The Effects of Pelvic Movement on Lumbar Lordosis in the Standing Position

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The purpose of this study was to investigate whether the maneuver of altering the angle of pelvic tilt when standing is effective in changing the angle of lumbar lordosis. The importance of the study was to establish a scientific basis for a common clinical assumption. Pelvic tilt and lumbar lordosis were measured during three conditions: with subjects in a normal standing posture, with subjects assuming a maximal anterior pelvic tilt posture, and with subjects assuming a maximal posterior pelvic tilt posture. Measurements of pelvic tilt and lumbar lordosis were obtained using a television/computer system that obtained the three-dimensional coordinates of markers on the pelvis and spine at 20-msec intervals. Each measurement was made three times, and all were found to be reliable, with intraclass correlation coefficients (3,1) ranging from 0.78 to 0.95 ($p < 0.001$). Adopting a maximal anterior pelvic tilt changed the pelvic attitude relative to the horizontal by an average of 11.4° ($p < 0.001$) and increased the lumbar lordosis by an average of 10.8° ($p < 0.001$). Adopting a maximal posterior pelvic tilt changed the pelvic attitude by an average of 8.7° ($p < 0.001$) and decreased the lumbar lordosis by an average of 9.0° ($p < 0.001$). The results of this study demonstrate that altering the pelvic tilt significantly changes the angle of lumbar lordosis. This lends support to the use of pelvic tilting exercises to increase or decrease the degree of lumbar lordosis, at least for the duration of the exercise.

Key Words: *posture, lumbar lordosis, spine*

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Many authors have speculated that low back pain may occur as a result of excessive stress on the lumbar spine and sacroiliac joints due to an exaggerated anterior pelvic tilt posture (3,5,9,10,14,17). The degree of pelvic tilt and lumbar lordosis are frequently assessed as part of a postural evaluation. Treatments based on decreasing the amount of anterior pelvic tilt and concurrently reducing the depth of lumbar lordosis, or increasing the amount of anterior pelvic tilt and concurrently increasing the depth of lumbar lordosis, are often prescribed in an attempt to correct postural deviations and to treat pain and dysfunction related to postural syndromes (3,8–10). Despite the often-stated relationship between pelvic tilt and lumbar lordosis, little has been published to demonstrate how voluntarily altering pelvic tilt affects lumbar lordosis. The purpose of this study was to investigate the effects of altering the angle of pelvic tilt on lumbar lordosis in the standing position.

Pelvic tilt (Figure 1) is defined as the angle between the horizontal plane and a line passing through the midpoint of the posterior superior iliac spines and the midpoint of the anterior superior iliac spines (12). Lumbar lordosis (Figure 2) is the curve assumed by the lumbar spine, where the lumbar spine forms an anterior convexity (2). The degree of lumbar lordosis is variable among individuals and is the result of many factors, including the fact that the L5 vertebra is wedge-shaped, with the anterior aspect of the vertebral body being approximately 3 mm higher than the posterior aspect (6). The intervertebral discs in the lumbar area are also wedge-shaped, especially at the L4-L5 and L5-S1 segments; the intervertebral disc at the L5-S1 interspace has been measured to be 6–7 mm higher anteriorly than posteriorly (15). The vertebrae above L5 are less wedge-shaped; however, due to the shape of the L5-S1 vertebral levels, each vertebra above this level lies slightly behind the vertebra above. All of these factors contribute to producing the normal lumbar lordosis.

The effects of voluntarily altering pelvic tilt on lumbar lordosis have been examined in one previous study (4), in which male subjects assumed three postures: a normal standing posture, a maximal anterior pelvic tilt posture, and a maximal posterior pelvic tilt posture. The maximal anterior pelvic tilt posture significantly increased the depth of lumbar lordosis ($p < 0.05$). Likewise, assuming a full posterior pelvic tilt posture decreased the degree of lumbar lordosis ($p < 0.05$). Although these relationships are generally assumed in the clinical and research communities, the study by Day et al (4) represents the only published evidence of these relationships. The present study was designed

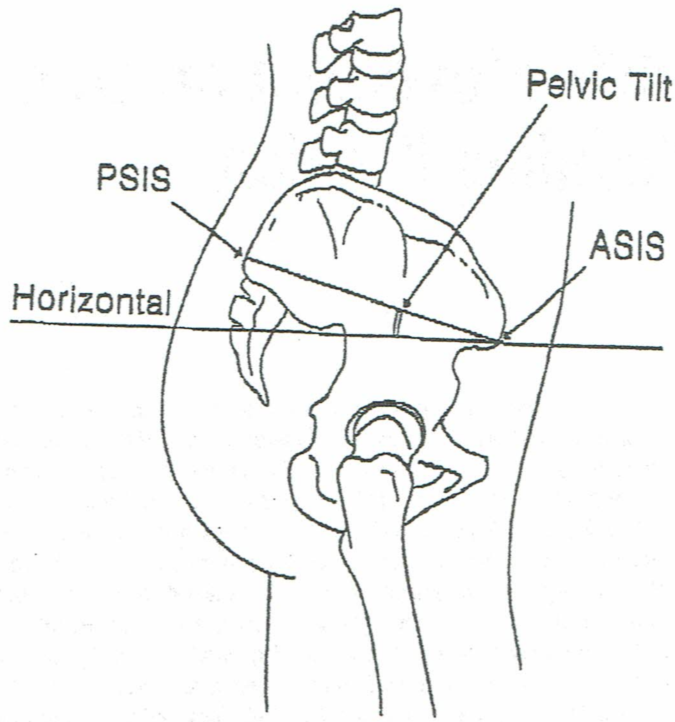

FIGURE 1. *Schematic diagram of pelvic tilt, the angle between the horizontal and a plane joining the anterior superior iliac spines (ASIS) to the posterior superior iliac spines (PSIS).*

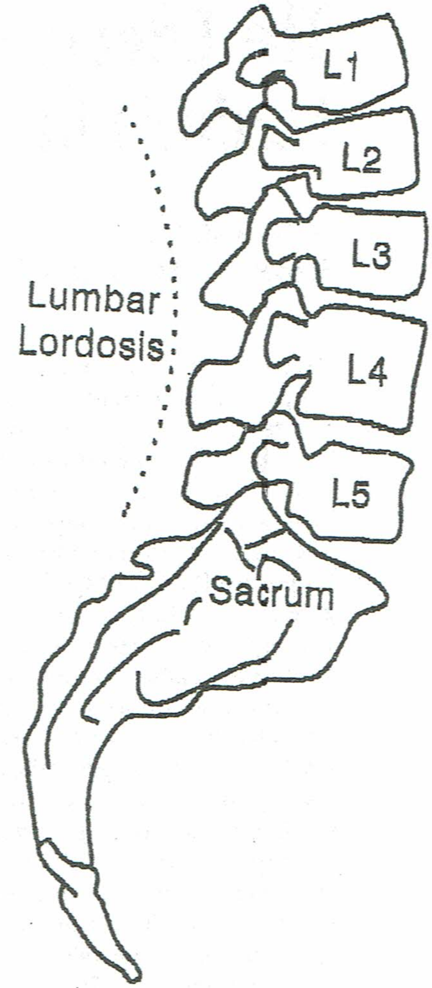

FIGURE 2. *Schematic diagram of lumbar lordosis. (Adapted from Link et al (11), reprinted from Physical Therapy with the permission of the American Physical Therapy Association).*

to examine these relationships in greater detail, using a new and more convenient method of measurement. In the present study, a noncontact measurement system was used, with all the coordinates being determined simultaneously, thus eliminating the risk of movement occurring between measurements. Day et al measured coordinates using a wand to contact each point in turn and then rotated a platform "with the subjects maintaining position" (4). Lordosis was defined as the angle of skin surfaces rather than the depth/length ratio which was used by Day et al. Our study also examined female subjects where they examined male subjects, and the present study quantified in greater detail the relationships between pelvic tilt and lumbar lordosis.

METHODS

Subjects

Twenty female subjects with a mean age of 23.4 years (range = 20–32) participated in this study after signing an informed consent form. This was a sample of convenience, with the subjects being physical therapy students who were volunteers and who met the following inclusion criteria: *1)* no current low back pain or past history of low back dysfunction and *2)* no known lower extremity dysfunction.

Instrumentation

To analyze pelvic tilt and lumbar lordosis, a Vicon three-dimensional kinematic system was used (Oxford Metrics Ltd., Oxford, England). Reflective targets were fixed to the skin of the experimental subjects in known anatomical positions on the spine, pelvis, and lower limbs using double-sided adhesive tape. The system used five infrared-sensing television cameras, operating at a frequency of 50 Hz, interfaced to a DEC MicroVax minicomputer (Digital Equipment Corporation, Maynard, MA), to detect the positions of these targets, which were illuminated by infrared irradiation and showed up as bright spots in the fields of view of the cameras.

Using the results of a calibration procedure, a computer program combined the two-dimensional information from the separate cameras into three-dimensional measurements. The angular spacing of the cameras around the room (Figure 3) enabled the third dimension (depth) to be measured with approximately the same accuracy as the width and height dimensions, giving an overall three-dimensional system accuracy of 2–3 mm within a field of view of 3 m × 2 m.

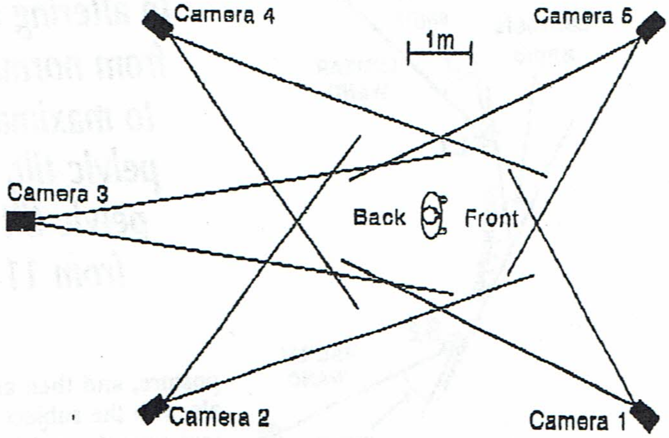

FIGURE 3. *Schematic of camera layout and subject position.*

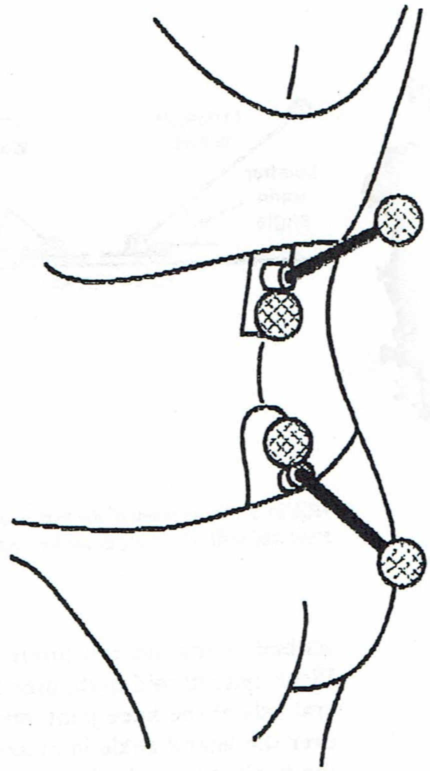

FIGURE 4. *Lumbar and sacral rigs in place on subject.*

Previous studies using the Vicon system have shown that it is possible to measure both pelvic and spinal attitude and motion in the sagittal plane during walking (13,18,19). Reliability of the Vicon system has previously been established for measurement of the pelvis (7,18,20) and for the measurement of lumbar lordosis (20). In the absence of an independent method of measuring lumbar lordosis, validity has not been established.

Measurement of Pelvic Tilt

The subjects were carefully positioned so that one axis of the room-based coordinate system corresponded to their sagittal plane. The angle of the pelvis was determined using one marker on each anterior superior iliac spine and one on the sacrum, midway between the two posterior superior iliac spines. This triangle is large enough to prevent small three-dimensional measurement errors from significantly affecting the angular measurements. Pelvic tilt was measured as the angle between the horizontal plane and the line joining the sacral marker to the midpoint between the two anterior superior iliac spines, corresponding to the generally accepted definitions (12). Pelvic motion in the sagittal (pitch), coronal (roll), and transverse (yaw) planes was determined from the relative positions of these three targets. However, only sagittal planes are reported here.

Measurement of Lumbar Lordosis

The measurement of lumbar lordosis involved the use of two measurement rigs, each of which consisted of a flat plastic plate that was firmly fixed (using double-sided adhesive tape) to the skin over the sacrum or the upper lumbar spine (Figure 4). These rigs were small enough and light enough that they did not appear to affect the subject's normal posture or gait. Each rig had one marker directly on the flat plate and one on the end of a light metal rod, with the separation between the center of the two markers being approximately 117 mm. The length of the plates covered two spinal levels; shorter plates would have permitted unacceptable oscillation of the wand. In the absence of a universally accepted definition of the upper end of the lumbar curve, we decided to fix the plate over the T12 and L1 spinous processes, with the reflective marker over L1. The lower plate was fixed over the sacrum, with the reflective marker midway between the posterior superior iliac spines, corresponding approximately to S2. The rod on the upper rig pointed backward and upward; the rod on the lower rig pointed backward and downward (Figure 4). The angles between the surfaces of the rigs and the lines joining the two markers (the lumbar wand angle and sacral wand angle) were determined by a static trial, in which the two rigs were placed on the floor, with the skin-contact surface horizontal; data were acquired to measure the relative positions of the two markers on each rig (Figure 5). The angle between the skin surfaces in the lumbar and sacral regions was then determined from the positions of the two markers on each rig and the known lumbar wand and sacral wand angles. The angles between the skin surfaces in the two regions were subtracted, thus giving a "lumbar lordosis angle." If the lumbar spine was totally straight, there would be no angle between the skin surfaces in the two regions, and the lordosis angle would be zero.

Reflective markers were also located bilaterally on the lower extremities in the following locations, as pre-

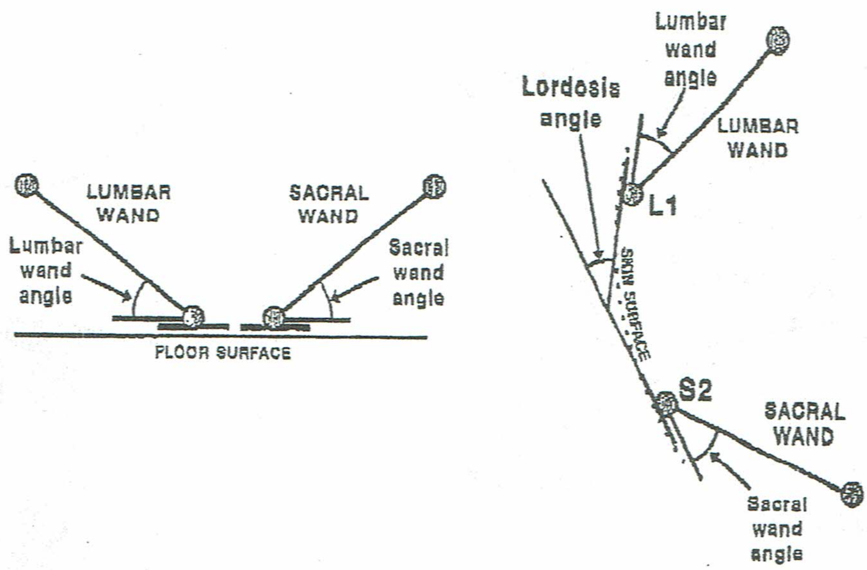

FIGURE 5. *Measurement of the lordosis angle. The lumbar wand and sacral wand angles are determined in a static trial (left). These angles are then used in the calculation of the lordosis angle (right).*

In altering the posture from normal standing to maximal anterior pelvic tilt, the mean pelvic tilt changed from 11 to 23°.

scribed by the manufacturers of the Vicon system: midthigh, over the lateral axis of the knee joint, midtibia, over the lateral ankle joint axis, on the heels, and at the base of the second metatarsal. These markers, though not needed for acquisition of data related to pelvic tilt and lumbar lordosis, were needed for identification of events in the gait cycle, so that pelvic tilt and lumbar lordosis could be measured during gait and related to identifiable events, such as initial contact and toe-off. The results from the gait analysis will form the subject of a separate paper.

Each subject in this study was required to dress in shorts or swimwear to sufficiently expose the areas of skin where targets were to be located. A number of anthropometric measurements required by the system software was obtained, including *1)* leg length, as measured from the anterior superior iliac spine of the pelvis to the medial malleolus in the supine position; *2)* knee width, measured at the level of the medial and lateral epicondyles of the femur; and *3)* ankle width, measured at the level of the medial and lateral malleoli of the tibia and fibula.

While each subject was being prepared for testing, the measurement system was tested and calibrated. Four rods, with five reflective markers each located in known positions, were hung from the ceiling; these were used to calibrate the five cameras. The calibration software ensured accuracy by providing an estimate of system measurement error.

Once the pelvic and lumbar rigs and all of the skin markers were fixed to the subject, three standing trials, four walking trials, and another three standing trials were performed to determine the angles of pelvic tilt and lordosis and to determine the reliability of the measurements. Standing data were collected for approximately 500 msec. Between each trial, the data were reconstructed to ensure that no errors had occurred during data collection. This process took between 2 and 4 minutes for each trial, during which time the subjects were instructed to walk about the room for at least 30 seconds; they were then free to either walk or stand until the next trial.

Data were then collected from three trials, with the subject maintaining a maximal anterior pelvic tilt posture, and then another three trials, with the subject assuming a maximal posterior pelvic tilt posture. These trials were collected in the following order: anterior, posterior, anterior, posterior, anterior, posterior. We felt that randomizing the order would not improve this aspect of the study. Data processing again took 2–4 minutes between each trial.

Data from all the trials were processed by the Vicon software to generate files of three-dimensional coordinates. These were then converted from the Vicon internal file structure into a form that could be read by the Microsoft Excel (Microsoft Corp., Redmond, WA) spreadsheet program. Calculations of the angles of pelvic tilt and lumbar lordosis and data smoothing by 5-point moving average were then done within Excel. The finished Excel files were used for statistical analysis by the Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL).

To determine reliability of the measures of pelvic tilt and lumbar lordosis, intraclass correlation coefficients (ICCs) were used (16).

RESULTS

Pelvic Tilt

Reliability was found to range from fair to very good for measures of pelvic tilt during normal standing (ICC 3,1 = 0.95), maximal anterior pelvic tilt posture (ICC 3,1 = 0.85), and maximal posterior pelvic tilt posture (ICC 3,1 = 0.78) (Table 1). All

Measurement	Values	Significance
Pelvic tilt: Normal standing	ICC = 0.95	$p < 0.001$
Maximal anterior pelvic tilt	ICC = 0.85	$p < 0.001$
Maximal posterior pelvic tilt	ICC = 0.78	$p < 0.001$
Lumbar lordosis: Normal standing	ICC = 0.94	$p < 0.001$
Lumbar lordosis: Maximal anterior pelvic tilt	ICC = 0.90	$p < 0.001$
Lumbar lordosis: Maximal posterior pelvic tilt	ICC = 0.91	$p < 0.001$

ICC = Intraclass correlation coefficient.

TABLE 1. *Static (standing) test-retest reliability of pelvic tilt and lumbar lordosis using the intraclass correlation coefficient (3,1).*

of these measures were highly significant ($p < 0.001$).

Lumbar Lordosis

Reliability also was good for measures of lumbar lordosis during normal standing (ICC 3,1 = 0.94), maximal anterior pelvic tilt posture (ICC 3,1 = 0.90), and maximal posterior pelvic tilt posture (ICC 3,1 = 0.91) (Table 1). Again, the measures were all highly significant ($p < 0.001$).

Effect of Pelvic Movement on Lumbar Lordosis

Group means for pelvic tilt and lumbar lordosis during all testing conditions are summarized in Table 2.

	Pelvic Tilt		Lumbar Lordosis	
	$\bar{X}$	SD	$\bar{X}$	SD
Normal standing	11.3°	4.3°	31.8°	7.3°
Maximal anterior pelvic tilt	22.7°	4.9°	42.6°	7.1°
Maximal posterior pelvic tilt	2.6°	5.3°	22.8°	9.4°

TABLE 2. *Group means and standard deviations of pelvic tilt and lumbar lordosis.*

	Pelvic Tilt		Lumbar Lordosis	
	Angle	Significance*	Angle	Significance*
Normal standing vs. anterior pelvic tilt	+11.4°	$p < 0.001$	+10.8°	$p < 0.001$
Normal standing vs. posterior pelvic tilt	−8.7°	$p < 0.001$	−9.0°	$p < 0.001$

* *Paired t test.*

TABLE 3. *Change in pelvic tilt and lumbar lordosis in changing posture from normal standing to maximal anterior pelvic tilt and to maximal posterior pelvic tilt.*

In altering the posture from normal standing to maximal anterior pelvic tilt, the mean pelvic tilt changed from 11.3 to 22.7°, a difference of 11.4°, and the mean lumbar lordosis changed from 31.8 to 42.6°, a difference of 10.8°. Both differences were highly significant ($p < 0.001$), using the *t* test for paired data (Table 3).

In altering the posture from normal standing to maximal posterior pelvic tilt, the mean pelvic tilt changed from 11.3 to 2.6°, a difference of −8.7°, and the mean lumbar lordosis changed from 31.8 to 22.8°, a difference of −9.0° (Table 2). Again, both differences were highly significant ($p < 0.001$), using the *t* test for paired data (Table 3).

DISCUSSION

This study demonstrated that, in a standing posture, increasing the degree of anterior pelvic tilt increased the angle of lumbar lordosis and increasing the degree of posterior pelvic tilt decreased the angle of lumbar lordosis. This is in agreement with the observations of Day et al (4), where the depth of lumbar lordosis was shown to deepen during a voluntary maximal standing anterior pelvic tilt and to become more shallow during a posterior pelvic tilt. The results of Day et al are not directly comparable with the present study, since they defined the magnitude of the lumbar lordosis as the depth of the curve at its apex, rather than as an angular change in the skin surface. The present study has quantified the relationship between pelvic tilt and lumbar lordosis, showing that a change in pelvic tilt, either anterior or posterior, produces an almost equal angular change in lumbar lordosis.

In the present study, maximal anterior and posterior pelvic tilt did not necessarily produce maximal amounts of lumbar flexion and extension, which could be increased by movement of the lower extremities and the thoracic spine. However, the results do show that a trained person can voluntarily alter his/her pelvic tilt enough to significantly change his/her angle of lumbar lordosis. This lends support to the idea that performing anterior pelvic tilt exercises can increase the amount of lumbar lordosis, and posterior pelvic tilting exercises can decrease the amount of lumbar lordosis. There is no evidence to date to suggest that these exercises will promote a permanent change in posture, but this study did demonstrate that the degree of lumbar lordosis does change significantly during the time period of the exercise. This may be impor-

In the present study, maximal anterior and posterior pelvic tilt did not necessarily produce maximal amounts of lumbar flexion and extension.

tant in teaching subjects to maintain a particular pelvic posture, such as performing an anterior pelvic tilt during lifting, thus increasing lumbar lordosis, which decreases intradiscal pressure (1).

The main limitation of the present study is that it was performed on a sample of college students who were devoid of low back troubles. The generalizability of the results is therefore limited. This population was chosen because it was felt that the relationships first needed to be investigated in normal individuals before analyzing the more complex relationships that may exist in individuals with low back dysfunction.

CONCLUSION

Measurements of lumbar lordosis and pelvic tilt using a three-dimensional television/computer system were found to be reliable. There is no "gold standard" that could be used to establish the validity of this method. However, the nature of the measurement is such that it could be expected to provide an accurate measurement of the lumbar lordosis, defined as the difference in the angle of the skin surface between the T12-L1 region and the upper sacrum. The results of this study also showed that voluntarily altering pelvic tilt changes the angle of lumbar lordosis. This supports the use of pelvic tilting exercises to alter the degree of lumbar lordosis, at least for the duration of the exercise. JOSPT

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