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VALIDATION STUDY OF THE PELVIC MODELLING APPROACH USING A MOTION CAPTURE SYSTEM

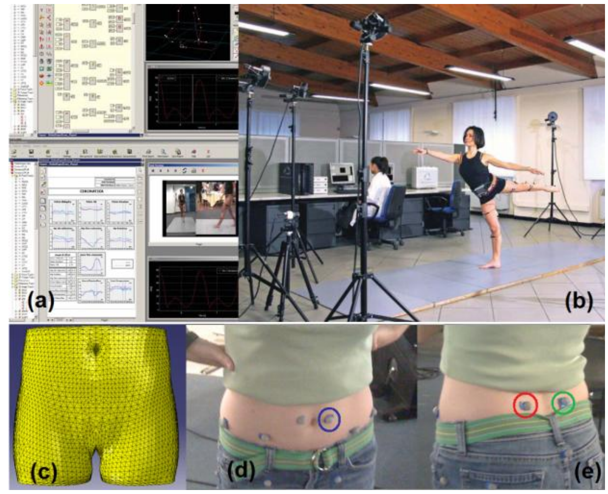

Fig 1. Validation protocol using the BTS SMART-e motion capture system. (a) SMART Analyzer, (b) motion capture system, (c) pelvic model of the 21-year-old female subject, (d) and (e) show the tracking marks on the female pelvis (marker in red, green and blue cycles indicates Left Back, Right Back and Left Belly marker respectively)

Hypothesis / aims of study

A subject-specific pelvic modelling approach has been developed to non-invasively assess urethrovaginal support function which is an etiologic factor associated with stress urinary incontinence (SUI) in female [1]. A validation study has been conducted to evaluate the performance of this approach by means of a motion capture system in preparation for applying it to clinical population.

Study design, materials and methods

The validation study was performed on a subject by means of the BTS SMART-e motion capture system (BTS SMART, BTS S.p.A.) to simultaneously measure the dynamic biomechanical response and landing impact of her pelvis when she lands a jump. The BTS SMART-e is a 9-camera, passive-marker motion capture system (Fig 1 (b)) with the accompanying analyzer software (Fig 1(a)). This system is capable of capturing quick movement with high resolution using digital optical techniques and is available to us in the Human Dimensioning Lab at UMN.

(1) MR Scan: A 22-year-old 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. The subject's specific pelvic model was constructed from her MR images using the subject-specific FE pelvic mesh model generation procedure.

(2) Tracking Markers on the pelvis. The subject was outfitted with reflective markers on anatomical marker points. Multiple markers were fixed over the lower back at the level of her posterior iliac crest or lumbar spine to measure the landing impact of the pelvic bones (Fig 1 (e)) and other markers were fixed over the bellybutton or other important points of her pelvis to measure the induced biomechanical response (Fig 1(d) and (e)).

(3) Simultaneously measurements. The subject was requested to jump off from a table with heights of 0.5 feet. The motion of each reflective marker was captured by the cameras at 60Hz. The BTS ANALYZER software used the generated models to calculate the inclination, landing velocities and accelerations for each marker.

(4) Dynamic fluid-structure interaction FE analysis based on subject-pelvic models. The biomechanical pelvic model was developed for this specific subject. The inclination and landing velocities of the left back marker were used to form load modules. Dynamic structure-fluid interaction finite element (FE) analysis was performed to simulate dynamic biomechanical response of her entire pelvis.

(5) Validation. The dynamic displacement, velocity and acceleration responses of reflective marker were pulled out from the FE analysis results. The simulated biomechanical responses were compared with the induced biomechanical responses simultaneously recorded for the same reflective marker to evaluate the proposed subject-specific pelvic modeling approach.

Results

The female pelvic FE model (Fig 2(a)) developed in this study 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. To the best of our knowledge, this subject-specific currently represents the most comprehensive female pelvic model in UI research field. The dynamic FE analysis based on the developed subject-specific pelvic model was conducted using the ABAQUS/Explicit function module to simulate the dynamic biomechanical response of the female pelvic during the jumping task. As an example, the simulated deformation distributions over the pelvic floor induced by landing the jump are shown in Fig 2 (b).

The generated model of reflective markers over the pelvis of the subject is shown in Fig 2(c), which was utilized to calculate inclination, velocities and accelerations of markers from the motions recorded by cameras of the motion capture system. Fig 2(d) shows the velocities of two markers of the female pelvis, and we can clearly see the deference of dynamic measurements between the pelvic bone (Left Back Marker) and other soft organs (Left Belly marker). These measurements will be used to evaluate the performance of our pelvic modelling approach.

<u>Interpretation of results</u>

Results show that the subject-specific pelvic modelling approach has the capabilities to simulate dynamic biomechanical responses of the pelvis induced by physical or daily activities. This dynamic response will be valuable in helping us assess urethrovaginal support function which is an etiologic factor associated with female SUI. The motion capture system can successfully capture dynamic response of the pelvis induced by physical or daily activities through reflective markers. These dynamic measurements can be used to evaluate the accuracy of simulated biomechanical response simulated by the pelvic modelling approach.

<u>Concluding message</u>

The proposed subject-specific biomechanical pelvic modelling approach has the capability to noninvasively assess the etiologic factors associated with SUI in females. This approach will be applied to clinical populations after its performance is validated. Validation results will be presented at ICS 2010 if this abstract is accepted.

<u>References</u>

1. Zhang, Y., Sweet, R.M., Metzger, G.J., Burke, D.M, Erdman, A.G., and Timm, G.W. 2009. Advanced Finite Element Mesh Model of Female SUI Research During Physical and Daily Activities. Stud Health Technol Inform. 142:447-52.

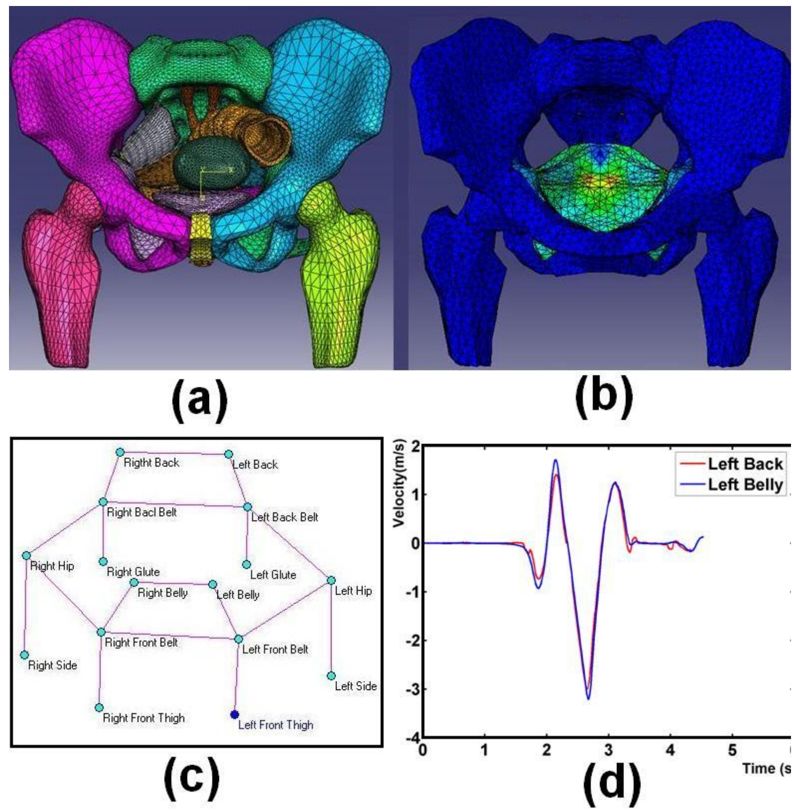

Fig 2. (a) shows the biomechanical pelvic model generated from the subject's specific MR images, (b) shows simulated deformation distributions over the pelvic floor induced by landing a jump, (c) shows the generated model of reflective markers in the motion capture system, (d) shows velocity recordings of Left Back and Left Belly markers on the subject's pelvic.

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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**