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COMPUTER MODEL BASED DYNAMIC URETHROVAGINAL SUPPORT ASSESSMENT FOR FEMALE SUI

Hypothesis / aims of study

The objective of this study is to develop a novel subject-specific biomechanical pelvic model to noninvasively assess urethrovaginal support in females which is an etiologic factor associated with female SUI. The hypothesis behind this research is that dynamic finite element (FE) analysis based on the subject-specific biomechanical pelvic model has the capability to noninvasively assess the urethrovaginal support in females.

Study design, materials and methods

Subject-specific pelvic FE mesh model generation: A female subject was recruited to participate in this University of Minnesota IRB approved study. Axial proton density and coronal T2-weighted high resolution MR images were obtained on the subject with a 3.0 Tesla scanner using a commercially available combined body-spine coil array for reception. A subject-specific FE pelvic mesh model generation procedure as shown in Figure 1 has been developed to build the realistic geometry female pelvis model from subject-specific high resolution MR images by means of a series of commercially available Computer Aided Design/Engineering (CAD/E) software packages [1]. A subject-specific pelvic FE model as shown in Figure 2 was developed by using this procedure from the high resolution MR images of a 21-year-old female subject. This female pelvic FE model consists of 35 anatomical parts including 10 pelvic muscles, 10 pelvic ligaments, 6 pelvic bones, skin, fat tissues, bladder, urethra, uterus, vagina, colon, rectum and anus.

Mechanical Properties: The mechanical properties of tissues involved in the pelvic model were derived from the literature [2, 3], and were used to form the Property module of the pelvic FE model in ABAQUS 6.8. A fresh cadaver urologic tissue properties database is under development by performing soft tissue testing procedure on tissue specimens harvested from fresh cadavers within 48 hours of the time of death. The present pelvic model could be refined in the future using the mechanical properties in this urologic tissue properties database after it is completely developed.

Interaction Conditions: Two interaction conditions were assumed and set in the pelvic model according to connecting status between organs, i.e., Tie interaction condition which forbids any relative movements of the touching organs, and Surface-to-Surface interaction condition which allows the touching organs to slide relative to each other along the interface.

Inputs of the pelvic model: An ambulatory device which includes a tri-axial accelerometer and an inclinometer has been developed and located over the lower back at the level of the posterior iliac crest or lumbar spine of the female subject to measure the accelerations of her pelvis in three axial directions during jumping. The data from the device were collected wirelessly by a laptop. The temporal acceleration recordings were used to form the Load module of the FE model in ABAQUS 6.8 (ABAQUS, Inc., Providence, RI).

Dynamic FE Analysis: ABAQUS, a robust, industry accepted FE modeling and dynamic analysis software package, was used in the present study to conduct the dynamic analysis based on the developed biomechanical pelvic model. The Explicit Module of ABAQUS 6.8 was used as the solver considering the proposed analysis is a large-deformation analysis task.

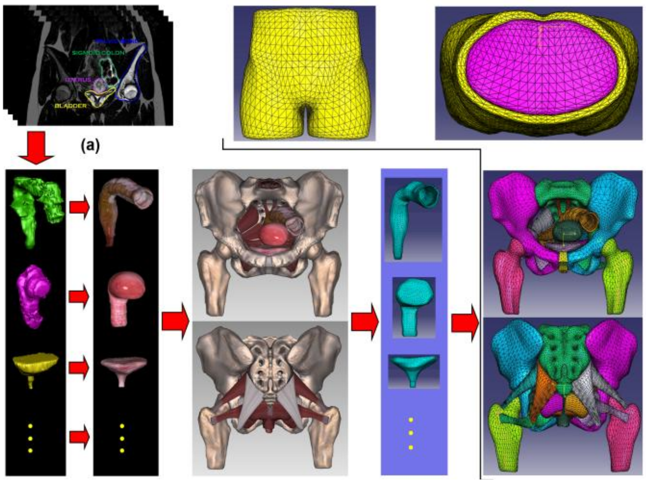

Figure 1: Subject-specific FE mesh model generation procedure based on high resolution MR images.

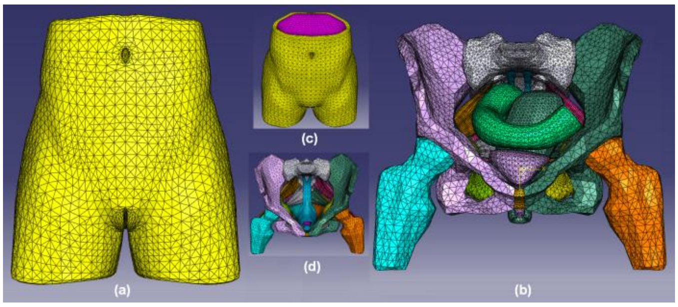

Figure 2: A 21-year-old female subject's specific pelvic FE model from her specific MR images.

Results

Figure 3 shows the acceleration data of the female subject's pelvis in three axial directions during a jumping task (repeated 3 times) from a 660-mm high table. The top 3 subfigures show the acceleration recordings in x, y, z directions respectively, and the 4th subfigure shows the integrated acceleration data of female pelvis during the jumping task. The load modulus of the pelvic model was calculated from the time-history accelerations recordings of the subject's pelvis as shown in the 4th subfigure in Figure 3. The dynamic FE analysis based on the developed subject-specific pelvic model was conducted using the ABAQUS/Explicit function module to assess the urethrovaginal support of the female subject during the jumping task. The deformation distributions over the pelvic floor and the bladder are shown in Figure 4 (a) and (b) respectively.

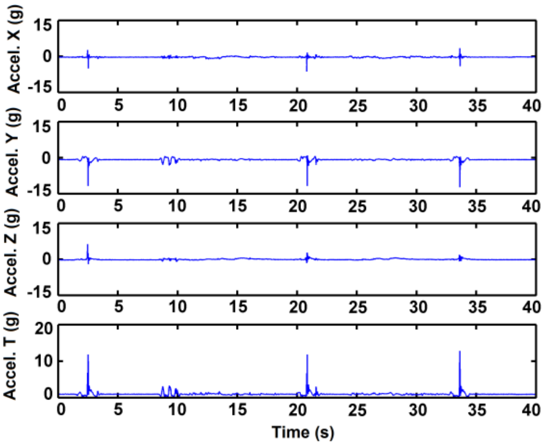

Figure 3: Acceleration recordings of the female subject's pelvis during her jumping.

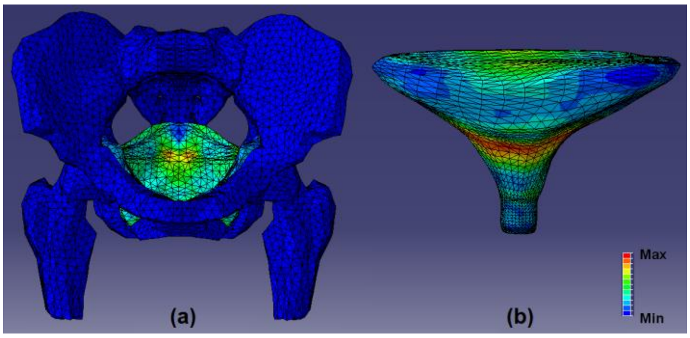

Figure 4: Deformation distributions over (a) the pelvic floor and (b) the bladder of the female subject.

Interpretation of results

Results show that the pelvic floor and the bladder neck have high level deformation distributions during the subject's jumping process. It can be surmised that the abdominal muscles and pelvic diaphragm play a very important role in supporting the bladder at the bladder neck area during vigorous physical or daily activities. Videos which show the dynamic biomechanical response of the pelvic floor and the bladder of a female subject induced by jumping will be presented at ICS 2009 if this abstract is accepted.

Concluding message

The proposed subject-specific biomechanical pelvic modelling approach has the capability to noninvasively assess the etiologic factors associated with SUI in females. The cause of pelvic floor dysfunctions such as pelvic organ prolapse, tissue weakness or sphincter injury can be better assessed and therapies proposed using this approach.

References

1. Zhang, Y., Sweet, R.M., Metzger, G.J., Burke, D.M, Erdman, A.G., and Timm, G.W. Advanced Finite Element Mesh Model of Female SUI Research During Physical and Daily Activities. Studies in Health Technology and Informatics. 142: 447-452. 2009
2. Haridas, B., H. Hong, R. Minoguchi, S. Owens, and T. Osborn. PelvicSim-A Computational-Experimental System for Biomechanical Evaluation of Female Pelvic Floor Organ Disorders and Associated Minimally Invasive Interventions. Studies in Health Technology and Informatics. 14:182-187, 2006
3. Yamada, H. Strength of biological materials. Williams & Wilkins, Baltimore. 1970

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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	**Univerisity of Minnesota IRBs**
Was the Declaration of Helsinki followed?	**Yes**
Was informed consent obtained from the patients?	**Yes**