INFLUENCE OF VELOCITY ON COUPLING MECHANISMS IN THE NORMAL SPINE

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Three-dimensional (3-D) quantification of spine kinematics provides a basic understanding of spine mechanics during different activities, injury or for surgical correction of scoliosis. 3-D coupling mechanism in dynamic movements of the spine is not well documented. Direct access to spine kinematics, in vivo, is not possible by any non-radiating technique. This paper presents a novel optical technique to explain the influence of velocity on intervertebral Range of Motion (ROM) and its relation on the coupling pattern during right lateral bending. A four 60-200 HZ video camera Motion Analysis Expert Vision System was used to obtain the 3-D coordinates of triad markers over skin landmarks, by means of Direct Linear Transformation (DLT) techniques after camera calibration. The markers were put over the spinous process of T1, T3, T6, T8, T10, T11, T12, L1, L3, L5, and S1 to approximate each vertebrae. Then Euler angles were used to estimate the three-axial rotations of any two vertebra in the following sequences: bending, rotation and flexion or extension. The preliminary results are given for five healthy subjects. The primary movement of lateral bending was followed by coupling rotation and flexion in both fast and slow movements. Though, the ROM and coupling pattern varied with speed it was not significant.

INTRODUCTION

Coupling phenomena in the spine, has already been documented in the literature (Devork et al. 1991, Percy et al. 1984). It is shown that dynamic ROM and its related coupling pattern in the spine during trunk motion have clinical importance. The limited range of motion and abnormal coupling pattern were observed among patients with low-back pain and scoliosis (Farahpour et al. 1995, Percy et al. 1984). Although the presence of coupling phenomena has generally been accepted in spine motion, the exact quantitative knowledge about this coupling is not available yet. The techniques based on x-ray are limited to static measurements. Therefore, 3-D measurements of the spine can not be obtained in motion. Few optical techniques have been developed and applied to estimate the spine motion indirectly through external markers (Farahpour et al. 1995, Gracovetsky et al. 1989). There is some evidence to show that the spinous process landmark position in space are correlated with that of the vertebrae (Gracovetsky et al. 1989, Sicard et al. 1993). In this paper, a novel technique is presented to explain the influence of velocity on three-dimensional behaviour of the normal spine during lateral bending.

METHODS

Five young healthy female subjects (16 yr±2.6 yr) participated in this experiment. They did not have nay history of musculo-skeletal or other injury which could influence their normal motor pattern. An Expert Vision Motion Analysis System with four camera 60-200HZ was used to record and reconstruct the 3-D coordinates of external markers put over the trunk skin. The triad markers were a V shape thin and rigid rod which was fixed vertically on a plastic frame (lcm x 1.5cm). Then one spherical reflective marker (3mm in diameter) was put on the base and two others (2mm in diameter) at the extremity of each rod. Every triad marker was glued by a double sided tape over the spinous process of T1, T3, T6, T8, T10, T11, T12, L1, L3, L5. To identify the sacrum and to control pelvic motion, three spherical markers (2cm in diameter) were put on S1 spinous process and right and left sacro-iliac spines.

A cubic calibration device (0.9m x 0.9m x 0.9m) located at trunk level was made up of 12 spherical reflective markers, three at each vertical edge. After calibration the subjects were placed inside the calibration space and the objection calibration device was removed. The camera position were fixed during all procedures and located at 1.5m distance from the centre of the calibration device. Data was collected during fast and slow lateral bending and reconstructed by means of DLT. The Euler angles were applied to calculate the relative rotation of any two vertebra. These measurements provided us with dynamic movement patterns. The student t-test was used to examine the differences between two types of movement. The indices of primary bending over coupling rotation and thoracic coupled rotation over lumbar coupled rotation were used for better explanation of the coupling mechanism.

RESULTS AND DISCUSSION

For all different segments of the spine, a coupling pattern having different coupling was observed. The primary movement of right bending was accompanied by rotation and flexion / extension. Slow and fast movement patterns of both lumbar and thoracic regions were estimated and shown in fig.(1) and (2). In both type of movements a similar pattern was observed. Table (1) presents the peak values. In both conditions, the lumbar spine showed significantly a larger range of motion. In slow motion (29° and 13.5") and in fast motion (28" and 15.6") indicating a larger mobility of lumbar (almost twice as mobile as the thoracic spine). The coupled rotation in the lumbar spine is shown to be almost 1.2 times more than that of the thoracic; but it should be reminded that the presented values for T1-L1 are due to 12 vertebra; while in lumbar region there are only five vertebra. It means that each single motion segment in the lumbar spine has much higher mobility than that of the thoracic spine. This larger ROM and coupling, combined with larger inertia components during loading of spine in sports and working condition provides a higher possibility of injury for lumbar disks than that of the thoracic spine. Though in fast movements, the ROM and related pattern were different, but it was not significant. This could be because of the small number of subjects. The effect of velocity was related to the different parts of the spine. It seems that geometry, orientation of the facets and the anatomy of spine play different roles and therefore intervertebral analysis is suggested to examine the influences of velocity. The ratio of bending/rotation showed that in both conditions the spine had similar behaviour. In conclusion, the coupling phenomena is always present in spine function. Each single motion segment in the lumbar spine has a considerably higher mobility in 3-D than thoracic spine. The 3-D ROM of different segments of spine was varied with speed, but it was not significant. A similar movement pattern was observed in both conditions. The velocity did not cause an abnormal coupling pattern, therefore other parameters should be examined as risk factors in sport activity and work conditions.

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