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Relationships Between Lumbar Lordosis, Pelvic Tilt, and Abdominal Muscle Performance

MARTHA L. WALKER, JULES M. ROTHSTEIN, SHERYL D. FINUCANE, and ROBERT L. LAMB

The purpose of this study was to examine the relationships between measurements of lumbar lordosis, pelvic tilt, and abdominal muscle performance during normal standing. In addition, the reliability of the measurements used in this study was examined. Measurements of lumbar lordosis, pelvic tilt, and abdominal muscle performance were taken from 31 healthy adults aged 20 to 33 years. Each measurement was taken twice, and the measurements were shown to be reliable. The Spearman's rho correlation of the abdominal muscle performance measurements with pelvic tilt was .18 and with lordosis was .06. The Pearson product-moment correlation of lordosis with pelvic tilt was .32. The results indicate that lumbar lordosis, pelvic tilt, and abdominal muscle function during normal standing are not related. This study demonstrates the need for a reexamination of clinical practices based on assumed relationships of abdominal muscle performance, pelvic tilt, and lordosis.

Key Words: Lordosis, Muscles, Pelvis, Physical therapy.

Much of the clinical literature suggests that lumbar lordosis, pelvic tilt, and abdominal muscle function are related to each other. Kendall and McCreary state that “in the erect position, weakness of [the rectus abdominis] muscle permits an anterior pelvic tilt and a lordotic posture [increased anterior convexity of the lumbar spine].” Apparently, this concept is based on their understanding of the anatomy of the abdominal muscles and on the effect they hypothesize these muscles have on lordosis. Experimental evidence, however, demonstrating the relationship of abdominal muscle “strength” (function), lordosis, and pelvic tilt has not been published.

The abdominal muscles can tilt the pelvis posteriorly. When subjects perform a posterior pelvic tilt in the standing position, a concurrent decrease occurs in depth of lumbar lordosis. In view of these observations, one could argue logically that during normal standing the degree of pelvic tilt is related to the depth of lumbar lordosis and that both are related to abdominal muscle function.

Despite the studies reviewed, no evidence exists that the ability of the abdominal muscles to contract actively and to hold that contraction against resistance relates to what occurs during normal relaxed standing. An important question regarding clinical practice is whether we can assume, because a relationship exists between movement of the pelvis and movement of the lumbar spine, that the position of one can be predicted by the position of the other. Kendall and McCreary appear to believe that this prediction is valid for subjects in a relaxed standing posture.

The purpose of our study was to correlate a clinically used measurement of abdominal muscle function, an index of lumbar lordosis, and a measurement of pelvic tilt in healthy subjects. In addition, to ensure that we could make valid conclusions from our data, we assessed the reliability of the measurements used in this study.

METHODS

Subjects

The subjects were 31 healthy physical therapy students, 23 women and 8 men, between the ages of 20 and 33 years, with a mean age of 23.9 years (SD = 3.8 years). We do not believe the subjects’ knowledge of muscle testing and of principles of kinesiology could have influenced our results because the proposed relationship among degree of lordosis, degree of pelvic tilt, and function of the abdominal muscles is based on a mechanical principle that is presumed to be universal and not dependent on learning.

Subjects were excluded from the study if they had acute or chronic back pain or a scoliosis of greater than 15 degrees, as determined by visual examination by the first investigator (M.L.W.). These exclusions were made because these factors could have caused postural abnormalities that might have interfered with relationships that might exist otherwise among the areas of study. Although several potential subjects were excluded because of the presence of low back pain, we did not need to reject any subjects because of scoliosis.

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Instrumentation

Lumbar lordosis was measured with a flexible curve* that was molded to the contour of the lordotic curve by placing it against the subject’s back. Pelvic inclination was measured using an inclinometer† to determine the angle formed with a horizontal line drawn between the anterior superior iliac spine (ASIS) and the posterior superior iliac spine (PSIS) (Fig. 1).

The test we used for abdominal muscle function was described by Kendall and McCreary. In this test, a subject’s score is the angle that the long axis of the legs forms with the horizontal plane during straight leg lowering. Subjects start in a supine position with the legs at a 90-degree angle to the table and end with the legs positioned horizontally (ie, at 0 degrees with the table). The angle that is measured is that formed by the legs and the horizontal plane of the table when the subject no longer can keep the low back and pelvis firmly against the table. To control for the speed of the movement, we modified the Kendall and McCreary protocol. Our subjects were instructed to keep time with a metronome so that the action of leg lowering took 10 seconds to complete.

Procedure

We informed the subjects about the nature of the study and had them sign a consent form. Measurements of pelvic tilt and lumbar lordosis were taken before testing the abdominal muscle function because of the possibility that repeated abdominal muscle contractions could influence these two variables. Each measurement was taken two times, allowing the subjects a one-minute rest in between, so that the reliability of the measurements could be determined. The first examiner took all measurements used in the study.

Location of bony landmarks. While the subject was standing, the first examiner palpated the right ASIS and PSIS and the spinous processes of S2 and L3 and marked them with adhesive markers. The barefoot subject then was asked to assume a normal standing posture with the weight evenly distributed on both feet. Then the examiner extended a dowel mounted on an adjustable stand horizontally until it touched the subject’s sternum. This device aided in the control of postural sway while subsequent measurements were obtained. A tracing then was made of the subject’s feet so that all measurements would be made with the subject in the same standing position.

Measurement of pelvic tilt. To measure pelvic tilt, the first examiner placed the arms of the inclinometer on the marked ASIS and PSIS, and the second examiner (S.D.F.) read and recorded the angle of inclination.

Measurement of lumbar lordosis. The subject remained in the normal standing posture while lordosis was measured. The flexible curve was pressed against the spinous processes of the lumbosacral spine, and the points that intersected the adhesive markers were recorded. The flexible curve then was lifted from the spine without changing the configuration of the curve. The convex side was traced on paper (Fig. 2). The points that intersected L3 and S2 were marked, and a line was drawn between them. The length of this line (labeled L) was measured using a micrometer caliper. Another line (labeled H), representing the height of the curve, then was drawn perpendicular from the midpoint of L to the curve and measured. These two measurements were used to calculate Theta (θ), an index of lordosis, using the following formula:

$$\theta = 4 \times \arctan (2H/L)$$

Reliability

After pelvic tilt and lordosis were measured, the first examiner removed the adhesive markers and allowed the subject a one-minute rest. To obtain second measurements so that intratester reliability could be assessed, examiner one then repalpated the bony landmarks and, using the same methods, repeated all the measurements.

Testing of abdominal muscles. Function of the abdominal muscles was tested according to the method suggested by Kendall and McCreary. The subject was positioned supine on a table with the knees bent. A metronome was started at

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* Truflex Dual Graduated Flexible Curve, Alvin & Co Inc, 1335 Blue Hills Ave Ext, Bloomfield, CT 06002.
† Sears Craftsman Universal Protractor, Sears, Roebuck & Co, Sears Tower, Chicago, IL 60604.
Fig. 3. Starting position for testing abdominal muscle performance.

1 beat per second. The first examiner assisted the subject in raising the legs to a vertical position with the knees fully extended (Fig. 3). Leg-lowering took 10 seconds to complete, as timed by a metronome. The subject was given the following instructions:

When I say go, you will lower both legs together keeping your knees straight. As you lower your legs, keep your lower back pressed against the table. You will complete the action in 10 seconds, keeping time with the metronome. Concentrate on keeping your back pressed against the table.

The angle between the extended legs and the tabletop at the moment the pelvis started to tilt anteriorly and the low back started to move up off the table was measured with a blinded goniometer (ie, the scale was covered). One examiner palpated the low back of the subject as the subject lowered both legs. The second examiner measured the angle by following the movement of the femur with the moving arm of the goniometer while keeping the stationary arm of the goniometer horizontal. When the first examiner felt the subject's low back start to move up off the table, she tapped the second examiner on the shoulder. On feeling the tap, the second examiner stopped the moving arm of the goniometer and recorded the angle. The subjects were not made aware of when the goniometer stopped so that all subjects completed the test regardless of their performance.

Kendall and McCreary convert the angles obtained from this method into percentages; however, for this study, the angle measurement was used. This measurement, like the others, was taken two times by the same examiner with a one-minute rest between the measurements.

For all measurements, the first examiner determined when the measurement should be taken, and the second examiner recorded the measurements without allowing the first examiner to know those measurements. Because the first examiner did not know the original values and could not be influenced by those values, the assessment of reliability was not compromised.

Data Analysis

The second examiner took measurements of lumbar lordosis, pelvic tilt, and abdominal muscle function twice on each subject so that the intratester reliability of these measurements could be determined. A Spearman's rho rank order correlation was calculated for the abdominal strength test-retest because this measurement is on an ordinal scale. To test the reliability of the lordosis and pelvic inclination measurements, intraclass correlation coefficients (ICCs: 1,1) were calculated. To examine the relationships between abdominal muscle performance, lordosis, and pelvic tilt, a Spearman's rho correlation was used. This ordinal scale test was necessary because although two of the measurements—lordosis and pelvic tilt—were ratio scaled, they were correlated with the ordinal scale measurement of abdominal muscle performance. To examine the relationship of pelvic tilt with lumbar lordosis, a Pearson product-moment correlation was used because both of these measurements are ratio scaled.

RESULTS

Reliability

The ICC values for repeated measures (ie, reliability) of pelvic tilt and lordosis were .84 and .90, respectively. The Spearman's rho correlation coefficient for repeated abdominal muscle tests was .71. The Spearman's rho correlation of abdominal muscle test values with pelvic tilt measurements was .18 and with lumbar lordosis measurements was .06. The Pearson product-moment correlation of lumbar lordosis measurements with pelvic tilt was .32.

DISCUSSION

Lumbar Lordosis

The measurement of lumbar lordosis with a flexible curve as used in this study had a high degree of reliability when repeated measurements with one-minute rest periods were taken by the same examiner. This finding is in agreement with results obtained by other investigators.

Hart and Rose obtained an ICC of .97 for intratester reliability of the flexible curve for measuring the lumbar curve during normal standing and in three types of forward bending (N = 89). They used the arctan formula for obtaining the angle θ as a single index of the lordosis. In addition, they tested the validity of this method by comparing measurements obtained using the curve with measurements obtained using two standard roentgenographic techniques. The flexible curve measure was determined to have good (r = .87, N = 8) clinical validity when compared with a roentgenographically derived measure of the angle between vertebral bodies.

Rather than starting at L1, as Hart and Rose did, we measured lordosis from S2 to L3. The choice of starting position depends on the investigator's definition of lumbar lordosis. The arctan formula for reducing the curve to one index of lordosis assumes that the peak of the curve occurs at exactly the midpoint of the length of the curve. Measuring from L3 to S2, therefore, puts the mathematical peak of the curve at about L5. Although our method did not include the entire lumbar spine in the measurement of lumbar lordosis, this procedure does fit the mathematical model used to estimate curvature of the lumbar spine. Preliminary studies in our laboratory also indicated that the landmarks used tended to yield more reliable measurements. We, therefore, chose to measure from L3 to S2 because of the reliability we could obtain and because we believed that the area measured is indicative of the lumbar curve.

Pelvic Tilt

The measurement of pelvic tilt with an inclinometer as used in our study had a high degree of reliability when
repeated measurements with one-minute rest intervals were taken by the same examiner. This finding also appears to be in agreement with observations made by other investigators.

Loebl first described the use of an inclinometer, and Sanders and Stavrakas characterize measurement of pelvic tilt by use of a trigonometric formula to determine the relationship between ASIS and PSIS. Gajdosik et al used this method of determining pelvic tilt in a reliability study. They obtained a Pearson product-moment correlation coefficient of .88 for intratester reliability. Rather than use a formula to determine the angle that a line between ASIS and PSIS made with the horizontal plane, we used an inclinometer to allow this measurement to be taken directly.

We have not found any studies that discuss the validity of using a line between ASIS and PSIS that intersects the horizontal plane as a representation of the angle of pelvic tilt. We believe, however, that on a theoretical basis the measurement we used would appear to reflect the angle of pelvic tilt. In addition, we believe that our method, although seldom used clinically, uses the same anatomical landmarks that clinicians observe when they assess pelvic tilt.

**Abdominal Muscle Function**

We used the leg-lowering test for abdominal performance because it is a widely accepted test and, therefore, has clinical relevancy. Because Kendall and McCreary are among the primary proponents of the idea that abdominal muscle performance relates to lordosis and because their test is used widely by physical therapists, we thought that their test should be used. Our study examined whether this test that is assumed to have predictive value does indeed predict lordosis and pelvic tilt. As with all manual muscle tests, the validity of the leg-lowering test as an indicator of a muscle’s ability to generate tension has not been demonstrated.

The measurement of abdominal muscle function by use of the leg-lowering test was moderately reliable under the conditions of this study. Even though we used standardized directions that explained the test, and even though all subjects were healthy physical therapy students, some of the subjects had difficulty performing the test correctly. Perhaps the difficulty was because the complexity of the task involved more than just use of the abdominal muscles. For the test, subjects were required to count to 10 with the metronome, lower their legs with the count, and maintain their low backs pressed against the table. Most subjects, however, had no trouble with this activity.

The leg-lowering test may have been easier to perform if the metronome had not been used. We believe, however, that not using the metronome would have resulted in more variability in the speed with which the legs were lowered, and changes in the speed of movement could have affected a subject’s measurements. In the clinic, where speed of movement is not necessarily regulated, this test of abdominal muscle performance is probably less reliable than under the conditions of our study.

**Relationship of Abdominal Muscle Function, Lordosis, and Pelvic Tilt**

The correlations between all measurements were so low that abdominal muscle function, pelvic tilt, and lumbar lordosis do not appear to be linked inextricably as has been proposed. Even though the measurement of abdominal muscle function was only moderately reliable, a strong relationship between abdominal muscle function and pelvic tilt or lordosis should have resulted in greater correlations than those we found.

Researchers examining the myoelectric activity of the abdominal muscles during quiet standing and walking have found minimal to no activity. The abdominal muscles are not active in normal standing. Abdominal muscle function, therefore, is not likely to be responsible for the degree of pelvic tilt or lumbar lordosis during quiet standing, even though this relationship has been assumed frequently.

Patients often are taught abdominal muscle “strengthening” exercises as a means of altering their standing posture. The theoretical basis on which this practice has been built is not supported by our data. No apparent relationship exists between abdominal muscle function and standing pelvic tilt, abdominal muscle function and lumbar lordosis, and lumbar lordosis and pelvic tilt.

A different method of evaluating abdominal muscle function might have produced different results. In our opinion, however, changing the method of abdominal muscle testing would not have changed the results. Although our study shows that abdominal muscle function appears to have no relationship to pelvic tilt or lumbar lordosis, we cannot eliminate the possibility that the structure of the abdominal muscles may contribute to the degree of lumbar lordosis and pelvic tilt. We propose, for example, that the relationship of abdominal muscle length to pelvic tilt and lumbar lordosis be examined. In addition, other factors, such as other muscles, may influence lordosis and pelvic tilt. Our study indicates the need to consider that lordosis and pelvic tilt may be influenced by a variety of complex factors and not simply one variable. Research is needed to determine what these factors are and how each contributes to lordosis and pelvic tilt.

**Conclusion**

The test-retest measurements of pelvic tilt and lumbar lordosis obtained in our study were shown to be very reliable when recorded by a single examiner and with one-minute rest intervals between measurements. The test-retest measurements of abdominal muscle function were found to be moderately reliable when obtained by the same examiner and with one-minute rest intervals between measurements. Using these measurements, we found no correlation between abdominal muscle function, pelvic tilt, and lumbar lordosis. A reexamination is needed of the clinical practices based on assumed relationships of abdominal muscle performance, pelvic tilt, and lordosis.
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