

## [ Physical Therapy ]

# Relationship Between Body Positioning, Muscle Activity, and Spinal Kinematics in Cyclists With and Without Low Back Pain: A Systematic Review

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**Context:** Low back pain is reported by more than half of cyclists. The pathomechanics and association of risk factors of lumbar spine overuse injuries in cycling are not clearly understood.

**Objective:** To determine whether relationships exist between body positioning, spinal kinematics, and muscle activity in active cyclists with nontraumatic low back pain.

**Data Sources:** In August of 2015 and April of 2016, a comprehensive search of the PubMed, CINAHL, Ovid MEDLINE, and Scopus databases was performed independently by 5 reviewers.

**Study Selection:** Included articles consisted of biomechanical studies examining factors relating to low back pain in cyclists as agreed upon by group consensus.

**Study Design:** Systematic review.

**Level of Evidence:** Level 4.

**Data Extraction:** Five reviewers appraised by consensus each article using the Downs and Black checklist.

**Results:** Eight studies met criteria for this review. There is evidence that cyclists with lower handlebar heights displayed increased lumbosacral flexion angles during cycling. Core muscle activation imbalances, back extensor endurance deficits, and increased lumbar flexion while cycling were found to be present in cyclists with low back pain.

**Conclusion:** Spinal and core muscle activation imbalances in a prolonged flexed posture associated with cycling may lead to maladaptive spinal kinematics and increased spinal stresses contributing to overuse low back pain.

**Keywords:** cycling; low back pain; muscle activity; spinal kinematics

In cycling, the occurrence of traumatic and nontraumatic (overuse) injuries is about equal,<sup>12</sup> with approximately 23 million cyclists developing at least 1 overuse injury in their lifetime in the United States alone.<sup>6,22,35</sup> The majority (51.5%) of cycling-related injuries reported over a 4-year period were considered due to overuse.<sup>5,12</sup> Of these overuse injuries, low back pain (LBP) is the most prevalent.<sup>10,13</sup> Fifty-eight percent of professional cyclists reported LBP, of which 41% sought medical attention, and up to 22% of cyclists with LBP lost time from activity.<sup>10</sup>

During cycling, various positions are used to achieve proper aerodynamics to increase speed and efficiency, including lumbar spine flexion.<sup>7,20,31,32</sup> A flexed spinal position commonly adopted by cyclists inverts the physiologic intervertebral angle, changing the area of spinal loading.<sup>32</sup> Sustained or repeated lumbar flexion is associated with LBP,<sup>8,11,29</sup> and the term *flexion pattern disorder* describes positional changes that occur in conjunction with nontraumatic LBP.<sup>7,14,28</sup> Core stability is essential to increase cycling power.<sup>1,32</sup> Bicycle component

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settings affect spine position during cycling, which subsequently impacts cycling efficiency.<sup>19</sup> Thus, it is hypothesized that altered spinal kinematics or core muscle activation patterns, combined with the prolonged repetitive nature of the activity, lead to lumbar overuse injury.

Several mechanisms are hypothesized for the pathomechanics of LBP in cyclists, including mechanical creep (a deformation or strain of ligaments that occurs with constant loading), disc ischemia, muscle fatigue, and overactivation of back extensors. Another mechanism is the flexion-relaxation phenomenon, in which deactivation of the erector spinae and/or multifidus muscles with a flexed spine causes vertebral body loading to shift to the passive spine structures of the spine, thus increasing risk to ligaments and intervertebral discs.<sup>15,21,22</sup> However, there is little scientific evidence to support these mechanisms.<sup>15,22</sup> Furthermore, several risk factors are related to LBP in cyclists, including muscle activation asymmetries, flexibility, bicycle fit, and training volume; however, the evidence in an early systematic review was not strong.<sup>22,24</sup> Of these risk factors, bike fit shows the strongest relationship with LBP in cyclists.<sup>13,17,22,31</sup> A 10° to 15° change in anterior tilt of the saddle eliminated LBP in 29 of 40 cyclists and decreased pain in 8 others.<sup>31</sup> However, the impact of bike fit on overuse LBP in cyclists in relation to the other risk factors is unclear. Thus, the aim of this systematic review is to determine whether relationships exist between body positioning, spinal kinematics, and spinal muscle activity in cyclists with nontraumatic LBP and how bike fit affects these factors.

## METHODS

### Search Strategy

The initial search was performed on July 16, 2015, using the following databases: PubMed, CINAHL, Ovid MEDLINE, and Scopus, focusing on cyclists with nontraumatic LBP. The initial search included the general terms *cycling*, *cyclists*, *bicycling*, *LBP*, *overuse injury*, and *back pain* in the following combinations across databases: cycling AND low back pain, cyclists AND low back pain, cyclists AND overuse injury, bicycling AND back pain. Search results were compiled and screened for titles of relevance using group consensus. Duplicates across databases were removed, resulting in 50 articles (Figure 1).

### Selection Criteria

Of the 50 articles selected, abstracts were screened based on inclusion criteria of biomechanical studies examining LBP in cyclists as agreed upon by group consensus. Studies included were comparison studies, cross-sectional studies, and case-based studies evaluating muscle activity and characteristics, spinal position or angles, and bicycle in subjects experiencing nontraumatic LBP, nonspecific LBP, or overuse LBP. Studies prior to 2007 that were included in the systematic review by Marsden and Schwellnus<sup>22</sup> were excluded to focus on the most current literature (Figure 1). An additional search was conducted on

April 1, 2016, using the same methodology as the original search (Figure 1).

### Data Collection

Five reviewers read and then discussed articles meeting the selection criteria. Articles were graded using the Downs and Black quality assessment scale for assessment of methodological quality and risk of bias, and all grades were assigned based on group consensus.<sup>16</sup> The Downs and Black scale is considered a valid and reliable checklist for nonrandomized studies and was deemed most appropriate due to the observational nature of the included studies.<sup>16,18</sup> Data extracted from articles included participant population, variables measured, and conclusions (see the Appendix, available at <http://sph.sagepub.com/content/by/supplemental-data>).

## RESULTS

### Study Selection

Of the 50 articles in the initial search, 16 were deemed eligible based on inclusion criteria. Nine articles were excluded due to inclusion in the review by Marsden and Schwellnus.<sup>22</sup> From the second search, 1 additional article was deemed eligible, resulting in a total of 8 included studies (see the Appendix). The number of subjects ranged from 1 to 120 subjects, with a total of 255 subjects.

### Study Characteristics

Studies included only men, aged 18 to 57 years (weight, 54.43–72.57 kg; height, 1.6–1.85 m). Four studies utilized a within-participant study design, 3 a case-control design, and 1 was a single case study. Six studies included participants with cycling experience, ranging from elite,<sup>25</sup> master,<sup>25</sup> professional,<sup>23</sup> professional competitive off-road,<sup>30</sup> competitive,<sup>34</sup> and unspecified,<sup>4</sup> with no definitions provided for these categories. Two studies<sup>3,9</sup> included participants without cycling experience. Four studies<sup>23,25,33,34</sup> reported cycling experience ranging from 6 to 17 years. Three studies<sup>4,30,33</sup> compared participants with and without LBP.

### Assessment of Included Studies

Four studies<sup>3,4,33,34</sup> had sample sizes of less than 20 participants, which limits statistical power. The median Downs and Black score of the studies was 12 of 27, with the highest score of 20. Therefore, studies were of low to moderate quality.<sup>18</sup> No blinding occurred in any studies.

### Methodology and Outcomes Measured Across Studies

Methodology and outcomes measured varied across studies. Four studies<sup>3,4,30,34</sup> utilized surface electromyography (sEMG), ultrasound, and biofeedback techniques to measure muscle fatigue, flexibility, and/or strength. Another study<sup>3</sup> examined 3 different frame types and their impact on muscle activity using sEMG. The frames included a rigid frame (rigid fork, fixed rear,

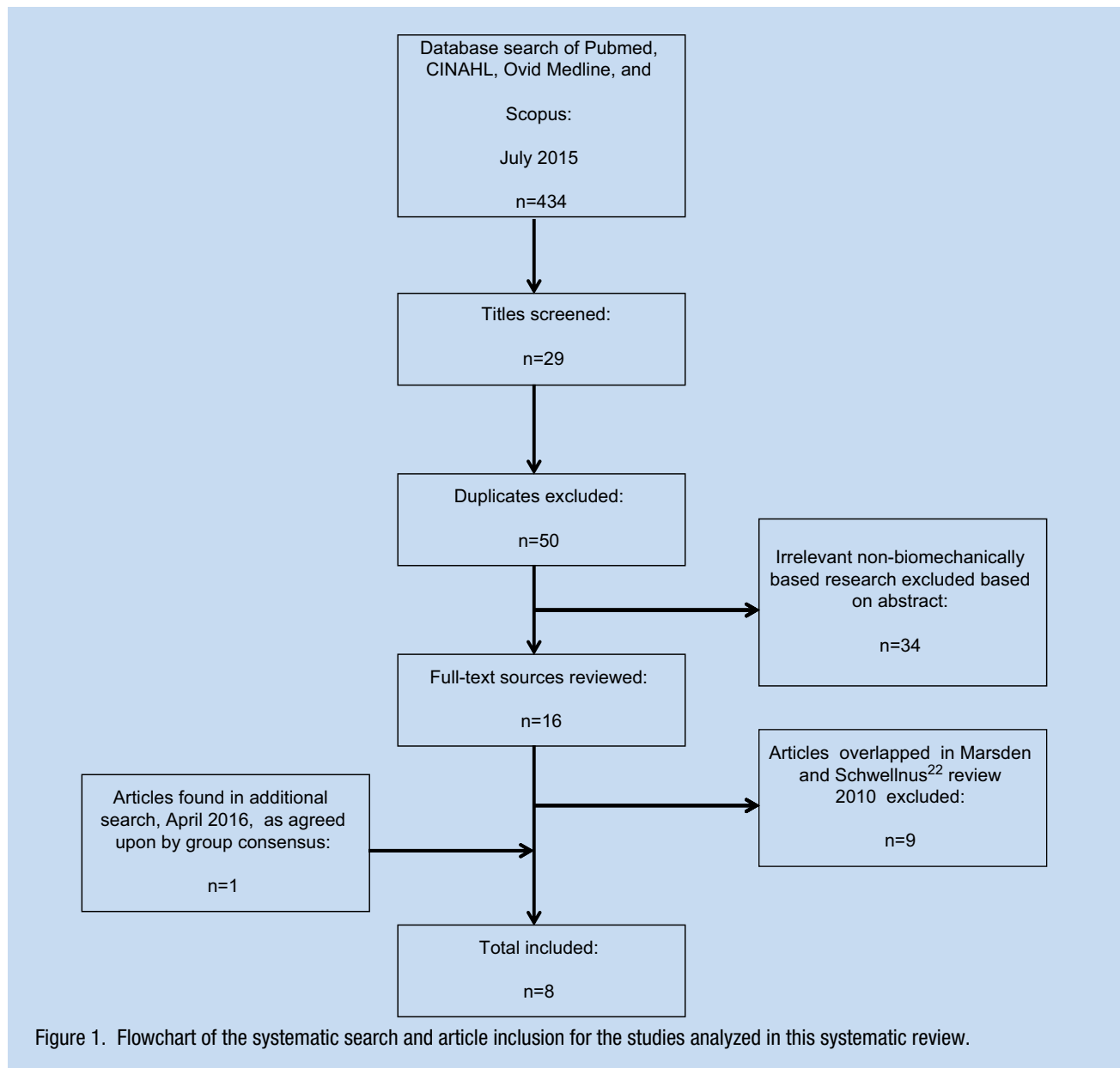


Figure 1. Flowchart of the systematic search and article inclusion for the studies analyzed in this systematic review.

no suspension), suspension frame (rear triangle attached by links to rear shock for a progressive spring rate), and sports frame (racing handlebar, narrow tires, no suspension).<sup>3</sup>

Three studies<sup>9,23,25</sup> examined spinal kinematics with different handlebar heights. Selected handlebar height, defined as the difference in height between the handlebars and the saddle,<sup>9</sup> was inconsistent across studies. Two of 3 studies<sup>23,25</sup> used an upper, middle, and lower handlebar-hand position, with 1 study also including an aerodynamic position with forearms on aerobars.<sup>23</sup> The remaining study<sup>9</sup> analyzed 5 specific handlebar height conditions.

One kinematic study<sup>33</sup> measured spinal flexion using a posture-monitoring system, which consisted of a lightweight strain gauge attached to the cyclist's lumbar spine that detected

changes in spinal flexion during cycling. Other studies used video motion capture to measure spinal angles<sup>9</sup> or a surface-based computerized technique using a mouse placed over landmarks to identify sagittal spinal range of motion and intervertebral angles.<sup>23,25</sup> Measures used to assess pain also varied across studies and included the Rehabilitation Bioengineering Group pain scale<sup>3</sup> and the Numeric Pain Rating Scale.<sup>33,34</sup>

#### Bicycle Fit, Muscle Activity, and Low Back Pain

Two studies<sup>3,4</sup> applied sEMG to spinal and arm musculature to measure muscle fatigue. Subjects with LBP experienced fatigue in arm and spinal musculature associated with postural support and stability.<sup>4</sup> Balasubramanian et al<sup>3</sup> reported greatest arm and

spinal muscle fatigue with a sports frame as compared with rigid or suspension frames. Utilizing ultrasound, Rostami et al<sup>30</sup> determined that participants with LBP had reduced abdominal and back musculature thickness at rest and during contraction compared with the asymptomatic group (see the Appendix).

### Bicycle Fit and Spinal Kinematics

Three studies examined the effects of various handlebar heights on pelvic and spinal position.<sup>9,23,25</sup> Chen and He<sup>9</sup> used handlebar heights of 16, 8, 0, -8, and -16 cm, while Muyor<sup>23</sup> investigated upper, middle, lower, and aerodynamic handlebar-hand positions (defined by the position of the hand placement on the handlebar). These studies reported that lower handlebar heights increased lumbar flexion,<sup>9,23</sup> decreased lumbosacral angle,<sup>9</sup> and increased anterior pelvic tilt relative to the vertical plane (see the Appendix).<sup>23,25</sup>

### Spinal Kinematics, Motor Control, and Low Back Pain

Spinal kinematics of cyclists with and without nonspecific LBP were compared during an on-road cycling task.<sup>33</sup> Subjects with LBP adopted greater lumbopelvic flexion and spent more time in end-range lumbopelvic flexion. In a case study,<sup>34</sup> a cognitive functional therapy intervention using lumbar biofeedback significantly reduced lumbopelvic flexion and reported pain after intervention (see the Appendix).

## DISCUSSION

The results of this systematic review provide support for the hypothesis that muscle activation imbalances of the core and spinal musculature are risk factors for LBP in cyclists. There is also some evidence that the prolonged, flexed-spine position during cycling is related to LBP. These findings thus add more evidence than the 2009 review by Marsden and Schwelnus,<sup>22</sup> which found limited empirical support for any proposed mechanism or associated risk factors other than proper saddle angle positioning.

The 3 studies that examined the relationship between bicycle positioning and muscle activity provide different insight into LBP in cyclists. The relationship seen between upper extremity fatigue in cyclists with LBP suggests that cycling with LBP may increase exertion by the upper extremity on the handlebars to compensate for pain.<sup>4</sup> Increased muscle recruitment and fatigue was also seen when subjects were positioned in an aerodynamic flexed posture on a sports cycle.<sup>3</sup> Cyclists with LBP also demonstrated asymmetrical co-contraction of the lumbar multifidi muscles,<sup>7,22</sup> decreased thickness of the transverse abdominus and lumbar multifidi,<sup>30</sup> and decreased back extensor endurance when compared with cyclists without LBP.<sup>30</sup> As back extensor muscle activity is proportional to pedaling intensity,<sup>32</sup> these alterations may decrease desired performance.

The 3 studies<sup>9,24,25</sup> examining the relationship between position on the cycle and spinal kinematics all demonstrated that lower handlebar positioning resulted in greater lumbar

flexion. The correlation between lumbar stability and nontraumatic LBP has significant support in the literature, and lumbar positioning, including prolonged flexion, negatively affects spinal pathology and symptoms.<sup>14,26-28,34</sup> This concept is supported by Van Hoof et al,<sup>33</sup> who showed that cyclists who reported significant increases in LBP during a 2-hour cycling task adopted greater lumbopelvic flexion and spent more time in end-range lumbopelvic flexion compared with age-matched asymptomatic controls. Burnett et al<sup>7</sup> also demonstrated increased lumbar spinal flexion and rotation in symptomatic cyclists compared with controls. Spinal kinematics in subjects with LBP in the study by Van Hoof et al<sup>33</sup> did not significantly change during the 2-hour cycling task, but the LBP group assumed greater lumbopelvic flexion at the start of the task.

It is unclear which comes first: muscle imbalances affecting spinal kinematics or altered spinal kinematics, which lead to muscle activation imbalance. Cyclists with LBP assume a more flexed position at the start of cycling, and this position does not change during cycling; however, pain increases. These findings may indicate maladaptive motor control of the spine during cycling as a causative factor.<sup>33</sup> Another implication is that decreased endurance of the low back musculature may play a role in spinal kinematics or spinal loading. If there are existing endurance deficits of the musculature supporting the spine, then it is possible that when fatigued, the spine may absorb an increased load and stress as stated by the flexion-relaxation hypothesis. This shift in spinal forces and load displacement reinforces the concept that it may not be the body positioning on the bike that matters but the time spent in that position and concurrent muscle activation imbalances or endurance deficits that may contribute to overuse LBP.

Only 1 study in this systematic review included an intervention for cyclists with LBP. Improved motor control of spinal kinematics during a bout of cycling and improved LBP symptoms were found after biofeedback training.<sup>34</sup> As the intervention is based on the subject's conscious motor control of spinal kinematics while cycling, there are implications that impaired motor control may result in more end-range flexed posture, including a loss of lumbar lordosis<sup>34</sup> while cycling, potentially contributing to flexion-related lumbar pain. The participant may have had difficulty maintaining lumbar lordosis due to back extensor endurance impairments, which matches the findings of Rostami et al.<sup>30</sup>

There are limitations in this systematic review, including small sample sizes, differing measurement techniques, varied populations, and varying areas of study focus. Studies were prone to selection bias as participants were not randomly selected from the population. Furthermore, participants and examiners were not blinded. The variance of participant's cycling experiences creates another limitation: the generalizability of the results. A categorization of cycling based on activity level has been proposed by Ansley and Cangle<sup>2</sup> to improve the ability to compare results across studies. Overall, these limitations impact the ability to compare findings directly across studies.

Based on this systematic review, there is greater evidence for altered muscle activity and increased spinal flexion in cyclists with LBP.

## CONCLUSION

The results of this review suggest that there are relationships between common risk factors that warrant further exploration. Spinal and core muscle activation imbalances in a prolonged flexed posture associated with cycling may lead to maladaptive spinal kinematics and increased spinal stresses contributing to LBP.

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