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Computational Mechanics of Human Gluteal Soft Tissue and Body Support Interaction

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ABSTRACT

Introduction. Pressure sores are the most common complication associated with patient immobilization. Body support design and material play a crucial role in sore development. Computational simulations have provided insight into tissue stress-strain distribution, subject to loading conditions and thus can contribute to help design more efficient anti-pressure sore patient body supports. In the simulation process, suitable material laws as well as adequate soft tissue and support material parameters are indispensable.

Methods. A finite element (FE) model of the human gluteal region based on magnetic resonance imaging (MRI) data has been developed (Fig.1a). In this process, the derived MRI data were digitalized and three dimensionally reconstructed. Human gluteal skin/fat and muscle long-term material parameters have been characterised via in vivo experiments [1]. Open-cell viscoelastic polyurethane foam support long-term material parameters have been determined. Both procedures were based on cyclic compression tests performed to extract the pure elastic material responses. In order to describe human gluteal soft tissue behaviour the Ogden form for slightly compressible materials was employed.
Interaction of the gluteal FE-model with various supports under body weight loading was simulated (Fig. 1b) and tissue stresses were evaluated and relatively compared with respect to the particular support.

(a) (b)

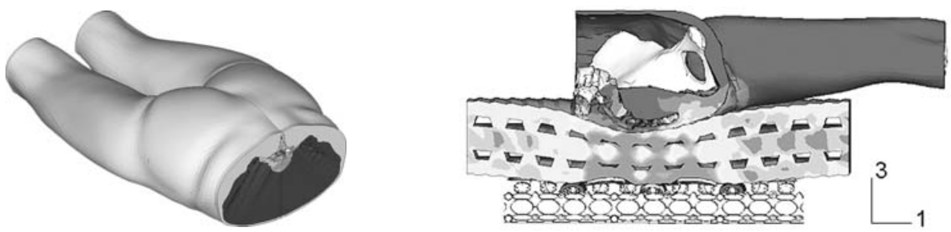

Figure 1: (a) FE-buttock model: face down position in full (non-sectional) view, (b) Recumbent FE-buttock model on a contoured soft foam mattress and active support system in half symmetry sectional view.

Results. Varying stress and strain distributions depending on the particular support could be quantified. Irrespective of the support material and geometry, simulations show that at the pelvic bone surface in supine position under loading, decided anatomic points predominate regarding stress accumulation (Fig. 2a). Compressive stress maxima were located in tissue adjacent to bone, not at the skin. Peak strain values were observed within the muscle tissue near the fat-muscle interface (Fig. 2b). Distinguished support designs lowered tissue stresses within the fat layer by more than 25%. Close to the sacral bone a stress relief of over 60% was evaluated.
Direct stresses within the muscle tissue near the bone were found to dominate shear stress by up to three orders of magnitude. In addition, it showed that maximum compressive stress magnitudes at the sacral bone depended strongly on the behaviour of the pelvic diaphragm musculature. It can be hypothesized that the compliance of these muscle groups governs the relative motion between the adjacent tissue regions and bone. Parameter studies revealed that, depending on the particular modelling technique of the pelvic floor, inadequate modelling may lead to discrepancy of tissue stress magnitudes of more than an order of magnitude.

(a) (b)

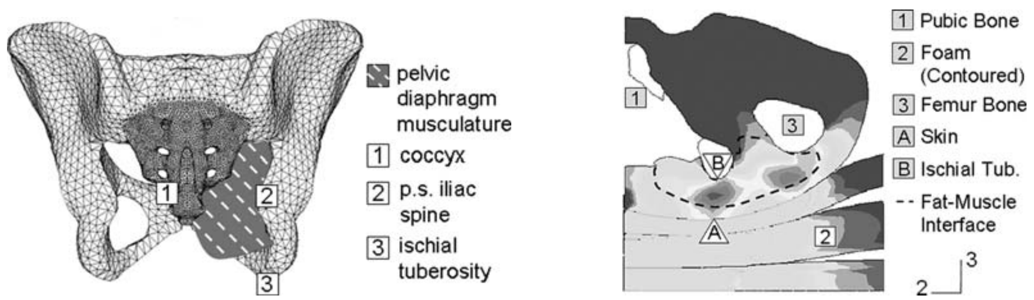

Figure 2: (a) Pelvic bone structure with most affected tissue sites, (b) Buttock model in section cut view at position of the ischial tuberosity on contoured foam support: contour plot of the nominal direct strain component ε_{33} at static equilibrium (nominal strain maximum located on the path from A to B within the muscle tissue).

Discussion. Beyond similar investigations e.g. [2, 3], the present investigation employs realistic anatomical buttocks structures, in vivo gluteal tissues parameters and adequate support material parameters. This allows shear and normal stress evaluation at most affected tissue sites (i.e. sacral bone edge laterally, posterior superior iliac spine, ischial tuberosity) which exhibit significantly different stress distributions. Regarding these sites, body supports could be optimized aiming on tissue stress reduction.

References.

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