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2D ULTRASOUND EVALUATION OF DYNAMIC RESPONSES OF FEMALE PELVIC FLOOR MUSCLES (PFM) TO A COUGH

Hypothesis / aims of study
It is proposed that observations using perineal ultrasound can be used to identify the functional capacity of the PFM to maintain continence by evaluating the dynamics of Ano-Rectal Angle (ARA) movements. In this study we examined this hypothesis by defining and extracting new quantitative parameters of PFM function during a cough from 2D ultrasound imaging.

Study design, materials and methods
Data was obtained from 22 controls, age 40.1±2.3 yr, (parity 0.5±0.2) and 9 SUI subjects age 52.1±5.9 yr, (parity 1.4 ± 0.2), recruited according to a protocol approved by the IRB committee. The investigators were blinded to the continence state of the volunteers, who after evaluation, were divided on the basis of history and self reported symptoms to controls: defined as no reported incontinence and to those with Stress Urinary Incontinence (SUI). Volunteers were imaged using a Hitachi EUB-52 ultrasound scanner (Hitachi, Japan) connected to a 128 element high definition linear array operating at 3.4-5.0 MHz.
To keep the out-of-plane rotation of the ultrasound transducer in an acceptable range (< ±5º), a six degrees-of-freedom measuring device a Flock of Birds, (FOB) (Ascension technology Corporation VA, USA) was used. We fixed the FOB on the handle of the ultrasound probe and the orientation (azimuth, elevation and roll angles) of the ultrasound transducer was visualized in real-time during scanning.
All volunteers were then asked to cough on command while imaging, in supine crook lying position and if time allowed in standing too. An average of three consecutive coughs was elicited. The timing of the cough was registered by recording the sound intensity simultaneously with the imaging data using a microphone: Plantronics Audio™ 60 stereo PC (Plantronics, CA, USA) headset placed at the foot of the examination couch on a fixed hook.
An orthogonal coordinate system fixed on the symphysis pubis (SP) was established to map the trajectory of the ARA in response to a cough. The motion artifact of the SP was tracked and subtracted from the motion of the ARA, and an adaptive motion tracking algorithm based on matching template was developed to measure the movement of the SP. Displacement signals, derived from each cough, episode were differentiated to generate the velocity of displacement, and the second derivative was computed to generate the acceleration values. The resulting values of velocity and acceleration were smoothed using an 8-order Butterworth low-pass filter (cutoff frequency=3Hz) and the filtered velocity and acceleration signals were used to graphically represent the data. Mean and SE of the displacement, velocity and acceleration were calculated and presented graphically.
Statistical comparisons, using the T-test, were performed to evaluate the level of significant differences of the displacement, velocity and acceleration components at the synchronization point and to compare the effects of a change, between standing to supine within each group.

Results
Table 1 Displacement of the ARA at the synchronisation point in supine (Mean ± SE, Unit: cm/s^2).

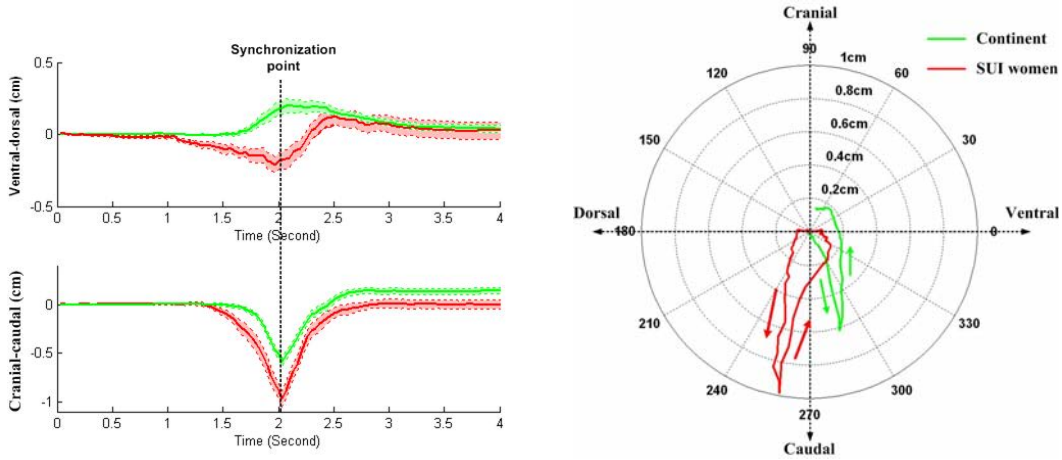
	Ventral-dorsal	Cranial-caudal
Continent women	0.18±0.05	-0.59±0.04
SUI women	-0.18±0.06	-0.97±0.08
P value	**P<0.0001**	**P<0.0001**

Table 2 Mean and SE of the averaged velocity of the ARA in the 0.5 seconds before the synchronisation point ($T_{0.5Before}$) and 0.5 seconds after the synchronisation point ($T_{0.5Before}$) in supine (Mean ± SE, Unit: cm/s).

	Ventral-dorsal		Cranial-caudal	
	$T_{0.5Before}$	$T_{0.5After}$	$T_{0.5Before}$	$T_{0.5After}$
Continent	0.36±0.09	-0.11±0.08	-0.94±0.07	1.19±0.06
SUI	-0.10±0.10	0.55±0.10	-1.33±0.14	1.56±0.14
P value	**P=0.0031**	**P<0.0001**	**P=0.0091**	**P=0.0056**

Table 3 Acceleration of the ARA at the synchronisation point in supine (Mean ± SE, Unit: cm/s^2).

	Ventral-dorsal	Cranial-caudal
Continent women	-2.61±1.55	26.82±2.06
SUI women	5.56±3.34	33.94±3.10
P value	**P= 0.0136**	P= 0.0669



(a) (b)

Figure 1. Ventral-dorsal and cranial-caudal displacements of the ARA in supine. The SEs of the displacements are marked by the coloured areas. (b) Trajectory of the movement of the ARA in supine. The continent and the SUI women are shown in green and red respectively.

Interpretation of results

The automated method of motion tracking the ARA is able to quantify dynamic parameters of PFM function that have not been previously analyzed using dynamic ultrasound imaging. Analysis of the displacement and trajectory of the ARA movement in supine and standing imply that the PFM of normal women functions very differently than those with SUI (see tables 1-3). It appears that the functional PFM, provides support to the urogenital structures prior to and during a cough, acting like a brake, to resist or limit the dorsal-caudal movement that occurs (see figure 1a,b). In women with SUI, this PFM "brake" appears to have been applied late, or has diminished effectiveness, demonstrated by the increased displacement of the ARA and the increased velocity and acceleration.

Concluding message

Our approach of processed ultrasound imaging of the pelvic floor provides significant new information relating to its dynamic response to stress. This non-invasive type of information is potentially of use in understanding the mechanisms of urinary continence. It is hoped that this study can help lay the foundations of determining a more reliable assessment of PFM function and eventually improve the rehabilitation of women with SUI and other pelvic floor disorders.

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