# Spinal Shape Changes Related to Posture for the Hong Kong and Indian Populations

**Ravindra S. Goonetilleke, Banna G. Rao, and Richard H. Y. So**
Department of Industrial Engineering and Engineering Management
Hong Kong University of Science & Technology
Clear Water Bay, Kowloon, Hong Kong

**ABSTRACT**

Researchers have recommended a trunk to thigh angle of at least 105 degrees to preserve the lumbar curve. However, with the rapid computerization of offices, even with a 105 degree trunk-thigh angle, most people suffer from upper-back and mid-back pain in addition to low back pain with prolonged sitting. The purpose of this study was to evaluate the spinal shape changes during sitting. A total of 20 subjects (10 Hong Kong Chinese and 10 Indians) were used. Fifteen points were marked on the spine and then digitized using a Science Accessories Corp., GP-12-3D, sonic digitizer. Seven postures corresponding to a trunk-thigh angle of 70, 80, 90, 100, 110, 120, and 180 (standing) degrees were investigated. The variations in spinal shape between subjects are seen to be similar within a population. High kyphotic curvatures are observed at angles of 70 and 80 degrees in all regions of spine. When the trunk to thigh angle is 100, 110 and 120 degrees, the cervical and thoracic regions approach the cervical and thoracic curvatures in the upright standing posture, but this is not the case with the lumbar curvature. The spinal deformation during sitting appears to be different between the Hong Kong and Indian subjects. One possible reason could be the differences in arch angle between the two populations.

**Keywords:** spinal curvature, lumbar-curvature, sitting

## 1. INTRODUCTION

With the rapid computerization of offices and industries, people spend a large portion of their time seated. Even with a recommended (Mandal, 1987) trunk to thigh angle of 105 degrees, these workers still suffer from low back pain with prolonged sitting. In order to better understand spinal deformations and their effect on pain and discomfort, mathematical models have been proposed too. Two such models are the cantilever model and the arch model (Aspden, 1988). The arch model takes full account of the curved nature of the spine and allows the posture and loading to be considered together to determine the stability of the spine. Rather than producing a unique solution, this model provides bounds within which the state of the spine must lie, and gives an indication of the optimum solution in terms of minimizing the stresses generated by the spine. The spinal stresses of this model are not as large as those calculated from the cantilever model.

On the experimental side, radiographic studies have confirmed lumbar flattening when sitting due to the backward pelvic rotation (Keegan 1953, Anderson, 1987). The uneven loading on the discs creates high localized stresses which are not too desirable. Hence a better understanding of the spinal deformation is important to minimize pain and discomfort related to the back. However, the quantification of these spinal deformations has been difficult due to the large variations between subjects and also due to the inherent structural variations. At the same time, it is important to identify the similarities and differences in the spinal shape between different populations too. The study reported here is an attempt to identify the spinal changes between the Indian and Hong Kong Chinese populations while obtaining shape variations during sitting.

## 2. METHODOLOGY

### 2.1 Subjects

Ten Hong Kong Chinese and ten Indian subjects were used in this experiment. Their ages ranged from 18 to 30. None of the subjects had any back pain or spinal abnormalities.

### 2.2 Equipment

A seat pan with height and tilt adjustment was designed specifically for this experiment. The tilt adjustment was calibrated to indicate the test angles. The seat was firmly fixed to the floor to minimize any movement.
Spinal shape was measured using a GP12, 3D-sonic digitizing system (Science Accessories Corporation). The digitizer tolerance was 0.05cm. Hip angle was measured using a mechanical-goniometer.

### 2.3 Procedure

Fifteen points were marked on each subject's spine prior to digitization. The marked points were bony prominences (vertebra) on the surface of the skin. Five points were selected from each region (i.e., cervical, thoracic and lumbar). The 3-D sonic digitizer was set to the user co-ordinate system (UCS) prior to digitizing. For the standing posture, the UCS was defined on the floor plane. The subject stood still, and each of the 15 points were digitized using a hand held probe. The testing procedure during sitting was as follows:

1. The UCS was defined by three points on the seat pan before the subject sat on the chair.
2. The chair height was adjusted to each subject's popliteal height.
3. The seat pan was tilted to obtain the predetermined trunk to thigh angle. The seat pan angles tested were $0^0$ (horizontal), $10^0$, $20^0$, and $30^0$ forward, as well as $10^0$ and $20^0$ backward (The respective trunk-thigh angles were $90^0$, $100^0$, $110^0$, $120^0$, $80^0$, and $70^0$).
4. The subjects sat erect at each pan angle and the experimenter digitized the 15 points.

The above procedure was repeated for all 20 subjects.

## 3. RESULTS

The data collected for each subject was 3-dimensional. However, data analyses were limited to only 2-dimensions in the sagittal plane. Figure 2 shows the variations in spinal shape for the different sitting angles for each subject. At angles of 70 and 80 degrees, the spine is more kyphotic. When the trunk angle is 100, 110, and 120 degrees, the cervical and thoracic regions approach the standing shape in almost all subjects. However, this effect was not seen for the lumbar region.

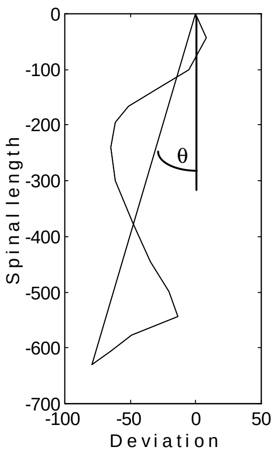


Figure 1. Arch angle

A correlation analysis was performed to evaluate the relationship between a subject's height and the spinal length (projection on the vertical plane). The correlation coefficients were comparatively low.

- Pearson correlation coefficient for all 20 subjects is 0.55 ($p < 0.05$)
- Pearson correlation coefficient for the Indian population is 0.56 ($p = 0.09$)
- Pearson correlation coefficient for the Hong Kong population is 0.52 ($p = 0.12$)

The inter-correlation between spinal lengths measured at different postures is statistically significant ($p < 0.05$) and the Pearson correlation coefficients are generally in the range of 0.58 to 0.91 for all twenty subjects. The lowest value is the correlation coefficient between the 20 degree backward tilted seat pan posture and the standing posture. This pattern is also true for the Hong Kong population. However, for the Indian population, the lowest correlation (Pearson coefficient = 0.49) occurs between the 90 degree trunk angle posture and the 20 degree backward tilted posture.

To study the differences in the shapes of the two populations, an angular measure was used. This angle was defined as the deviation of the line drawn from the first digitized point to the last digitized point, from the vertical (Figure 1). In other words it is a measure of the total *arch angle* of the whole spine from the vertical plane. An analysis of variance on the arch angle showed a significant ($p < 0.05$) difference between the Hong Kong population and Indian population, $F(1, 18) = 6.04$. The Hong Kong population had a higher angle (mean = 6.5 degrees) compared to the Indian population (mean =4.2 degrees). This angle may be considered as a goodness index of standing posture. Further study is needed to comment on its value.

## 4. DISCUSSION

Variations in spinal length and shape have been studied. The inter-correlation analysis among the spinal lengths for the different posture seems to indicate two different patterns for the two populations. This seems to suggest a different deformation model for the two populations. Spinal shape variations within a population are of course predominantly due to anatomical differences in the spinal structure. However, the significant difference in the arch angle between the two populations could be one of the causes for the different deformation patterns between the two populations.

It was observed that the lumbar spine is more kyphotic at a $70^0$ pelvic angle. At $70^0$, the pelvis tilts backwards, hence the lumbar spine becomes more kyphotic and at the same time the kyphosis of the thoracic spine is also increased. Another observation is that the cervical and thoracic curvature in sitting posture approached the standing curvatures as the trunk angle increased from $70^0$ to $120^0$ . However in the case of the lumbar region, the kyphosis is only reduced and far from lordotic.

One limitation of the study is the digitizing probe which may have caused slight skin movement during digitization.

## 5. CONCLUSIONS

Spinal shape variations at different trunk angles have been measured non-invasively using a sonic digitizer. Even though some researchers have claimed that a 105 degree trunk-thigh angle preserves the standing lumbar curvature, such a variation was not seen in this study. Although thoracic and cervical curvatures resembled the curvatures during standing with a 105 degree trunk-thigh angle, lumbar curvatures were far from close to those of standing.

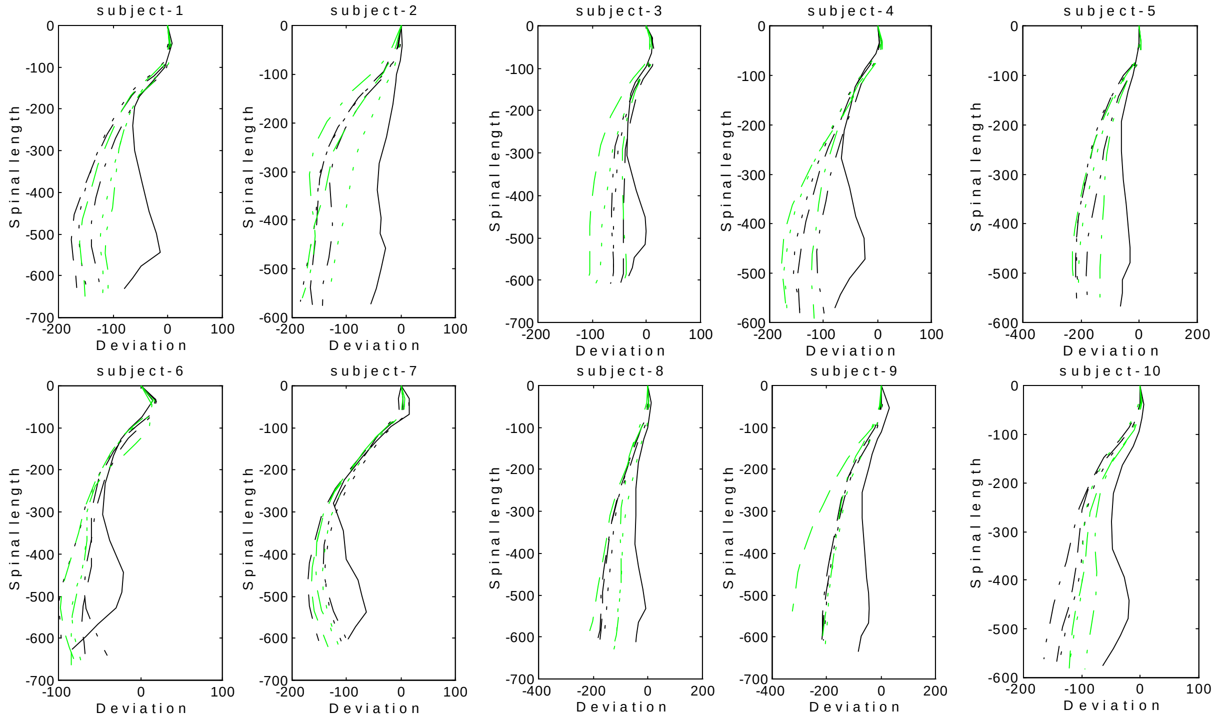
## 6. REFERENCES


Andersson, B.J.G. (1987). Biomechanical aspects of sitting: An application to VDT terminals. Behavior and Information Technology, Vol.6, No. 3, 257-269

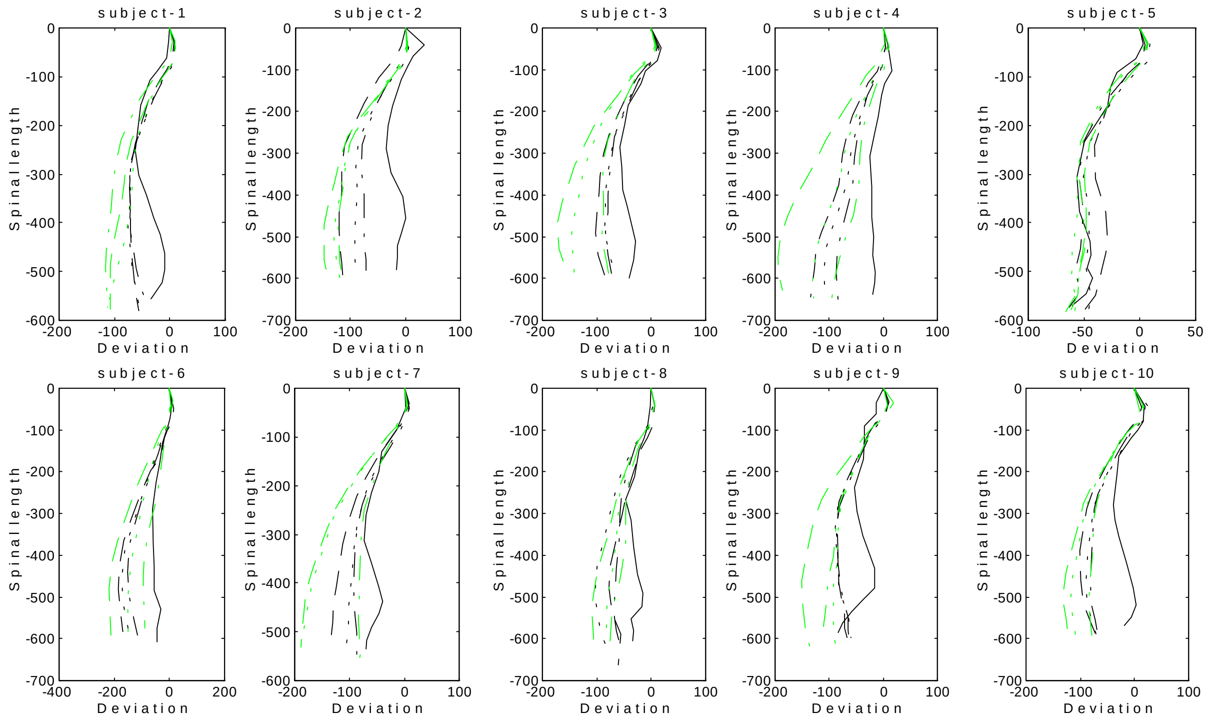
Aspden, R. M. (1988). A new mathematical model of the spine and its relationship to spinal loading in the workplace. Applied Ergonomics, 19.4, 319-323

Keegan, J. J. (1953). Alterations of the lumber curve related to posture and seating, Journal of Bone and Joint Surgery, Vol. 35-A, No. 3, 588-603, July, 1953

Mandal, A. C. (1987). The influence of furniture height on back pain. Behavior and Information Technology, Vol. 6, No. 3, 347-352.




**Hong Kong Population**




**Indian Population**

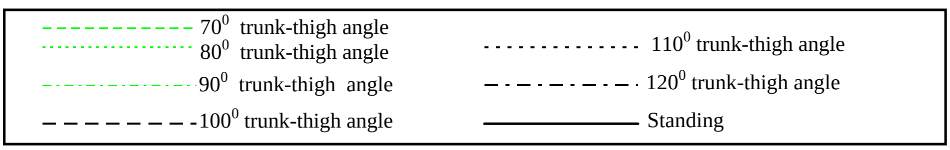



**Figure 2. Spinal Shape for Sitting and Standing Postures**

All dimensions in mm. The deviation is measured from the vertical plane.