A NEW APPARATUS FOR TRIAXIAL MEASUREMENT OF LUMBAR MOMENTS IN ISOMETRIC MODE

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INTRODUCTION

Quantification of the functional capacity of the human lumbar muscles has been of interest during the past decades. Until now several apparatuses have been designed to fulfill this need. One of the most widely used triaxial apparatus in this field has been Isostation B200, from Isotechnologies Ltd., which was produced in 1980's. The most important problem with this apparatus is the cross-talk among its joint torques and the subsequent error in complex postures. In this paper, a new apparatus is introduced. The main features of the new apparatus are: 1-simultaneous measurement of the three lumbar moments, 2-relatively accurate measurement due to absence of cross-talk among joint torque data, 3-ability to accommodate the subject in any combination of the three anatomical trunk angles, 4-ability to operate in two different working modes, i.e. strength testing and tracking. In the strength testing mode, the maximum moments of the subject are measured, while in the tracking mode the subject is asked to exert moments to comply with the moment profile shown on the screen. The tracking mode is a novel measurement method which may be used for evaluation of the neuromuscular performance of the lumbar spine.

DESCRIPTION OF THE APPARTUS

The apparatus consists of two main assemblies. The upper assembly is a 3-DOF mechanism with three revolute joints having coincident axes of revolution, coinciding at the "reference point" of the apparatus. Three torque sensors are placed in the joints. A cushion is fixed on the third link of this mechanism to hold the thorax of the subject. The lower assembly holds and fixes lower limbs and hip during the tests. The subject is accommodated in the apparatus in such a way that his/her lumbosacral joint (L5/S1) coincides with the reference point. Tests can be done in both standing and sitting postures. There are several moving parts in the apparatus to facilitate accommodation of a wide range of body sizes. The coordinate system and the related lumbar moments are defined in accordance with the ISB recommendations [2].

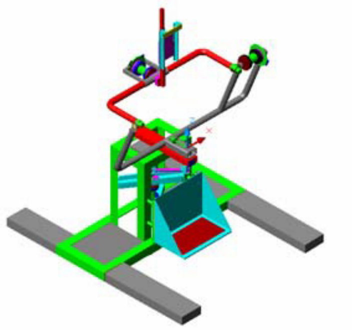

Figure 1: Model of the new triaxial apparatus

To design the new apparatus, ten possible arrangements of the tri-axial mechanism were explored, and the optimum mechanism was chosen by comparing the candidate arrangements against nine criteria including size, weight, stability, natural frequency, etc [1]. For this purpose, finite element models were used to estimate natural frequencies of these arrangements, as well as their deflections under loads. The jacobian matrix for such three-joint mechanisms is normally a 6*3 matrix, but since the three joint axes coincide in the designed mechanism, the jacobian reduces to a 3*3 matrix and the robotic equation of the mechanism simplifies to:

$$\begin{pmatrix} M_x \\ M_y \\ M_z \end{pmatrix} = \begin{bmatrix} \frac{\cos\theta_3}{\sin\theta_2} & \sin\theta_3 & \frac{\cos\theta_2\cos\theta_3}{\sin\theta_2} \\ 0 & 0 & 1 \\ \frac{\sin\theta_3}{\sin\theta_2} & -\cos\theta_3 & \frac{\sin\theta_3\cos\theta_2}{\sin\theta_2} \end{bmatrix} \begin{pmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \end{pmatrix} \quad (1)$$

in which $(\theta_1,\theta_2,\theta_3)^T$ is the joint angle vector, $(\tau_1,\tau_2,\tau_3)^T$ is the joint torque vector, and $(M_x,M_y,M_z)^T$ is the vector of the lumbar moments at the L5/S1 level.

CALIBRATION AND ERROR ANALYSIS

Due to the inevitable imperfections found in the materials, manufacturing processes, sensors, and electronic equipment, and also the elastic deformations occurring during exertions, the tests will not be without errors. In fact the errors resulting from geometrical imperfections and elastic deformations modify the jacobian matrix. In the same way, the errors arising from imperfect sensor data and electronic equipment modify the joint torque vector.

Although the deflection analyses done with finite element codes show that the errors due to load deflections are negligible, experimental data are needed to assess the total errors of the apparatus. Two approaches are available for identification of these errors: 1-Using the detailed geometrical and kinematic model, 2-Black box approach. Taking into account the complexities in the first approach, the black box approach is chosen. In this approach, a large number of specific loads are applied in different directions and magnitudes and the output data are measured. Then without analyzing the sources of these errors in a reductionistic way, the actual 6*3 Jacobian matrix of the system is obtained from these data. By knowing the actual Jacobian matrix and comparing it to the idealized 3*3 matrix of Eq. 1, maximum measurement errors can be calculated.

CONCLUSION

Presently the calibration and error analysis is on the way. The construction of this device alleviates the difficulty (errors due to cross-talk) encountered by the previous devices such as B200 during testing at complex postures.

REFERENCES

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