171

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A 3D STATISTICAL SHAPE ANALYSIS OF PELVIC FLOOR MORPHOLOGY IN NULLIPAROUS WOMEN

Hypothesis / aims of study

The morphology of the female pelvic floor (PF) musculature, including the levator ani (LA) and the external anal sphincter, is closely related to the performance of various urogenital functions. Thus, a detailed 3D understanding of PF muscle anatomy is required to help with the diagnosis of pathogenic structure variations by means of medical imaging. In this study, a population-based shape analysis was conducted to quantify the normal morphological variations among individuals. The results provide a generic description that characterises the global features of healthy PF muscles.

Study design, materials and methods

Computer models of the PF were created from the magnetic resonance images (MRI) collected in a previous study [1]. Twelve healthy nulliparous women, with no evidence of PF disorders, were imaged using a Siemens 1.5T MRI scanner and T2 weighted turbo-spin echo sequence. The MR images were segmented to outline the bony pelvis, PF muscles and surrounding organs, which were subsequently fitted by finite element models using the CMISS software. Five readily identifiable bony landmarks, including the ischial spines, base of the coccyx and cranial and caudal extremities of pubic symphysis, were used to define an anatomically related coordinate system to consistently align the PF models and eliminate variations in position and orientation. A series of mathematical transformations were performed to provide point-to-point correspondence of anatomical features and locations in the models. This is an essential pre-requisite for reliable and valid feature identification and analysis across individuals. A principal component analysis was applied to determine the shape variation across the population. The computed shape descriptors were then ranked according to their relative contributions to explain the differences in the PF muscle features.

Results

To quantitatively validate the modelling procedure, morphological parameters that represent the shape and volume of the PF muscles were extracted from the fitted models and compared to the published data [1] collected from the images of the same group of subjects (Table 1). There is reasonable agreement between the parameters estimated from the models and the published data.

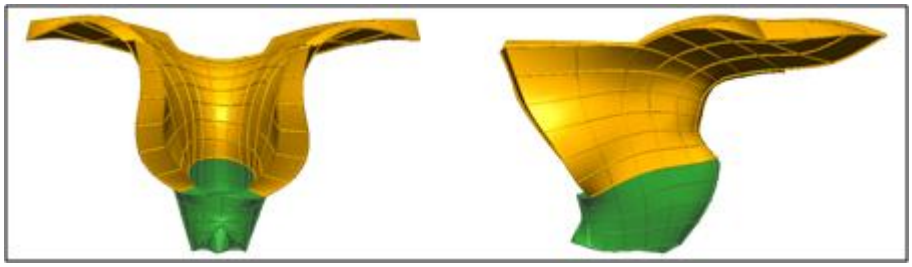

Figure 1: Generic PF model for nulliparous women. (a) Front and (b) side views are illustrated. Gold, coccygeus and LA; green, external anal sphincter.

A generic model of the PF muscles for nulliparous women was obtained from the statistical average of the twelve subjects (Figure 1). The external anal sphincter was also included in the analysis since it fuses with the LA posteriorly and the two form a continuous muscular structure. Figure 2 illustrates the three most predominant shape descriptors, which collectively explain 80% of the shape variation across the sample population. The first mode of variation describes the LA thickness and span of the coccygeus and iliococcygeus arms in the anterior-posterior direction; the second mode captures primarily the axial span of the PF muscles; while the third mode illustrates a combination of shape variations, including the LA thickness and the curvature at the posterior aspect of the transition between the LA and external sphincter.

Table 1: Summary of measured parameters (mean ± standard deviation) from the models and the published data

Measurements (unit)	Data from models	Published data	% Diff.
Urogenital hiatus (cm^2)	8.2 ± 1.6	8.32 ± 11.4	-2%
Right LA area (mm^2)	90.1 ± 7.1	83.4 ± 21.2	8%
Left LA area (mm^2)	86.9 ± 11.5	89.4 ± 34.5	-3%
LA pooled data (mm^2)	88.5 ± 9.5	86.4 ± 28.0	2%
Right puborectalis width (cm)	0.70 ± 0.19	0.65 ± 0.16	8%
Left puborectalis width (cm)	0.71 ± 0.22	0.69 ± 0.16	3%
Puborectalis pooled width data (cm)	0.70 ± 0.20	0.67 ± 0.15	5%
Right puborectalis volume (mm^3)	1122 ± 355	1267 ± 330	11%
Left puborectalis volume (mm^3)	1092 ± 331	1111 ± 225	-2%
Puborectalis pooled volume data (mm^3)	1107 ± 336	1189 ± 286	7%

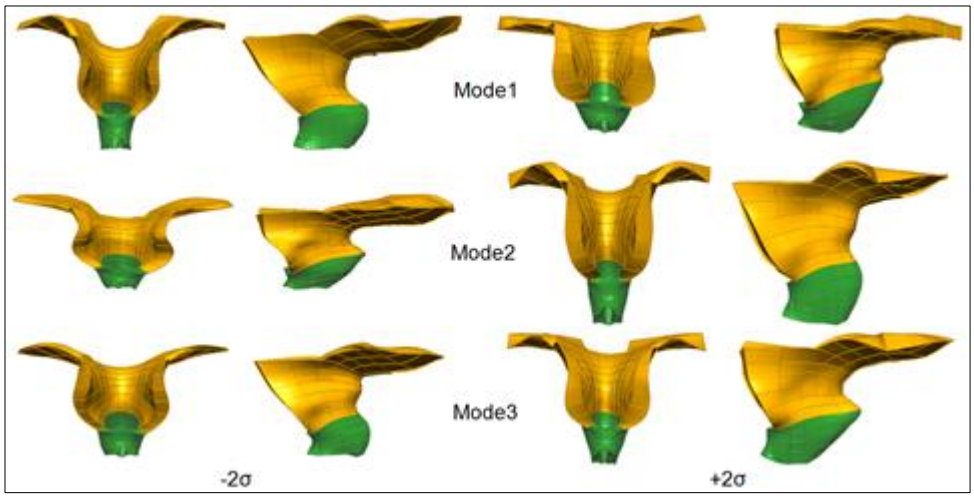

Figure 2: The three predominant modes of shape variation across the sample population. For each modes, the left panels illustrate the (mean - 2SD) PF models. The right panels show the (mean + 2SD) PF model.

Interpretation of results

The results are generally consistent with findings from a previous study [2]. However, the uniqueness of the present approach is that anatomical feature correspondence between individuals was achieved in the model construction, which makes the quantification of shape variations more reliable. The shape descriptors extracted here may be utilised to investigate sensitivity of various physiological processes (e.g. childbirth and pelvic organ support) to the PF muscle morphology.

Concluding message

A systematic approach for statistical shape analysis of the PF muscles has been developed to quantitatively describe their feature variations among a population of nulliparous women. In the future, this technique may be adopted to extract patterns in PF muscle morphology that may occur with PF dysfunction (such as urinary incontinence and pelvic organ prolapse).

References

1. Kruger, J. A., B. A. Murphy, et al. (2005). "Alterations in levator ani morphology in elite nulliparous athletes: A pilot study." Australian & New Zealand Journal of Obstetrics & Gynaecology 45(1): 42-47.
2. Lee, S. L., P. Horkaew, et al. (2004). "Statistical shape modelling of the levator ani with thickness variation." Medical Image Computing and Computer-Assisted Intervention - MICCAI 2004, Proceedings 3216: 258-265.

Specify source of funding or grant	**The University of Auckland**
Is this a clinical trial?	**No**
What were the subjects in the study?	**HUMAN**
Was this study approved by an ethics committee?	**Yes**
Specify Name of Ethics Committee	**University of Auckland Human Participants Ethics Committee**
Was the Declaration of Helsinki followed?	**Yes**
Was informed consent obtained from the patients?	**Yes**