EFFECT OF THE INTERNAL STRESS RELIEF THROUGH THE ALTERATION OF THE GLUTEUS MAXIMUS MUSCLE THICKNESS USING FINITE ELEMENT ANALYSIS

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INTRODUCTION

In the United States, many of the 1.4 million people who rely on wheelchairs and sit in them for prolonged time periods develop serious tissue breakdown, and pressure ulcers, at pressure sensitive areas such as the ischium and trochanter [1]. Recently, functional electrical stimulation (FES) has been proposed as a means to prevent pressure ulcer development through the redistribution and the reduction of the internal stresses within the deep tissue of the buttocks, this is achieved by increasing muscle thickness, particularly in the gluteus maximus [2]. However, little information is currently available regarding the effectiveness of FES for reducing the incidence of deep-tissue injury and pressure ulcers. Therefore, the objective of the current study was to evaluate, using finite element analysis, the degree of the internal stress relief resulting from altering gluteus maximus muscle thickness.

MATERIALS AND METHODS

The buttock Finite Element Model (FEM) was consisted with femur, pelvis, skin, fat, five muscle groups, and a rectangular cushion. To evaluate the effectiveness FES, two modified FE models were developed to represent status of the degenerated buttock model and after the FES application as an effective treatment based on the healthy model. The effect of FES treatment was represented as the increase of the gluteus maximus muscle thickness below the ischial tuberosity (Figure 2).

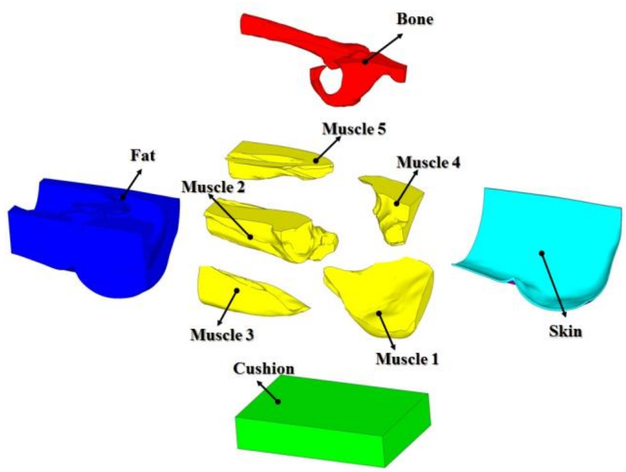

Figure 1 Finite Element Model: bone (femur, pelvis), skin, fat, five muscle groups, and a rectangular cushion. Muscle 1: Minimus, Medius, and Maximus Gluteus; Muscle 2: Adductor Longus, Adductor Brevis, Adductor Magnus, and Pectineus; Muscle 3: Biceps Femoris(long head), Semitendinosus, and Gracilis; Muscle 4: Piriformis, Superior and inferior Gemellus and Obturator Internus; Muscle 5: Vestus Lateralis, Vastus Intermedius, Vastus Medialis and Rectus Femoris.

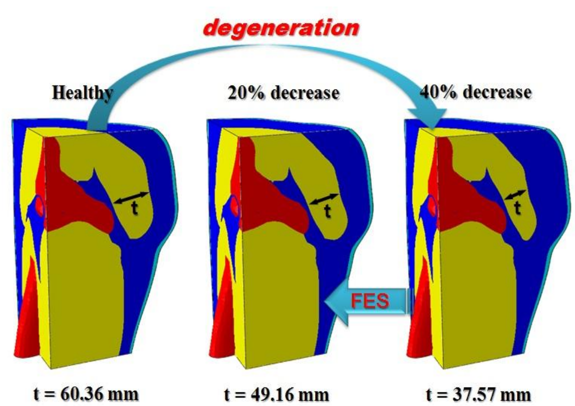

Figure 2 Model for degenerative changes in gluteus maximus thickness.

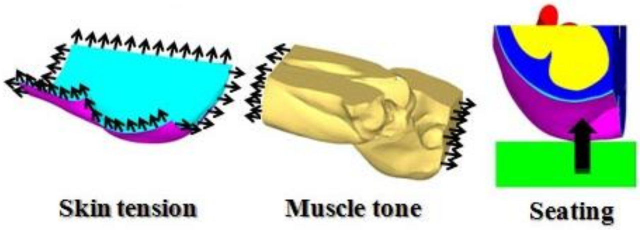

Figure 3 Loading conditions used in the FE model.

A first order Ogden model, which can account for large deformation behaviors of materials, was employed for skin, fat, and muscle. A static analysis was performed. The material parameters for skin, fat, and muscle were determined based on values obtained from literature [3]. The femur and the pelvis were assumed to be rigid bodies and constrained to obviate rigid body motion.

The medial plane was constrained against the medial-lateral motions because of the symmetric condition of the buttocks. Also for this boundary condition was that the upper plane was constrained from the anterior-posterior movement. The ends of tissues that connect to the rest of the body (distal end to the thigh, proximal end to the lumbar region) were constrained against longitudinal motions. When the load from sitting was considered as the specific loading applied as the input to the FEM, an initial strain was applied into the skin layer. A muscle tone, equal to 1% of the maximal muscle force, estimated from physiological cross-sectional area (PCSA), was applied along the line of action of each muscle. An interface pressure was applied as an additional cushioning condition. (Figure3)

RESULT

High internal pressure was concentrated in the area close to the bony prominence of the ischial tuberosity. The pattern of von-Mises stress distribution was similar to that of pressure distribution. The maximum von-Mises stresses values for the healthy, FES treatment, and degenerated model were 54.5 kPa, 60.8kPa and 69.7kPa, respectively. The results showed that the distribution of the high von-Mises stresses and internal pressure within the gluteus maximus muscle gradually decreased with increasing muscle thickness.

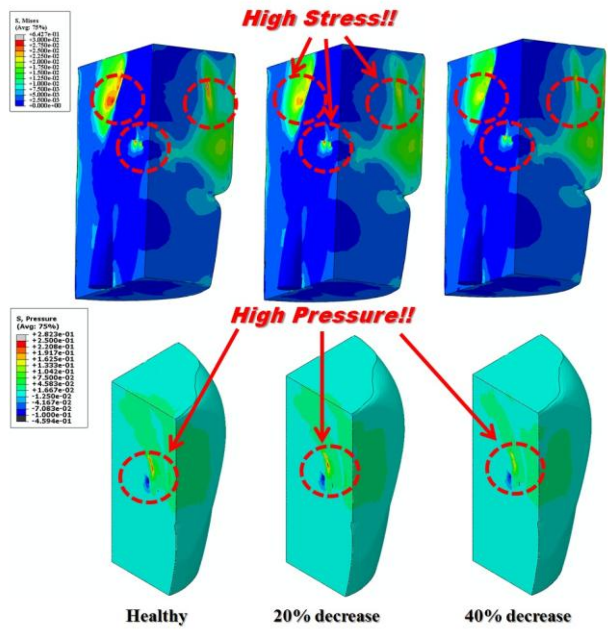

Figure 4 Internal stresses and pressure distribution on the entire buttock-thigh structure.

DISCUSSIONS AND CONCLUSIONS

The results of the current study for help identify the therapeutic effect, (internal von-Mises stress and pressure relief by muscle thickness increase), of FES for preventing pressure ulcers. This finding may contribute to designing a prevention or treatment program for individuals with sitting-related pressure ulcers. It can also be concluded that incorporating the FES system into a rehabilitation and treatment program may promote the healing progress while maintaining mobility.

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