INCREASE OF LUMBAR SPINAL STAIBLITY UNDER FOLLOWER LOAD IN SAGITTAL PLANE

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INTRODUCTION

There has been a discrepancy between in vivo and in vitro experiments investigating the load carrying capacity of human lumbar spine. A follower load concept was introduced to explain this discrepancy [1]. A follower load is a compressive load applied along a path that approximates the tangent to the curve of the column. The trunk muscles are supposed to generate the follower load in vivo, but it is still difficult to assess the muscle contraction forces by experimental techniques. Hence a musculoskeletal modeling of the spine and trunk muscles is indispensable. The purpose of this study is to show that there is muscle activations generating the follower load and the lumbar spine is more stable under the follower load using the finite element model of the lumbar spine and trunk muscles in the sagittal plane.

METHODS

A two-dimensional finite element model of a human lumbar spine (T12-S1) and 66 pairs of trunk muscles was developed in the sagittal plane. Each motion segments were assumed to beam elements with elastic stiffness properties in [2], and the muscles were assumed to act statically. A follower load path was defined as having a direction parallel to the bisection of two adjacent segments at each node. At each node, the resultant joint force could be decomposed into two perpendicular force components, follower force in the follower load path direction and shear force.

The forces and moments used in the analysis consist of muscle forces and moments derived by muscle forces, motion segment forces and moments by the stiffness property, and applied external forces and moments. Since the number of unknowns including muscle forces and displacements exceed that of equations describing the equilibrium state of the lumbar spine model, the optimization technique was used. The cost function was the summation of squared muscle stresses and it was minimized in order to decrease the efforts of muscles. The follower load was represented by restricting the shear forces to zero at all vertebral body centers while the non-follower load was unconstrained at all about the shear force. The physiologic limits were assumed as in [2, 3].

In this paper, the deformed shapes of the model and the muscle force combination were examined under the follower load and the non-follower load respectively when 410N of vertical load and 41Nm of moment were applied at T12. The corresponding resultant joint forces (the follower forces and the shear forces) and moments at all nodes were investigated

RESULTS AND DISCUSSION

The patterns of muscle activity on the lumbar spine model generating the follower loads could be estimated under the given external load: 31 pairs of muscles were activated while no muscle acted on the lumbar spine under the non-follower load.

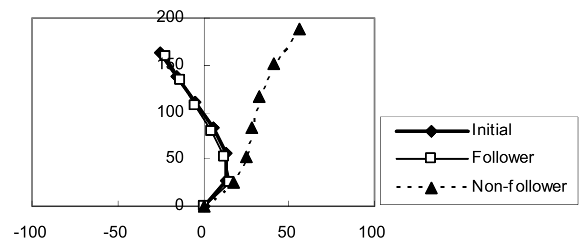

Figure 1: The initial posture of the spine model and the deformed shapes under the follower load and the non-follower load when the external load of 400N and 41Nm applied at T12

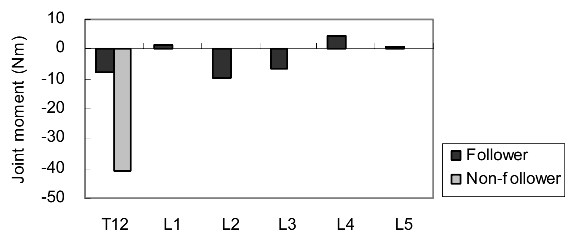

Figure 2: The joint moments at all vertebral body centers under the follower load and the non-follower load when the external load of 400N and 41Nm applied at T12

The deformed shape of the lumbar spine for the follower load was very similar to the initial posture of lumbar spine model in contrast to that for the non-follower load which assumed no muscle activation (Figure 1). The follower forces at all vertebrae under the follower load were around 1000N and there were no shear forces. In contrast, the magnitudes of shear forces were over 100N under the non-follower load though the follower forces were far below those under the follower load. The joint moments under the follower load were smaller that 10Nm while the external moment 41Nm was preserved at T12 under the non-follower load (Figure 2).

It was proved that the follower load could be successfully generated by trunk muscles from the observation that the shear forces were eliminated at all vertebral body centers in contrast with the non-follower load. Also, it was confirmed that the spinal stability under the follower load is much higher since the deformation of posture and the resultant joint moments were much smaller than those under the non-follower load. In addition, the validity of the investigated results is obtained by comparing with the previous studies [1-3].

REFERENCES

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