FE MODELING AND ANALYSIS OF COMPRESSED HUMAN BUTTOCK-THIGH TISSUE

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INTRODUCTION

Prolonged high compressive sitting stress in the buttock soft tissue of wheelchair users increases the risk of pressure ulcer (PU). However, interface pressure is currently the only available clinical tool to assess sitting load. The objective of this study was to develop a 3D finite element (FE) model to investigate how the buttock-thigh soft tissue responds to external sitting load. It was expected that this FE model would be a powerful tool for better understanding of the biomechanical response of buttock tissue to sitting load.

METHODS

A healthy subject was posed and loaded in a customer-designed apparatus at a simulated sitting posture. MRI scan was performed with two loading conditions: "No Load" and "Sitting Load". Volumetric sagittal MR images of the right buttock-thigh were acquired in the two loading conditions.

The "No Load" image sequence was segmented to reconstruct the geometry for femur, pelvis, muscles, fat and skin. Based on the geometry, the FE mesh of the buttock-thigh was created with tetrahedral elements (Fig. 1). Neo-Hookean material was employed to model each soft tissue with published data.

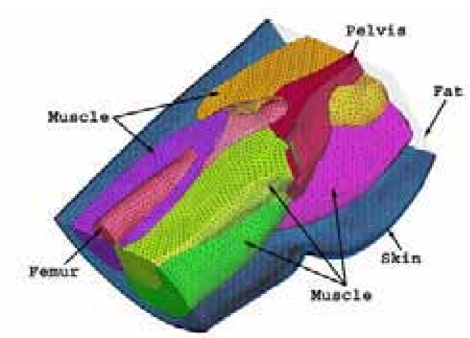

Figure 1: FE model of the buttock-thigh.

The bones were assumed as fixed boundary. Since the simulation was focused on the sitting area, the upper plane was assumed to be fixed while the longitudinal ends of muscles and skin that connect the rests of thigh or buttock structures were constrained from longitudinal motion. The medial buttock plane was assumed to be constrained from the medial-lateral motion due to the symmetry of the buttocks. The measured interface pressure (157-160mmHg) was applied on the skin in the sitting area. The static FE analysis was performed using ABAQUS. The results were examined for three regions of the tissues in the sitting area that represented the soft tissues under IT, under femur, and with no bone above, respectively.

RESULTS AND DISCUSSION

The results of the simulations showed that the internal compressive and shear stress distributions were substantially different among muscles, fat, and skin. The maximum compressive stress occurred in the muscle under IT (Table 1), which is consistent with the experimental observation from other researchers [1]. The compressive stress in fat layer was distributed relatively uniform, while in muscle and skin layers, the soft tissue under bony prominences bore substantially higher internal compressive stress (Table 1). The maximum shear stress occurred within muscle under IT and skin under femur. The shear stress within muscle and skin were significantly higher than that in fat. This supports the conclusion that the shear stress may be one of factors to form PU's in the skin by other researchers [2]. The study also showed that the soft tissues were deformed significantly and the deformation was not uniform among the soft-tissue layers of the sitting area: The maximum deformation involved the deep layer, i.e. muscular layer, which was consistent to the observation from the unloaded and loaded MRI images.

Table 1: Comparison of the compressive and shear stress levels in deep soft tissues.

Region	Layer	Compressive Stress (mmHg)		Shear Stress (mmHg)	
		Mean ± SD	Max	Mean ± SD	Max
Under IT	**Muscle**	316.9 ± 99.1	568.6	144.4 ± 28.2	205.3
	Fat	182.5 ± 7.1	200.8	20.7 ± 1.3	25.3
	Skin	280.4 ± 81.8	527.9	41.3 ± 13.5	67.3
Under Femur	**Muscle**	245.6 ± 81.8	458.7	96.7 ± 13.6	136.4
	Fat	189.1 ± 20.1	233.2	42.5 ± 7.5	56.5
	Skin	325.2 ± 91.8	486.9	159.4 ± 26.9	234.8
No Bone Above	**Muscle**	206.3 ± 22.5	262.9	96.9 ± 7.9	117.5
	Fat	183.3 ± 21.7	252.3	24.8 ± 4.3	38.6
	Skin	271.2 ± 58.9	419.4	75.8 ± 15.2	133.9

The study indicates that tissue necrosis may first occur in the deep buttock-thigh soft tissue of wheelchair users because the higher internal pressure would clog the vascular system and thus reduce or terminate the supply of blood. The high shear stress within the skin and muscle may contribute to the formation of PU's in skin and muscle. The FE model will be further improved to predict the normal biomechanical response, the outcomes from potential interventions, and the interaction between the buttock-thigh and cushion.

REFERENCES

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