

# The Relationships between Lumbar Curves, Pelvic Tilt and Joint Mobilities in Different sitting postures in Young Adult Males

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**Abstract.** The lumbar lordosis and pelvic tilt of twenty male subjects were measured in standing and in three different sitting postures with the trunk-thigh angles of 120 (sitting A), 90 (sitting B), and 60 (sitting C) degs and the knee angle was constant at 90 deg. Ten more male subjects participated in the supplemental study, in which additional condition of the knee angle was employed in postures of the trunk-thigh angles of 90 and 60 degs. Some joint mobilities were also measured to investigate the relations of the mobilities to lumbar lordosis and pelvic tilt. The lumbar curve decreased and the pelvis rotated rearward significantly as the trunk-thigh angle and the knee flexion decreased. The great alteration of the lumbar curve was observed between standing and sitting A, which was much different from the results of Keegan (1953) studied in the subjects of lateral recumbent position. There was a high correlation coefficient between the lumbar curve and the pelvic tilt ( $r=0.909$ ), so that the relations of the pelvic tilt to the joint mobilities were investigated. When the knee angle was constant, the pelvic tilt is related significantly to the hamstrings between standing and sitting A and to the gluteus maximus between sitting A and sitting C. However, at different sitting postures with the trunk-thigh angles of 90 and 60 degs involving different knee flexions, hamstrings added to gluteal muscles affected significantly lumbar curve and pelvic tilting. It was concluded that the different sitting postures produced flexion of the spine through pelvic inclination caused by different hip extensors to an extent dependent upon the trunk-thigh angle combined with the knee angle.

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**Keywords:** lumbar lordosis, pelvic tilt, trunk-thigh angle, joint mobilities, hip extensors

## Introduction

It has been well known that lumbar lordosis, observed in standing, diminishes as the angle between the trunk and the thighs decreases, or as the hips are flexed. Keegan (1953) has suggested by tracings from roentgenograms that the pelvic inclination is influenced by the

change in relative tension of the anterior and posterior thigh muscles caused by the change in trunk-thigh angle, through which the lumbar curvature is altered. Therefore, many researchers, who study the design of workplaces for sedentary workers, have drawn attention to Keegan's model which demonstrated the relationships between the lumbar curves, the pelvic inclination and the trunk-thigh angles (Mandal, 1981; Bendix and Bloch, 1986; Bridger et al., 1988). However, since Keegan's model was obtained by the subjects in the lateral recumbent position, it seems that the relation may not always be applied to the subject sitting on the chair. Further, it is questioned whether the contribution of thigh muscles to pelvic inclination is same between sitting and recumbent positions.

The purposes of this study are to investigate how lumbar curvature and pelvic rotation change with changes in the trunk-thigh angles from standing to sitting on a chair and to reexamine the relationship between the pelvic tilt and some joint mobilities, or some muscle lengths.

## Methods

### *Subjects:*

Thirty male students participated in this study; twenty males in the main study and another ten males in the supplemental study. All subjects were healthy and had not suffered from any musculo-skeletal disorder of the spine or lower limbs, any neuromuscular disorder, or any general systemic disease. The means and standard deviations of body height and weight were  $172.4 \pm 6.2$  cm and  $61.8 \pm 5.8$  kg in the main study and  $171.6 \pm 6.7$  cm and  $61.4 \pm 9.2$  kg in the supplemental study, respectively.

### *Body positions for measurements:*

In the main experiment (series M), measurements were taken at standing and at three sitting postures with the trunk-thigh angles of 120, 90, and 60 degs (called sitting A, B, and C, respectively) and the knee flexed at 90 deg for all sitting conditions (Fig.1). At standing position, the head was erect and the eyes focussed directly ahead with feet together and hands by the sides. The trunk-thigh angles were determined by two lines;

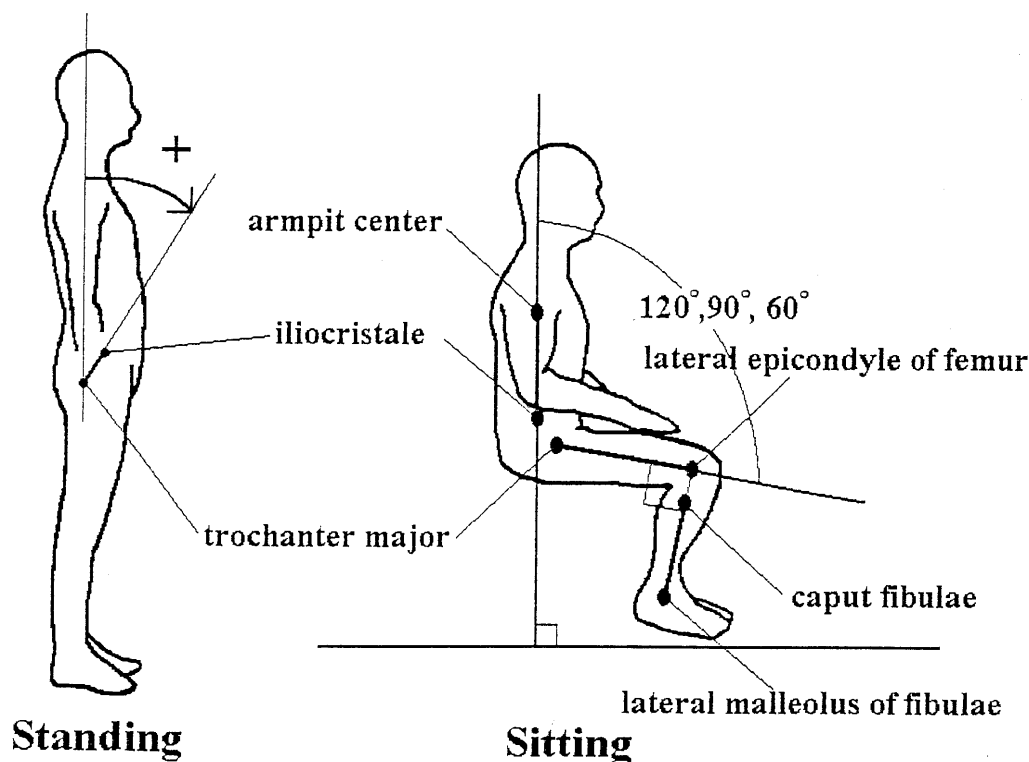


Fig.1 The condition of postures in the main study (series M).

one was taped between points of armpit center and ilio-cristale and another was taped between points of trochanter major and lateral epicondyle of femur. Subjects were instructed to keep their trunk upright and to have body weight fallen on the ischial tuberosities on the seat. The chairs used were stools for the sitting B and C and a forward-sloping stool for the sitting A.

In the supplemental experiment (series S), the conditions of the knee flexion were added to the postures of sitting B and C in series M. The knee flexion was identified as the angle between the lower leg line and the extension of the thigh line. Five sitting postures were selected for the measurements; the trunk-thigh angle of 90 deg with the knee flexed at 60, 90 and 120 degs and the trunk-thigh angle of 60 deg with the knee flexed at 90 and 120 degs.

#### *Measurement for lumbar lordosis:*

An inclinometer was employed for measuring lumbar curve. Initially, the subject lay down on the bed and points were marked at the interspaces of L5-S1 and T12-L1. The measurement of spinal inclinations were taken in all postural conditions. The inclinometer was placed along the slope of the vertebrae at each of the levels of the two marked interspaces for the measurement of the sagittal curve of the spine. Lumbar lordosis was determined from the two angles, a and b (Fig. 2), read on the inclinometer according to Toppenberg and Bullock(1986).

#### *Measurement for pelvic inclination:*

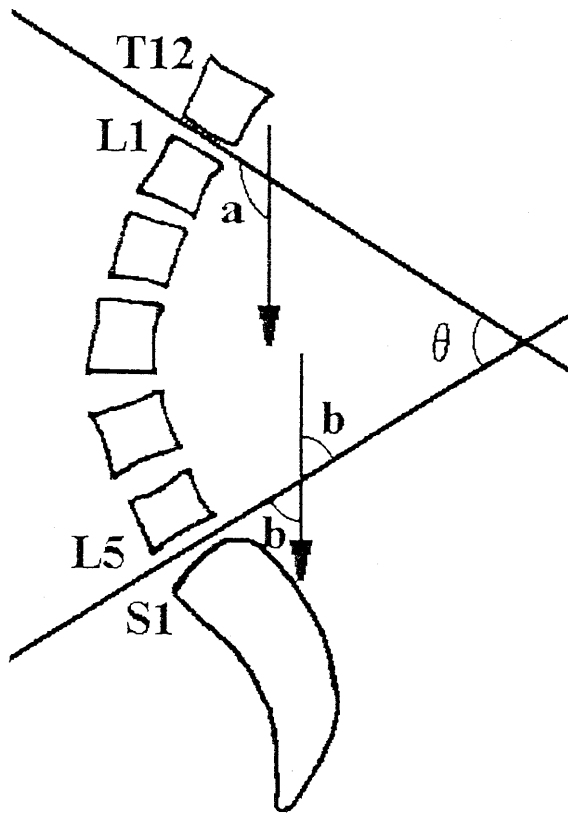
At each condition of posture in serieses M and S, skin markers were placed over tronchanter major and ilio-cristale and lateral photograph was taken. The line between these points and vertical line through trochanter major were drawn on the picture. Pelvic tilt was measured as the angle of the two lines(Fig. 1).

#### *Measurements for functional muscle lengths:*

The degree of mobility of body or body segment was limited by muscle length, so that the angle of movement gives an index of muscle length. A number of the muscle length indices were found to correlate with spinal curve and pelvic inclination. Six muscle lengths were investigated in series M of twenty subjects. Three of the six muscle lengths, i.e. lumbar erector spinae, iliopsoas and rectus femoris, were related to lumbar extension or anterior pelvic tilting, which were called lumbar extensors. Conversely, the other three, i.e. rectus abdominus, gluteus maximus and hamstrings, were related to lumbar flexion or posterior pelvic tilting, which were called lumbar flexors. These muscle lengths, that is, angles of the movement were measured according to a method of Toppenberg and Bullock (1986).

#### *Lumbar erector spinae length:*

Since these muscles limit the extent of lumbar flexion on forward bending, the degree of lumbar curvature in maximally forward bending was used as an index of



### Calculation of lumbar lordosis( $\theta$ ):

$$\theta = 180 - (180 - a) - b = a - b$$

Fig.2 Measurement of the angle of lumbar loadosis.

lumbar erector spine length. In this posture, the inclinometer was placed on the interspaces of L5-S1 and T12-L1 and these two angles of inclination measured gave the lumbar kyphosis angle (Fig. 3a), that is, the index of lumbar erector spine length.

#### *Rectus abdominus length:*

Rectus abdominus is lengthened maximally when the spine is fully extended. The maximum lumbar lordosis measured in this posture was taken as an index of rectus abdominus length. In order to obtain the index, the subject pushed up on his hands as shown in Fig. 3b and extended his back until a stretching sensation in the abdominal muscles was perceived. The inclinometer was placed at the L5-S1 and T8-T9 levels and maximum lumbar lordosis was calculated by the geometrical approach.

#### *Gluteus maximus length:*

The gluteus maximus is the most powerful extensor, so that the range of hip flexion from the horizontal without the pelvis rotation was considered an index of the length of this muscle.

At first, greater trochanter and lateral epicondyle of the femur and the head and lateral malleolus of the fibulae were marked with the subject supine.

The lines were made by tapes between each pair of points on the femur and fibulae. The subject lay down with the legs over the edge of the plinth and the tested leg was flexed at hip and knee so as not to lift the buttock from the plinth (Fig. 3c). In this position, the angle of the line of femur from the horizontal provided

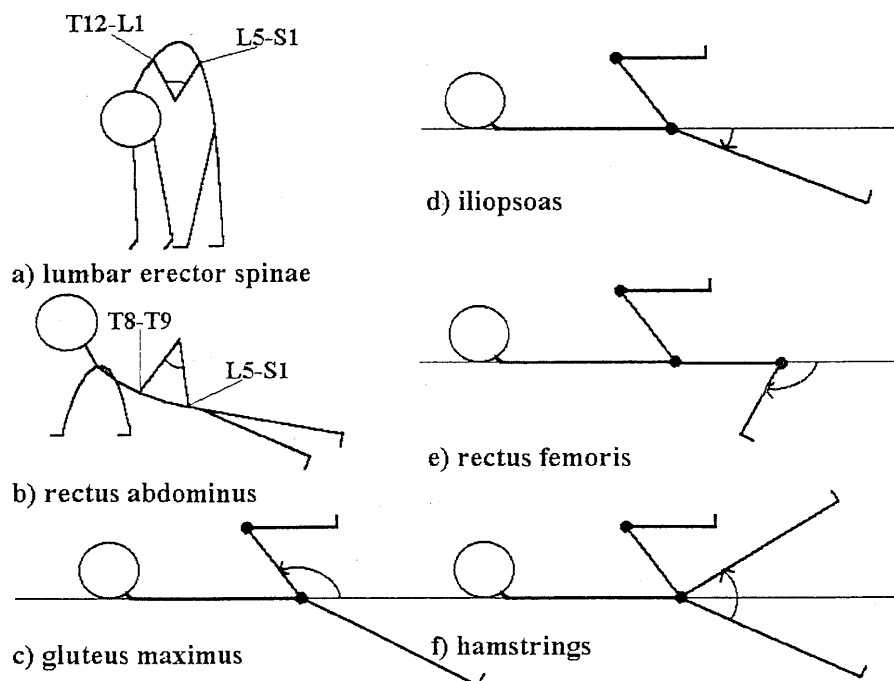


Fig.3 Measurements of functional muscle lengths of lumbar extensors and flexors.

the index of gluteus maximus length.

#### *Iliopsoas length:*

The mobility of the thigh extension from the horizontal gave the estimation of iliopsoas length. Followed by the measure of gluteal length, the hip was passively extended from the horizontal until resistance was encountered, while the opposite hip was flexed and pelvis stabilized (Fig. 3d). In this position, the angle of the extended thigh with the horizontal gave the index of iliopsoas length.

#### *Rectus femoris length:*

Taking into consideration that rectus femoris is a two-joint muscle, the muscle length was expressed as the maximum degree of knee flexion possible when the thigh was stabilized in the horizontal position (Fig. 3e).

The subject lay and the measured thigh was stabilized manually in a horizontal position while the opposite hip and knee were flexed as described for the iliopsoas length test. The knee of the measured side was then flexed until a stretch in the muscle belly was perceived.

The magnitude of knee flexion from the horizontal was measured by a inclinometer positioned on the distal end of the fibula, which was the index of rectus femoris length.

#### *Hamstring length:*

Hamstring length was estimated from the measure of hip flexion with the knee extended and the pelvis stabilized (Fig. 3f). A inclinometer placed on the fibulae proximal to the lateral malleolus and the first reading was taken in the starting position. Then, the leg was raised passively to the point where the knee began to flex or the examiner palpating the ipsilateral anterior superior iliac spine perceived backward movement of the pelvis. At this position, the second reading was taken and the difference between the two readings gave the index of hamstring length.

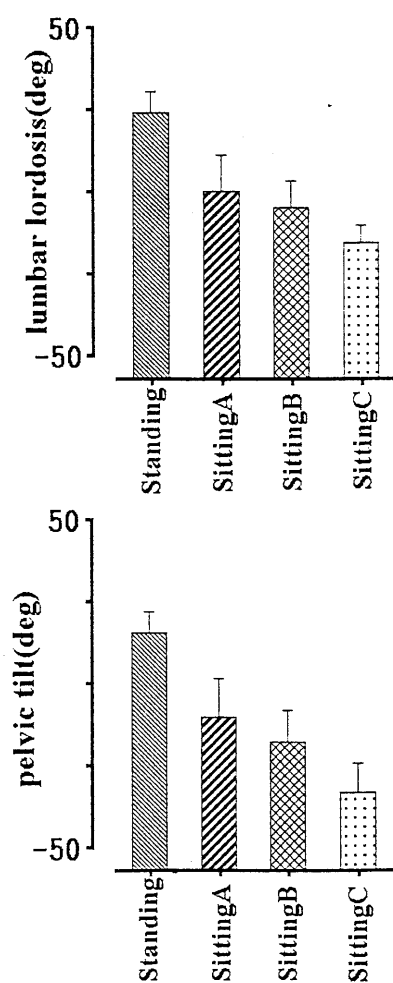


Fig.4 Means and standard deviations of lumbar curves and pelvic tilt in the main study (series M).

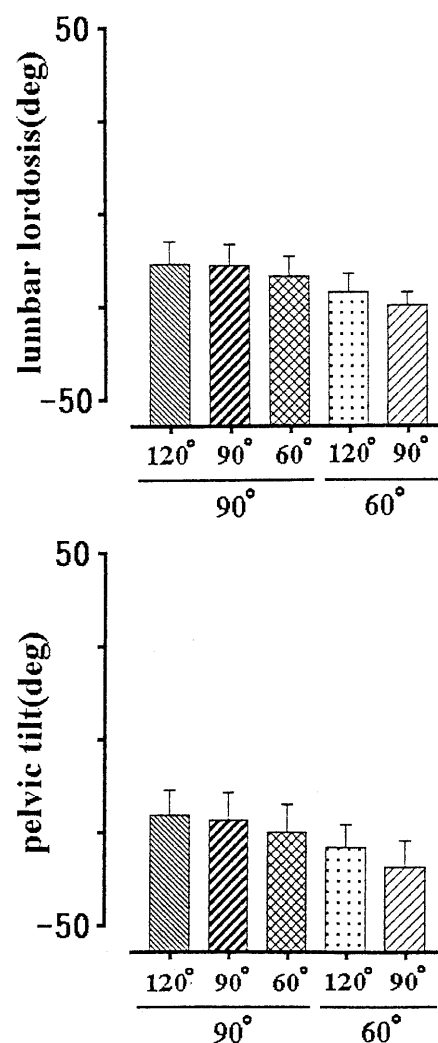


Fig.5 Means and standard deviations of lumbar curves and pelvic tilt in the supplemental study (series S).

Note: The upper and lower values on the abscissa showed the knee angles and the trunk-thigh angles, respectively.

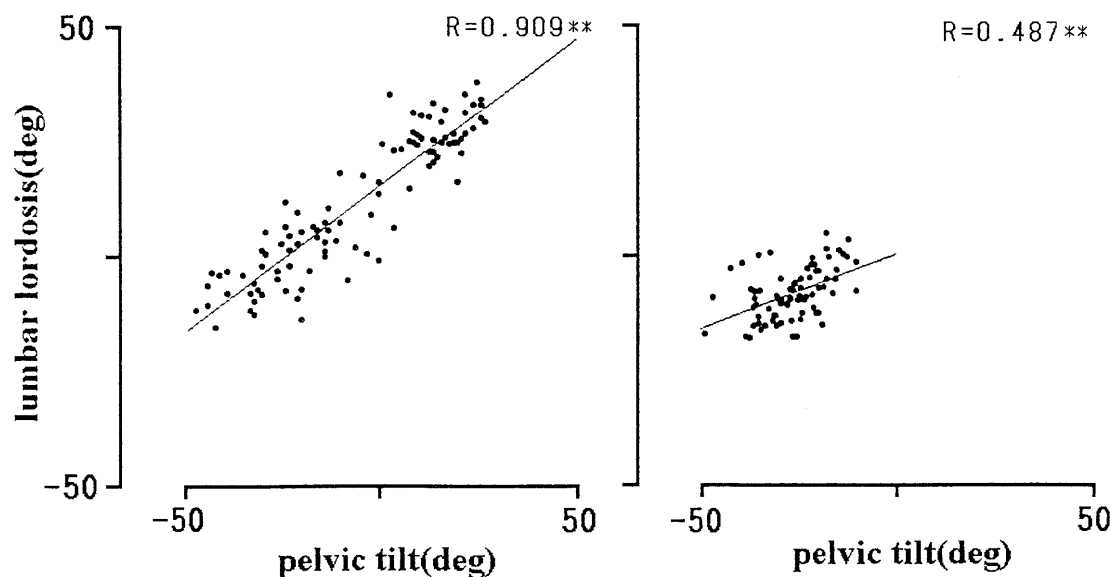


Fig.6 Relationships between lumbar curve and pelvic tilt in series M (left) and series S (right).

## Results

Figs. 4 and 5 present the mean lumbar and pelvic angles for serieses M and S, respectively. The analyses of ANOVA showed that lumbar lordosis decreased and pelvis rotated rearward significantly as the trunk-thigh angles decreased in serieses M and S and as the knee flexion decreased in series S. The changes in lumbar curves and pelvic inclination showed the same pattern across the different postures and the significant correlation coefficients between them were observed in series M ( $r=0.909$ ) and in series S ( $r=0.487$ ), as shown in Fig. 6. Lumbar curves decreased by 60 % of the average difference between standing and sitting C when posture was transferred from standing to sitting A. On the other hand, the change was 13% from sitting A to B and 27% from sitting B to C. The greatest change in lumbar lordosis angle was occurred before the trunk-thigh angle reached 120 deg.

Since an intimate relationship between lumbar lordosis and pelvic tilting was found, the relation of pelvic tilt to functional muscle lengths of lumbar extensors and flexors was investigated. Table 1 shows the correlation coefficients between them obtained in each posture of series M. In standing posture, only rectus femoris showed a significant correlation coefficient ( $r=-0.468$ ), which act pelvis to tilt anteriorly. However, there was no significant relationship between them in three different sitting postures.

Several significant correlation coefficients were found between muscle lengths and the degrees of pelvic tilt with change in posture (table 2). A negative correlation coefficient was demonstrated only in hamstring length when posture was changed from standing to sitting A

and only in gluteus maximus length when posture was changed from sitting A to B or C.

## Discussion

The lumbar lordosis is normally observed in standing position and the lumbar curve is flattened by sitting or stooping. The anatomical underpinnings of this research are derived from the work of Keegan (1953). He has demonstrated that postural change represented by the change in the trunk-thigh angles involves the pelvic rotation which is caused by passive stretching of the hip flexors or extensors. Keegan held that the neutral position of the lumbar spine occurred when the trunk-thigh angle is about 135 deg at which the anterior and posterior thigh muscle tensions are balanced. In the state of postural adaptation to sitting, the passive tensions of their limited length of the posterior thigh muscles become superior to those of the anterior thigh muscles, which tilt pelvis rearward. Thus, further hip flexion from the neutral position would cause hip extensors, which arise from the ischial tuberosities, to tilt the pelvis so that the upper portion moves rearward and then this flattens the lumbar lordosis. However, in the study of Keegan, the relationships between lumbar curves, pelvic inclination and the trunk-thigh angles were not obtained from the subject in an upright position but in the lateral recumbent position. Therefore, whether these relationships are different have to be examined between findings of this study and those of Keegan's.

On the correlation between lumbar curve and pelvic tilt, no statistically significant relation was observed in standing and in sitting C when each postural condition was investigated. Since Voutsinas and MacEwen (1986)

**Table 1** Correlation coefficients between muscle lengths and pelvic tilt in standing and three sitting postures.

muscle lengths	pelvic tilt in each posture			
	Standing	SittingA	SittingB	SittingC
lumbar erector spinae	$r=0.031$	0.301	0.078	$8.75 \times 10^{-3}$
rectus abdominus	-0.081	-0.039	0.108	-0.032
gluteus maximus	0.117	-0.351	0.143	-0.045
iliopsoas	-0.443	-0.172	-0.128	-0.270
rectus femoris	-0.468*	-0.059	-0.300	-0.254
hamstrings	-0.216	0.312	0.197	0.226

\* $P < 0.05$ **Table 2** Correlation coefficients between muscle lengths and change in pelvic tilt from standing to sitting A and from sitting A to other sitting postures.

muscle lengths	change in pelvic tilt in postural changes		
	Standing to SittingA	StandingA to SittingB	StandingA to SittingC
lumbar erector spinae	$r = -0.302$	0.254	0.441
rectus abdominus	$-6.72 \times 10^{-3}$	-0.137	-0.022
gluteus maximus	0.468*	-0.502*	-0.475*
iliopsoas	-0.082	-0.071	0.046
rectus femoris	-0.225	0.202	0.197
hamstrings	-0.486*	0.161	0.214

\* $p < 0.05$ 

who studied 670 normal subjects indicated significant correlations between sacral inclination and lumbar lordosis in standing for both males and females, no significant relations observed in this study might be caused by the relative small number and the small range of measurements in a given posture. However, high correlation coefficient between them was obtained when data of all postural conditions are pooled in series M ( $r=0.909$ ) and in series S ( $r=0.487$ ) in this study. This supported the Keegan's model, in spite of the different postural condition of upright or recumbent, which is based on a close relation between lumbar curve and pelvic tilt observed in various hip flexions.

When the relation between lumbar curve and the trunk-thigh angles was examined, the greatest change in lumbar curve was found between standing and 120 deg of the trunk-thigh angle (sitting A) and the magnitude was about 60% of total change from standing to 60 deg of the trunk-thigh angle (sitting C). The smallest change was observed between 120 and 90 degs of hip flexions, which was about 13% and about 27% between 90 and 60 degs. In the Keegan's study investigated from 180 to 50 deg of the trunk-thigh angle, the greatest change was observed from 135 deg in neutral position to 90 deg. This result was much different from our study in the comparable range, from 120 to 90 deg, in which the smallest change was shown in our results. The magnitude of the change between 180 and 135 degs was obviously smaller than that observed between 90 and 50 degs in Keegan's

study. This was also inconsistent with the results of this study. Thus, it was concluded that the relation between lumbar curve and the trunk-thigh angles was obviously different by the postural conditions, that is, in the state of seating on a chair with the upright position or in the lateral recumbent position in the Keegan's study.

Furthermore, Andersson et al.(1979) has studied the effect of the backrest-seat angle on the lumbar curve by radiography on 38 healthy subjects and revealed that an increase in the backrest-seat angle from 90 to 110 deg does not significantly influence the lumbar curve and sacral-pelvic angle. Considering our results together with that of Andersson et al.(1979), it was suggested that the effect of changes in the trunk-thigh angle involving the pelvic inclination on the lumbar curves were different by the direction of gravitational force to the body.

Many studies have been reported on the relation between anthropometric characteristics and low-back pain (Nachemson, 1969; Heliövaara, 1987; Walker et al. 1987; Mellin, 1988). Several authors have found a decrease in the hip mobility to be correlated with back pain in general population (Fairbank et al.,1984, Pope et al.,1985, Triano and Schultz, 1987 ). However, there are only a few reports concentrated on the degree of change in pelvic tilting across different postures with reference to individual difference in joint mobilities, or muscle lengths.

As has been considered in general, given that hamstrings cause posterior pelvic tilting and flattening of

the lumbar curve as shown by Keegan's model, individuals with short hamstrings in sitting position is suspected to have more posterior inclined pelvis than individuals with long hamstrings. Our results in series M (with constant knee angle), however, indicated that significant correlation of hamstring length with change in pelvic tilting was found only between standing and sitting A (the trunk-thigh angle of 120 deg). On the other hand, gluteal muscle but not hamstrings became a more important factor to affect pelvic tilting, as shown by correlation coefficient in Table 2, when posture was changed from sitting A to B or C. It was unexpected that gluteal muscle indicated significant positive correlation between standing and sitting A. This positive correlation could not be explained here as hip extensors. It was possible that spurious result was obtained caused by the concomitant influence of other factors.

Stokes and Abery (1980) and Bridger et al. (1989) suggested that diminution of lumbar lordosis at different sitting postures was caused mainly by knee flexion rather than the trunk-thigh angle. Bridger et al. (1989) also pointed out that muscles playing an important part in flattening of the lumbar curve in sitting were hamstrings but not muscles such as the glutei crossing only the hip joint among hip extensors. In our study in series S, additional condition of knee angle was employed in the trunk-thigh angles of 90 and 60 degs. Lumbar curvature was also observed to decrease as the knee angle decreased even if the trunk-thigh angle was constant. Since hamstrings are two-joint muscles, crossing the hip and knee, our result of series S indicated that hamstrings affected the lumbar curve across sitting postures with different knee angles. However, our results also showed that posterior pelvic tilting was significantly greater in 60 deg of the trunk-thigh angle with knee flexed at 120 deg than in 90 deg of the trunk-thigh angle with knee flexed at 60 deg although the hamstrings were less restricted when flexing the knee from 60 to 120 deg. This implied that the gluteal muscles as well as hamstrings would be important factors to affect pelvic tilting at different sitting postures.

It was concluded that the relationships between lumbar curves, pelvic tilt and the trunk-thigh angle were different by the direction of gravitational force to the body, that is, upright posture or recumbent posture. It was also concluded that muscles which played an important role in tilting pelvis in sitting were hip extensors among lumbar extensors and flexors and that the change in pelvic tilt was caused by different hip extensors to an extent dependent upon the trunk-thigh angle combined with the knee angle.

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