MODELLING THE VERTEBRAL COLUMN MECHANICS IN WEIGHT LIFTING

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INTRODUCTION

The vertebral column performs, throughout the life of the individual, a heavy mechanical load resisting role which often leads to painful complaints and damage.

The simulation of the geometry and loading response of the vertebral column has attracted the attention of many researchers over the past decades. The majority of the studies regarding the biomechanics of the spine (Anderson et al. 1985; Chaffin, 1969; Gagnon et. al., 1987) however, simulated the equilibrium of the forces and moments applied to a cross section of the spine at the lumbar level. At the opposite extreme, the existing models of the of scoliotic spine (Ghista et. al. 1988; Stokes and Laible, 1990; Wynarski and Shultz, 1991) take into account all the lumbar and thoracic vertebrae but are restricted to the analysis of the mechanical stability of the column and the muscular forces which are responsible for the onset of a scoliotic condition or for the actions conducing to its compensation and correction. In this paper we describe a finite element model of the complete vertebral column.

This work describes the application of a numerical model of the vertebral column (Rebelo et al. 1992) to the calculation of the biomechanical stresses developed in it during the performance of a 2000 N weight lifting task.

METHODS

The mechanical response of the vertebral column to loading is simulated with the help of an kinematical model which replicates the configurations the former takes up throughout the performance of any postural task The corresponding geometrical data is passed on to a finite element numerical package which computes the internal forces, moments and stresses occurring all along the entire spinal structure. The method quantifies the static equilibrium condition reached by the structure under the effects of these actions applied to its joints and is expressed by the following matrix relationship between the actions and the linear and angular displacements they originate at the joints (Weaver, 1967):

$$\mathbf{A} = [\mathbf{S}] \cdot \mathbf{D} \qquad (1)$$

RESULTS AND DISCUSSION

Figure 1 is the screen image of the kinematical model corresponding to an intermediate posture during the lifting of a 2000 Newton load. The weight lifting performer is filmed, a set of time equidistant frames are digitized with a frame grabber and the kinematical model is fitted to each of then by adjusting the corresponding values of its fifteen control parameters. The three windows on the right show the values of the axial and shear forces and of the bending moments in each of the vertebrae of the lumbar and dorsal regions. These forces and bending moments exceed the limits beyond which lesions may occur, namely, 150 Nm for the bending moments and 640 N for the shear forces, respectively. Table 1 shows the values of these results.

Tab. 1 - Axial force, shear force, bending moment and stress in the lumbar and thoracic zones for the posture illustrated in figure 1.

Inter-Vertebral Level	Axial Force N	Shear Force N	Bemding Moment Nm	Stress MPa
L5/S1	1.07E+03	5.94E+02	1.63E+02	5.2
L5/L4	1.13E+03	4.26E+02	1.44E+02	5.0
L4/L3	1.16E+03	2.91E+02	1.30E+02	4.93
L3/L2	1.18E+03	1.59E+02	1.19E+02	4.92
L2/L1	1.17E+03	1.23E+02	1.13E+02	4.85
L1/D12	1.16E+03	9.67E+01	1.08E+02	3.9
D12/D11	1.14E+03	1.47E+02	1.05E+02	3.86
D11/D10	1.12E+03	1.94E+02	1.00E+02	3.80
D10/D9	1.10E+03	2.54E+02	9.45E+01	3.44
D9/D8	1.05E+03	3.67E+02	8.78E+01	3.67
D8/D7	9.97E+02	4.75E+02	7.88E+01	3.61
D7/D6	9.23E+02	5.83E+02	6.78E+01	3.25
D6/D5	8.38E+02	6.81E+02	5.47E+01	3.20
D5/D4	7.55E+02	7.55E+02	4.06E+01	2.46
D4/D3	7.16E+02	7.76E+02	2.57E+01	2.71
D3/D2	4.76E+02	5.19E+02	1.20E+01	2.28
D2/D1	2.70E+02	2.25E+02	3.52E+00	0.91

CONCLUSIONS

The results illustrate a method for evaluating the mechanical stresses occurring during the performance of a physical task in sports and which, thus makes possible the assessment of the corresponding risk factors.

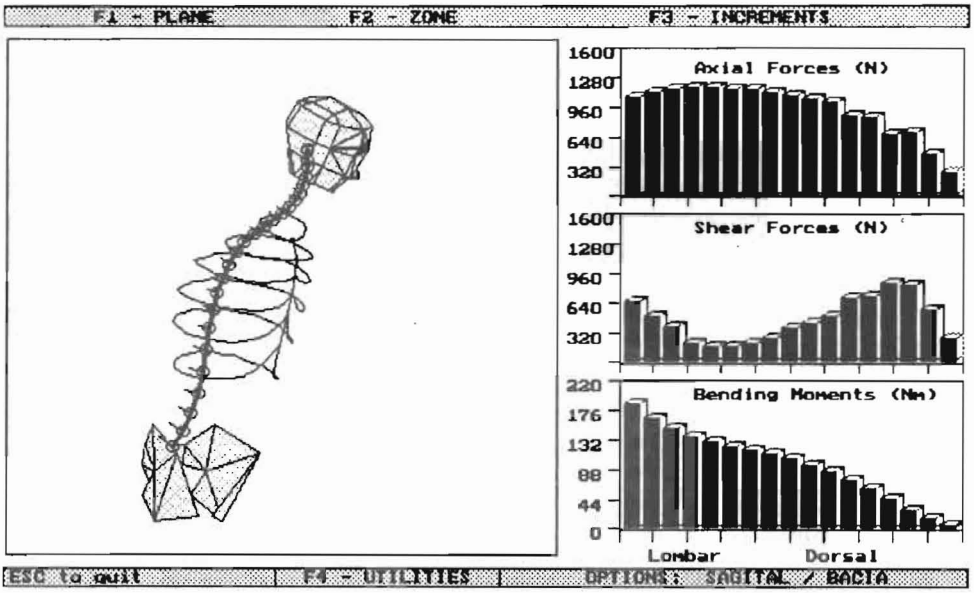

Fig. 1- Print-screen of the model fitted to one of the film frames and the corresponding mechanical parameters.

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