Relationship Between a Lumbopelvic Stabilization Strength Test and Pelvic Motion in Running

Dale Bickham, Warren Young, and Peter Blanch

Objective: To determine the relationship between lumbopelvic (LP) stabilization strength and pelvic motion during running.

Design: Runners were assessed for pelvic motion and undertook an LP stabilization strength test.

Participants: Sixteen elite male middle- and long-distance runners.

Interventions: Pelvis kinematics were assessed while subjects ran at 5 m/s on a treadmill.

Main Outcome Measures: Angular pelvis displacement was divided into 3 axes of rotation: pelvic tilt, obliquity, and rotation. LP stabilization strength was the capacity to resist increasing static loads applied to each leg and maintain a neutral LP zone. Intercorrelations were calculated for all measures of pelvic motion and LP stabilization strength.

Results: There were no significant relationships found among any of the variables (P > .05). However, the LP stabilization strength test possessed good interday reliability.

Conclusions: The relationship between pelvic motion and muscle function should be studied under a variety of other conditions.

Key Words: kinematics; pelvic tilt, obliquity, and rotation


There are few studies that show clear evidence regarding the incidence of lower back injury in runners. There are, however, various other sources of information, such as athletic magazines, coaching texts, and anecdotes from coaches, that suggest that it is relatively high. There are a variety of explanations of the causes or mechanics of lower back injury. The most likely factor in such injuries in the lumbopelvic (LP) area is associated with the increased range of movement around the pelvis.

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The biomechanics related to gait and, in particular, abnormal pelvic mechanics have been examined from a clinical perspective. For running it has been suggested that there might be excessive movement in any of the 3 axes (pelvic tilt, pelvic obliquity, and pelvic rotation) because of poor control of the stabilizing muscles, leading to less effective transmission of forces through the pelvis and inefficient movement. A relatively large amount of movement around the LP area is thus related to lack of stabilization in the LP region. Commonly, abnormalities are said to exist in more than 1 angle of rotation of the pelvis, and lack of stability in 1 axis can predispose an athlete to developing problems in another angle. Muscles associated with 1 angle of rotation, if tight or loose, affect adjoining muscles related to rotation in another angle. The most common abnormalities found are excessive pelvic tilt, pelvic obliquity, and pelvic rotation. Thus, if there were excessive range of motion around 1 of the angles of rotation, at least 1 of the other 2 angles would be affected with more or less movement. Excessive pelvic obliquity can lead to excessive strain and inflammation of lateral hip structures, as well as of the lumbar spine. Again, these theories suggest that excessive movement of the pelvis is a cause of lower back injury.

To date, there are few published studies quantifying the 3-dimensional kinematics of the LP region during running, and those studies are all limited by small samples and relatively slow running speeds. Also, the subjects were mostly young children and race walkers. In 1 study, only sagittal-plane movements were measured, and other kinematic data were discarded. Therefore, the data from these studies cannot be used to define the normal kinematics of the LP region during running in mature, elite distance runners.

In general, the forces and moments generated in the spine during running are of magnitudes that do not place the spine at risk for injury. However, biomechanical abnormalities and situations such as hill running can increase the forces and aggravate existing lower back injuries. During normal activity there is some necessary rotation of the pelvis in the 3 axes, encompassing the "neutral zone." Movement out of the neutral zone or excessive or abnormal forces increase the risk that some type of injury will occur. This is primarily because the LP region is the site of origin and insertion of many muscles of the trunk and lower limbs, with a combination of these muscles working to maintain posture.

The purpose of this study was to determine whether there is a relationship between LP stabilization strength and pelvic motion during running on a treadmill. If a greater degree of pelvic rotation is associated with poorer LP stabilization strength, the latter might potentially influence the risk of lower back injury. Such a link would assist coaches and medical staff in designing programs aimed at injury prevention. There are few tests that assess LP stability, and there are no sport-specific tests for runners. Finally, there have been no previous investigations into the relationship between LP stabilization and pelvic motion during running.
Methodology

Sixteen elite male middle- and long-distance runners, with a mean weight of 65.28 kg (± 6.56) and height 178.72 cm (± 6.21), ranging in age from 18 to 30 years participated as subjects. Half were of an international standard, and the rest were of a national standard.

LP Stabilization Strength Test

An LP stabilization strength test was developed for the study. It required that the subject lie supine on the floor (Figure 1, top), with a pressure biofeedback device (Stabilizer, Chattanooga Pacific, Australia) that is sensitive to the pressure exerted on it placed in the space between the lumbar curve and the floor. The legs were held in a "neutral position," with the hip and knee at 90°. A neutral position was defined as when the pelvis was not rotated, the muscles around the pelvis were totally relaxed, and the full weight of the legs was held by the tester.

The biofeedback device was inflated to 40 mmHg, and a knee brace was used to maintain the knee at 90° to minimize the effort exerted by the vasti muscle group. The knee brace was made of a lightweight, hard polycarbonate plastic and resembled a shell of the outside of the back of the knee and leg. It was constructed by draping a large sheet of polycarbonate over a plaster cast of a human knee bent at 90°, which was built up so it

![Diagram of lumbopelvic stabilization strength test, side and top views.](image-url)
could be used for the left or right leg. The polycarbonate shell was held on the leg using 4 Velcro™ straps, 2 above and 2 below the knee. A weight was attached to the shoe of 1 foot. When the foot was weighted there was a tendency for the lower back to hyperextend, thus increasing pelvic tilt and reducing the pressure reading. The athlete resisted this movement by contracting the LP musculature to maintain the body in a neutral position. If pressure was maintained between 40 and 50 mmHg (allowing fluctuations resulting from breathing) during the muscular contraction for 3 seconds, the abdominal musculature was considered to have successfully stabilized the LP region. The weight was increased in relative increments to minimize the factor of fatigue associated with repeated trials to reach the maximum weight. The test was based on a 1-repetition-maximum procedure, wherein the test was repeated until LP stability could no longer be maintained. The LP stabilization strength was the maximum weight held without losing the neutral position.

Because the load was placed on 1 foot only, it would tend to cause rotation around a longitudinal axis, wherein the leg would move away from the body (Figure 1, bottom). The subjects were instructed to maintain their feet and knees the same distance away from the midline in order to decrease the variation of the rotation when 1 foot was loaded. Two axes of rotation were involved during the test—anterior and longitudinal—unique for an LP stabilization test.

**Pelvic Motion Analysis**

The second test examined pelvic motion during running using the VICON motion-analysis system (Oxford Metrics Ltd, Oxford, England). The data were processed using Clinical Manager software, version 2.5. The initial step involved measuring and noting various anatomical measures according to specifications in the manual, for example, height, weight, leg length, and knee width. The information was used by the software to calculate joint centers with respect to retroreflective markers, which were placed over anatomical sites as described in the Clinical Manager Handbook. There were 6 cameras (operating at 200 Hz) used, which were positioned as shown in Figure 2. A combination of cameras was used to detect and coordinate the markers to build a 3-dimensional model. Calibration was undertaken as described in the Clinical Manager Handbook.

The running test required the participant to perform a submaximal treadmill run at a speed that was approximately 10-km race pace (5 m/s) for 2 min. The subjects ran at 3.3 m/s for 5 min as acclimatization to the treadmill. The velocity was then increased to 5 m/s for 2 min. At the end of the 2 min, 5 seconds of data were recorded. All complete gait cycles in the 5 seconds were averaged. The maximum ranges of angular displacement of the 3 angles were collected and analyzed. Pelvic tilt was measured by the rotation of the pelvis around the anterior–posterior axis defined by the 2 anterior–superior iliac spines (Figure 3). Pelvic obliquity was measured
Figure 2  Placement of video cameras for assessment of pelvic motion.

Figure 3  Diagrams of (A) positive pelvic tilt (side view), (B) pelvic obliquity (front view), and (C) pelvic rotation (top view).

about an axis of 90° to the pelvic-tilt axis through the bisection of and a marker between the posterior-superior iliac spines. The pelvic rotation axis is at 90° to both the anterior-posterior axis and the anterior-superior iliac spine axis.

Data Analysis

The project involved determining the relationship between LP stabilization strength and pelvic motion. Results from the LP stabilization test were divided into several variables. The weight each leg lifted was measured in absolute terms (the weight of the load) and relative to body weight (body weight divided by load weight). The measurements relative to body weight
were used as a normalization method, because heavier individuals tend to lift heavier weights. The difference between the left and right legs was also analyzed and also noted in absolute and relative terms. Pelvic motion was divided into 3 categories: pelvic tilt, pelvic obliquity, and pelvic rotation. A summary of the results from the LP stabilization strength test and pelvic motion assessment is shown in Table 1. Each value of the LP stabilization strength test was correlated with each of the individual angles of pelvic rotation (Table 2). Thus, a total of 18 correlations was calculated, using a 2-tailed Pearson’s correlation coefficient with a .05 level of significance.

To determine the reliability of the LP stabilization strength test, it was conducted on 2 separate days for both the left and the right leg. The reliability was determined using technical error of measurement, which com-

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
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<td>LP stabilization strength test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute left</td>
<td>6.10 kg</td>
<td>1.44 kg</td>
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<tr>
<td>Relative left</td>
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<td>.018</td>
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<tr>
<td>Absolute right</td>
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<td>.021</td>
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<tr>
<td>Absolute difference</td>
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<td>0.72 kg</td>
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<tr>
<td>Relative difference</td>
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<td>.012</td>
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<td>Pelvic tilt</td>
<td>7.63°</td>
<td>1.47°</td>
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<tr>
<td>Pelvic obliquity</td>
<td>15.84°</td>
<td>2.81°</td>
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<td>Pelvic rotation</td>
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<td>5.27°</td>
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<table>
<thead>
<tr>
<th>Variable</th>
<th>Pelvic Tilt</th>
<th>Pelvic Obliquity</th>
<th>Pelvic Rotation</th>
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<tr>
<td>Absolute left</td>
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<td>.32, P = .221</td>
<td>.15, P = .569</td>
</tr>
<tr>
<td>Relative left</td>
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<td>.22, P = .415</td>
<td>.03, P = .917</td>
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<tr>
<td>Absolute right</td>
<td>.02, P = .950</td>
<td>.26, P = .338</td>
<td>.20, P = .468</td>
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<td>Relative right</td>
<td>.04, P = .880</td>
<td>.12, P = .647</td>
<td>.07, P = .800</td>
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<tr>
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<td>-.02, P = .943</td>
<td>.04, P = .879</td>
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<td>Relative difference</td>
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<td>-.04, P = .872</td>
<td>-.01, P = .974</td>
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pared both sets of data and an intraclass correlation (Table 3). The intraclass correlations for the left and right legs were similar, at .91 and .92, respectively.

### Results

Overall there were no significant correlations ($P > .05$) between any of the variables (Table 2). The strongest correlation, .32, was between absolute right and pelvic obliquity. The low correlations indicate that there is no significant relationship between any values of the LP stabilization strength test and the 3 angles of rotation. The test was found to have an adequate level of reliability (Table 3).

### Discussion

From the interday reliability data, the slight increase noted might be expected, possibly the result of learning. The biofeedback device used in the LP stabilization strength test is believed to be useful in a clinical setting to assess postural and muscular dysfunction in the LP area. However, further refinement of the technique is needed to validate it as a research tool. It was also found that there was no significant relationship between LP stabilization strength and pelvic motion in the 16 runners who were tested.

A few reasons for the lack of a significant relationship between the LP stabilization strength test and pelvic motion in the 3 angles are possible. It might be that other muscle groups, aside from the abdominals, control LP stabilization. The LP stabilization test aimed to involve some of the other muscle groups, but too much emphasis was placed on the abdominals and not enough on other regions. Most pelvic stabilization tests involve the use of both legs, producing a rotational effect only in 1 axis (anterior–posterior). The loading of the pelvis in 2 axes of rotation was a unique factor of the LP stabilization strength test; the aim was to include not only the abdominals but also other stabilization muscles. It is also possible that, because the LP stabilization strength test was conducted in a supine position and the pelvic motion assessment in the erect position, they might not be compatible.
The effect of gravity on the weight-bearing muscles might have altered the pattern in which muscles were activated. Electromyographic analysis of the muscles in the region would be a way of assessing the appropriate innervation of the associated muscles. One or two muscles alone do not control stabilization of the pelvis, but rather a large number of muscles interacting in a pattern. With movement of the pelvis controlled by a large number of muscles that attach to or are associated with the area, it is difficult to determine which were activated; for example, stabilization of the pelvis in the stance phase relies on the lateral musculature of the hip.

Angular displacement of the pelvis during running might only become excessive when one is fatigued, which suggests that LP stabilization strength and endurance would be more relevant to assess. An LP stabilization strength-endurance test could involve holding a set weight until there is deviation from the neutral zone, using time as the method of measurement. The original test could also be completed after a fatiguing run such that the stabilization muscles have been exerted. We also suggest that pelvic motion be analyzed until fatigue. The stabilization muscles might be able to maintain the neutral zone when they are in an unfatigued situation, but in a race situation or during hard training this might not be the case.

Pelvic motion assessment, using the VICON, was conducted at the speed of 5 m/s to standardize with other tests and as the pace for a 10-km race. This pace might have been too slow to stress the muscles involved in stabilization of the pelvis and thereby increase the amount of pelvic motion. It might be beneficial in future research to use a variety of speeds. At the pace that was chosen for this study, the body might have been able to maintain a good posture. But if the pace were increased the associated relationship might occur, because the muscles would be unable to maintain the movement of the pelvis in the “normal” range. In a biomechanics review of running, it was concluded that when significant differences were reported they were generally for speeds higher than 5 m/s. Thus, a significant increase in the range of the movement in the 3 axes of rotation of the pelvis might be associated only with a speed higher than 5 m/s.

The elite group of runners tested was relatively homogeneous with respect to pelvic stability, and different results might be obtained for recreational runners or a more heterogeneous group. If a wider sample were taken, including recreational runners or women, a greater variety of body types would be included and assessed.

The VICON and Clinical Manager test procedures appear to be clinically useful for assessing abnormalities in pelvic motion, but there is no evidence at present of their reliability or validity.

**Conclusion**

There was no significant relationship found between LP stabilization strength and pelvic motion in runners. However, the LP stabilization test
that was designed for the study, specifically for runners, was found to be reliable. Further investigation is needed to determine whether the LP stabilization strength test is a valid research tool.

Recommendations for further research include assessing the relationship between LP stabilization strength and pelvic motion under a variety of conditions. Electromyographic analysis of muscles activated during running and muscles activated during the test might also prove useful. A running test to the point of fatigue should be considered when testing for longer periods or for speeds greater than 5 m/s. One might also consider a strength-endurance test of LP function whereby a time factor is entered. An evaluation of the tightness/flexibility and strength of all muscles controlling pelvic motion might also be useful, and pelvic motion assessment could be conducted over a range of running speeds. Finally, because this study included only elite male athletes, it is necessary to assess recreational runners and women, also.

Acknowledgments

The following people are acknowledged for their contribution to this manuscript: Peter Lendiers, from the Prosthetics and Orthotics department of the Queen Elizabeth Hospital, Ballarat; Dick Telford, head distance-running coach at the Australian Institute of Sport (AIS); and David Rath, VICON Clinical Manager technician, AIS.

References


