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Case report

3-dimensional buttocks response to sitting: A case report

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Abstract *Aim of the study:* The aim of this study was to describe an individual's 3-dimensional buttocks response to sitting. Within that exploration, we specifically considered tissue (i.e., fat and muscle) deformations, including tissue displacements that have not been identified by research published to date.
Materials and methods: The buttocks anatomy of an able-bodied female during sitting was collected in a FONAR Upright MRI. T1-weighted Fast Spin Echo scans were collected with the individual seated on a custom wheelchair cushion with a cutout beneath the pelvis ("unloaded"), and seated on a 3″ foam cushion ("loaded"). 2D slices of the MRI were analyzed, and bone and muscle were segmented to permit 3D rendering and analyses.
Results: MRIs indicated a marked decrease in muscle thickness under the ischial tuberosity during loaded sitting. This change in thickness resulted from a combination of muscle displacement and distortion. The gluteus and hamstrings overlapped beneath the pelvis in an unloaded condition, enveloping the ischial tuberosity. But the overlap was removed under load. The hamstrings moved anteriorly, while the gluteus moved posterior-laterally. Under load, neither muscle was directly beneath the apex of the ischial tuberosity. Furthermore, there was a change in muscle shape, particularly posterior to the peak of the ischial tuberosity.

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Conclusion: The complex deformation of buttocks tissue seen in this case study may help explain the inconsistent results reported in finite element models. 3D imaging of the seated buttocks provides a unique opportunity to study the actual buttocks response to sitting.

Introduction

Sitting for extended periods has the potential to compromise tissue health for individuals with mobility impairments. Reduced mobility and impaired sensation, two factors common in individuals who use wheelchairs for mobility, combine to make tissue breakdown and pressure ulcer development a major economically and psychologically costly complication of wheelchair use [1]. Development of a pressure ulcer adversely impacts multiple aspects of the affected individual's quality of life, including autonomy, socialization and financial status [2,3]. Pressure ulcers are also a significant burden on health care systems with treatment costs estimated to be in excess of $1.3 billion annually [4].

External pressure is the defining cause of pressure ulcers [5,6]. External pressure deforms the internal soft tissue and initiates a sequence of events resulting in pathophysiological responses [7]. While the precise mechanisms by which loading and the pathophysiological responses lead to pressure ulcers have not been established, *tissue deformation* appears to be the underlying factor that needs to be considered in assessing pressure ulcer risk and prevention [8–10].

Studies of buttock tissue deformation have used observation of tissue thickness directly underneath the ischial tuberosity (1-dimensional) based on MRI [11–13], or finite element (FE) modeling [14–18]. 1D measurement under the ischial tuberosity had limited sensitivity to different sitting surfaces, but differences were seen across large postural changes. Still, the measurements provided little insight into the nature of the buttocks response. FE models have used a number of different approaches to estimate this response. One group has used Open-MRI to measure upright sitting [14,15,19,20]. Their FE models were built based on the anatomy of an individual and "reverse engineered" to ensure that the unloaded and loaded anatomical geometry within a coronal plane were preserved. Although described as 3-dimensional, these models are limited to a 4 mm coronal slice. Another study, utilizing a simulated sitting posture scanned in a standard MRI, built a 3-D FE model of the buttocks [18].

All FE models require some critical assumptions that impact their validity. To reduce the complexity of the models, most models assume linear isotropic properties for human tissues, and use simplified boundary conditions between tissue layers [18,19,21,22]. Finally, coronal models assume that tissue deformations occur in the inferior, superior, medial or lateral directions. Taken together, these assumptions result in models reporting anywhere from 5 to 85% compressive strain underneath the ischial tuberosity, and an incomplete picture of what happens to the buttocks tissue during loading.

If the implications of their assumptions were addressed, FE models could be highly valuable, as they allow us to estimate how an individual's tissue might respond to different support surfaces. For the results of these models to be improved, it is necessary to accurately understand tissue deformation and apply that knowledge to optimizing the assumptions used in FE model development.

Therefore, this study seeks to describe an able-bodied individual's 3-dimensional buttocks response to loaded sitting, as compared with unloaded sitting. Within that exploration, we will specifically consider tissue deformations, including tissue distortions (or change in shape) as well as tissue displacements (movement of tissue or structures) that might not have been identified by research published to date.

Methods

Protocol

One healthy, female adult (32 years old, height 1.57 m, weight 49.9 kg) was scanned in a 0.6 T resistive FONAR Upright MRI (FONAR Corporation, Melville, NY) which permits a seated scanning posture (Fig. 1). Scans were collected in two conditions. The first scan was collected in a seated, unloaded condition using a custom wheelchair cushion (Fig. 2). This cushion shape is based on common anthropometry and uses a more rigid foam to ensure that the ischial tuberosities were fully unloaded. The second scan was collected on a 7.6 cm piece of flat HR45 foam. In both conditions,