urinary incontinence and POP: is it important to control abdominal pressure in addition to train the pelvic floor muscle? Update on therapies aiming to reduce intra-abdominal pressures</td>
<td>Chantale Dumoulin</td>
</tr>
<tr>
<td>10:00</td>
<td>10:20</td>
<td>Pressure during exercise. Its relevance and current research. How is this information helpful?</td>
<td>Margaret Sherburn</td>
</tr>
<tr>
<td>10:20</td>
<td>10:30</td>
<td>General wrap up and questions</td>
<td>Jennifer Kruger, David Budgett, Chantale Dumoulin, Margaret Sherburn</td>
</tr>
</tbody>
</table>

Aims of Workshop
The aim of the workshop is to provide a basic understanding of the biomechanics associated with the development of a vaginal pressure profile. It will explore how changes in the pelvic anatomy (usually due to pelvic organ prolapse or urinary incontinence) are likely to impact on vaginal pressures and how this may influence the pressure differential along the length of the vagina. Participants will have an up to date review of instrumentation development used to measure pressure to assess pelvic floor muscle function/dysfunction. Recent advances in instrumentation development, data interpretation and the potential application of the profile (intra-abdominal pressure vs pelvic floor muscle pressure) will also be discussed.

Learning Objectives
1. Understanding the basic biomechanics that are involved the development of pressure and how these changes can be measured in the vagina.
2. Awareness of the instrumentation that has been developed to measure pressure/force in this area: the pro’s and con’s
3. Application of the profile to a clinical condition

Target Audience
Urology, Urogynaecology, Basic Science, Conservative Management

Advanced/Basic
Basic
Biomechanics of pressure and how we measure it
Associate Professor David Budgett
Technical Lead Development Engineer, Pelvic floor research group Auckland Bioengineering institute. The University of Auckland New Zealand

Pressure is a measure of force over a defined surface area. The SI unit for pressure is Pascal, representing 1 Newton over 1 square metre. Pressure has historically been measured by its ability to displace a column of liquid in a manometer, hence the units of millimeters of mercury (mmHg) or centimetres of water (cmH2O) have become commonly adopted. Today solid-state sensors, electronic circuits and microprocessors support reporting pressure in any familiar unit of pressure. Unlike force, pressure is a scalar such that any point in the body will have a pressure that is independent of direction. The pressure in a static fluid (e.g. in the bladder) is a single value and the pressure value is the same everywhere in the bolus of fluid. So what does it mean when we talk about a pressure profile along the vagina?

To start this workshop, we will clarify what can realistically be measured by typical pressure sensing devices, used to assess pelvic floor muscle function. We will discuss these measurements in relation to other types of physiological pressures that are routinely measured in the body i.e. intra-cranial pressure, or blood pressure. Finally, the potential value of measuring pressures along the length of the vagina, which requires an understanding of absolute pressure values which are generated at rest, and differences in pressure generated from intentional muscle exercising.

Review of instrumentation developed to measure vaginal pressures: how do they work, assumption, advantage and disadvantages and recent updates
Dr Jennifer Kruger
Principal Investigator Pelvic Floor Research Group. Auckland Bioengineering Institute. The University of Auckland New Zealand.

A review of the literature will provide a historical perspective of the use of instruments to measure pressure/force in a clinical context, and a critique on the current, more commonly used instruments used for research and clinically. Discussion will focus on instrumentation that includes either force transducer(s) or pressure sensor(s) The advantages and disadvantages of the various systems will be presented. This will include myometers, elastometers, and pressure sensing devices. Commercially available devices, in which the measurement system is public knowledge will be included as part of the discussion and a brief look at the use of mobile technology linked to devices, as a means for encouraging pelvic floor muscle training. We will discuss any evidence of reliability or validity for these products.

The development of a vaginal pressure profile and the association between the features of the anatomy that are thought to contribute to this profile in relation to pelvic floor function/dysfunction will be presented.

Measurement of any physiological parameter (muscle force/pressure/) is dependent on how the data is collected and analysed. Each instrument will collect data differently dependent on the characteristics of that instrument. How this data is analysed, presented, interpreted, and any potential clinical implications will be part of the discussion.

Repeatability and validity of intravaginal pressure measurements.
Conservative management of urinary incontinence and POP: is it important to control abdominal pressure in addition to train the pelvic floor muscle?
Update on therapies aiming to reduce intra-abdominal pressures
Professor Chantale Dumoulin
Chercheure et directrice de laboratoire. Titulaire de la Chaire de Recherche du Canada Santé Urogynécologique et vieillissement
Centre de recherche, Institut Universitaire de Gériatrie de Montréal, University of Montreal, Canada

Intra-vaginal pressure measurements have been used since Kegel’s first perineometer to evaluate and document PFM function in women. Originally intra-vaginal pressure was measured with one large intra-vaginal pressure sensor. Recent intra-vaginal pressure measurement units use multiple pressure sensors to document pressure profile throughout the vaginal cavity. In this section of the workshop, we will present the psychometric properties (repeatability, validity and sensitivity) of both types of intravaginal pressure measurements. Further, we will discuss advantages and disadvantages of these measuring instruments in clinical practice.

Conservative management of urinary incontinence and POP aims to increase pelvic floor muscle strength and tone (making it resistant to stretching) in order to limit downward movement during effort and exertion, thereby preventing urine leakage and symptoms of POP. Up until now the conservative management has mainly focussed on the PFM. Recent studies have documented the impact of certain sports, exercise and activities on intra-vaginal pressure and indirectly on the PFMs. The impact of these new data and their impact on choice of exercises will be discussed. We will further discuss the importance of controlling or reducing intra-abdominal pressure in addition to train the PFM as a conservative management for urinary incontinence and POP.
Finally, therapies aiming to reduce intra-abdominal pressures and thereby improve PFM tone (hypopressive technics) have become more popular in the last decade. We will present and discuss the evidence on the impact of these approaches on PFM function and on urinary incontinence and POP.

**Pressure during exercise. Its relevance and current research. How is this information helpful?**

Dr Margaret Sherburn: Coordinator, Women’s Health Programs; Physiotherapy, School of Health Sciences. The University of Melbourne

Clinicians have long understood that raised intra-abdominal pressures during exercise may have deleterious effects on the pelvic, floor heightening the risk of pelvic floor dysfunctions. Measuring the pressures developed during different exercises has now become possible with wireless technologies. Initially intra-abdominal and pelvic floor pressures were able only to be measured separately, giving clinicians some information on which to base their rehabilitation of women at risk of PFD, but many questions remain unanswered.

The Pelvic Floor First program of the Continence Foundation of Australia (http://www.pelvicfloorfirst.org.au/) was set up to assist clinicians make decisions on the use of pelvic floor ‘safe’ exercises for women at risk of pelvic floor dysfunction. Decisions at to what constituted a pelvic floor ‘safe’ exercise was based on best knowledge at the time. The development of a vaginal pressure profile device now means that both intra-abdominal and pelvic floor pressures can be measured simultaneously during an exercise, giving us more information about safe exercise for the pelvic floor.

A recent study undertaken by this group investigated nine exercises, using a vaginal pressure profile device, and compared the pelvic floor ‘safe’ version versus the conventional form of the same exercise. We will present the results from this study and open it up for discussion.

References: