Lumbar spine and pelvis alignment in cycling

A Chapman, R J Newsham-West, P D Milburn

Centre for Physiotherapy Research, School of Physiotherapy
University of Otago, Dunedin

ABSTRACT

Background: Despite the prevalence of low back pain (LBP) in cyclists, little is known regarding the motion of the lumbar spine and pelvis during cycling.

Hypothesis: An increase in motion of the lumbar spine occurs with an increase in cycling intensity.

Study Design: Descriptive laboratory study.

Methods: Nine male cyclists who competed in the top category in the regional road cycling competition (age: 34.8, SD 10.9 years) volunteered to participate in this study. Retro-reflective markers (N=36) were placed on subject landmarks and 3D kinematic data were collected at 100 Hz using a 12 camera motion analysis system (Motion Analysis Corporation, USA). Three cycling protocols - 50%, 90% steady-state, and accelerating from 50 to 90% - were repeated three times and all were conducted during one session per subject.

Results: The motion segments which showed the greatest range of movement (ROM) were lateral tilt of the pelvis in both the slow (50%) and fast (90%) trials, with a slightly larger pelvic tilt ROM in the faster trial. The motion segments with the smallest ROM were the mid lumbar and thoraco lumbar flexion consistently through all trials. There was a leg-dependent pattern of increased trunk and hip flexion when the pedal was at the 3 and 9 o’clock position and increased lateral pelvic tilt towards the leg at the bottom of the pedal stroke at the 12 and 6 o’clock position.

Conclusion: Eight of the 9 subjects had a history of LBP in the previous 12 months and tended to fall into two groups; larger range of motion or limited range of motion. Movement in both the sagittal and coronal planes is dependent on the phase of the pedalling cycle, with an increase in sagittal flexion occurring when a leg is at the anterior position of the pedal stroke (at the 3 and 9 o’clock pedal position) and an increase in side flexion towards the leg at the bottom of the pedal stroke (at the 12 and 6 o’clock pedal position).

Clinical Relevance: While there were two patterns of motion identified that occur with cycling, it is unclear whether greater or reduced motion is a risk factor for developing non specific LBP.

Key words: Cycling, motion, 3D kinematics, lumbar spine

INTRODUCTION

Low back pain (LBP) in cyclists has long been recognised anecdotally and in the literature as a common injury. In a study of recreational cyclists, Wilber et al. reported back pain or injury to the lower back in 30% of cyclists, while Callaghan & Jarvis showed that 60% of elite British cyclists reported LBP during an annual medical review. Despite its prevalence there is a paucity of published information regarding the role of lumbar spine and pelvis posture, trunk posture relative to bike motion, and lower limb motion in the etiology of LBP in cyclists.

The onset of insidious LBP has been linked anecdotally by clinicians to poor cycling biomechanics and bike set-up. McGill suggested that both sustained lumbar flexion and the duration of sitting were risk factors for low back injury, and because cyclists adopt a flexed trunk posture for long periods of time during training, it is believed this sustained flexed posture is a cause of LBP. Another possible mechanism associated with overuse back injuries in cyclists include the flexion-relaxation phenomenon of the erector spinae muscle and the associated increased tissue strain across lumbar spine from over-activation of erector spinae and associated microtrauma to the posterior annulus.

The basis behind these aetiological factors associated with insidious onset LBP is the biomechanical model of cycling posture and bike set-up. However, one study that investigated lumbar spine and lower
limb motion at different positions using single plane x-ray analysis concluded that "...cycling does not generate biomechanical forces that are dangerous for the lumbar spine" 9 (p 1969). These results are of limited utility as they were based on a static analysis of spinal positioning and did not take into account the three dimensional (3D) nature of movement nor the change in posture associated with change in intensity of cycling. Intensity has been anecdotally described by clinicians associated with elite cycling teams as one of the aggravating factors for LBP in this population.

Despite the fact that the cyclist is supported by the hands and seat whilst sitting, movement is still available in all planes due to the seat design. The seat is designed for minimal support and accepts weight predominantly from the ischial tuberosities onto a wider posterior aspect with a thin nose between the thighs allowing free lower limb movement. It can therefore be assumed that poor co-ordination of movement within the kinetic chain (lumbar spine, pelvis and lower limb) will result in movement of the weight-bearing pelvis, particularly when a change in cycling intensity occurs.

Most published literature on lumbar movement in cycling has focussed on movement that occurs in the sagittal plane and has not considered rotation or side flexion2. Burnett et al2 looked at trunk rotation in cyclists on a static ergometer and found that cyclists with non-specific chronic LBP tended to have greater lower lumbar spine rotation and flexion along with greater asymmetry of lumbar multifidus as measured with electromyography (EMG). As the lumbar multifidus is a key stabiliser of the lumbar spine and acts as a rotator when activated unilaterally, asymmetric EMG activity may indicate that rotation is occurring. There also appears to be a movement pattern of rotation or side flexion that occurs naturally with cycling. At lower power outputs the cyclist is able to maintain a static position on the saddle, but once at a higher work load, altered patterns become more evident.

The design of the elite cyclist’s bike seat is to maximise lower limb movement, but may have reduced the stability provided by the seat. If the muscles that stabilise the trunk are not effective, either through poor activation, inadequate strength or asymmetry, then compensatory movement of the lumbar spine and pelvis are likely to occur during cycling. The aim of the present study was to describe the posture and motion of the lumbar spine and pelvis of competitive cyclists during steady-state cycling and to determine if changes occur in the posture and motion of the lumbar spine and pelvis of cyclists when there is a change in cycling intensity.

METHODS

Nine male cyclists who competed in regional road cycling competition were recruited for this study. Subjects who had current or a history of back pain or injury within the last six months that prevented them from participating in training or racing were excluded, and all subjects were given a brief screening examination by a physiotherapist to exclude any clinically significant back dysfunction. Ethical approval was obtained from the University of Otago Human Ethics Committee.

Testing was conducted at the School of Physiotherapy during one session per subject. Height, weight, seat height and in-seam length measurements were recorded as were cycling experience and workload. The warm-up consisted of 10 minutes at a self selected easy pace that produced mild sweating and was performed on the same air braked ergometer that was to be used during recording (Bike Technologies-Advanced Training System, BT-ATS). Following the warm up 36 retro-reflective markers were placed on the subject at the following locations: sternal notch, T1, T4, T12, L3 and L5; and bilaterally on

Figure 1: A: Side view demonstrating retro-reflective marker placement; B: rear view demonstrating retro-reflective marker placement. Subjects used their own bicycles which were fitted onto an air-braked ergometer (BT-ATS). The marker set allowed 3D reconstruction of trunk, pelvis, thigh and shank.
each lower extremity: posterior superior iliac spine (PSIS), anterior superior iliac spine (ASIS), iliac crest, greater trochanter, mid-thigh, anterior and posterior thigh, medial and lateral femoral condyles, medial and lateral malleoli, posterior heel, great toe, base of the 5th metatarsal (Figure 1). This marker set allowed the reconstruction of a trunk, pelvic, thigh, shank, and foot 3D link-segment definition of the cyclists. All subjects used their own bike during the testing procedures. A 12 camera motion analysis system (Motion Analysis Corporation, USA) was used to collect 3D kinematic data for 10 sec at a sampling rate of 100 Hz. A marker accuracy of <0.6mm was obtained within the calibrated volume of 2500 x 1500 x 2500mm for each subject.

A static recording was performed before removal of the medial condyle and malleoli markers of both legs and the subject mounted their bicycle to establish the thigh and body-fixed coordinate systems. Virtual marker points were calculated for the mid point between the two PSIS markers, mid point between the two ASIS points, mid point between the left ASIS and left PSIS and the mid point between the right ASIS and the right ASIS. The included angles of T4 - T12 - L3, T12 - L3 - L5, L3 - L5 - mid PSIS - mid ASIS, and the X, Y and Z components of the mid ASIS, mid PSIS, mid lateral right and mid lateral left virtual markers were calculated. The degree of anterior pelvic tilt was calculated using the X and Z coordinates of the mid PSIS and mid ASIS virtual markers and the extent of lateral pelvic tilt was calculated using the Y and Z coordinates of the mid lateral right and mid lateral left virtual markers.

The task consisted of three randomly-assigned protocols, each of which was performed three times. The first protocol was to ride at a self-selected 50% perceived exertion for 10 sec, the second protocol was at 90% of perceived exertion, and the final protocol involved the subjects achieving 50% of perceived exertion and 3 seconds after recording was started they were asked to accelerate up to 90% perceived exertion and continue at that pace for the remainder of the 10 seconds.

In order to compare various subjects and trials, the data were then appropriated to the points of a clock face, with the numbers denoted the position of the right pedal as viewed from the right side of the bicycle. Top dead centre (TDC) of the right pedal represented 12 o'clock and bottom dead centre (BDC) as 6 o'clock (Figure 2). The most anterior position of the right pedal was referred to as 3 o'clock and the most posterior 9 o'clock, with the other numbers of the clock face calculated at 30 deg. intervals from these points. Three consecutive complete pedal revolutions were analysed from each steady-state slow and fast trial and 4 consecutive pedal strokes were selected from the acceleration trial. Pre-analysis observation of the cycling protocol indicated the second and third pedal strokes represented the cycling kinematics of the acceleration phase between the slow and fast speeds (pedal stroke 1 and 3 respectively). As bicycle cranks are reciprocal the left crank is in the opposite position – at 12 o'clock it is at BDC and at 3 o'clock pointing posteriorly on the horizontal.

**RESULTS**

**Anthropometric Data**

The mean age of subjects was 34.8 (± 10.9) years, with a mean height of 180.1 (± 6.0) cm and weight of 79.7 (± 5.9) kg. All subjects had been competing in cycling for at least 3 years with a mean of 15.9 (± 11.6) years of cycling experience. The average duration of training at the time of data collection was 11.7 (± 5.5) hours per week (Table 1).

**Cadence**

While there was some variety in the self-selected cadences between trials and between individuals, intra-trial cadence remained consistent throughout the 10 sec. of slow and fast trials, and for the acceleration
Table 1: Descriptive data subjects.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Height</th>
<th>Weight</th>
<th>%Inseam</th>
<th>Leg length difference</th>
<th>Years cycling</th>
<th>Hours per week</th>
<th>Leg dominance</th>
<th>Current LBP</th>
<th>History LBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26</td>
<td>186.5</td>
<td>82</td>
<td>0.983</td>
<td>0</td>
<td>13</td>
<td>12</td>
<td>R</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>46</td>
<td>173</td>
<td>81</td>
<td>0.943</td>
<td>-1.5</td>
<td>16</td>
<td>17</td>
<td>R</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td>182</td>
<td>74</td>
<td>0.913</td>
<td>0</td>
<td>13</td>
<td>15</td>
<td>R</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>57</td>
<td>174.5</td>
<td>75</td>
<td>0.899</td>
<td>1</td>
<td>44</td>
<td>11</td>
<td>R</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>28</td>
<td>177</td>
<td>81</td>
<td>0.946</td>
<td>1</td>
<td>12</td>
<td>6</td>
<td>R</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>179</td>
<td>85</td>
<td>0.956</td>
<td>0</td>
<td>16</td>
<td>14</td>
<td>R</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>39</td>
<td>183</td>
<td>69</td>
<td>1.009</td>
<td>-0.5</td>
<td>3</td>
<td>4</td>
<td>R</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>21</td>
<td>191</td>
<td>88</td>
<td>0.951</td>
<td>0</td>
<td>7</td>
<td>20</td>
<td>R</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>36</td>
<td>175</td>
<td>82</td>
<td>0.938</td>
<td>0.5</td>
<td>19</td>
<td>6</td>
<td>L</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td>0.949</td>
<td>0.1</td>
<td>15.9</td>
<td>11.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>s.d.</td>
<td>11.6</td>
<td>6.0</td>
<td>5.9</td>
<td>0.033</td>
<td>0.8</td>
<td>11.6</td>
<td>5.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1Seat height as a percentage of inseam (bottom bracket to top of seat), 2Leg length difference as measured from greater trochanter to lateral malleolus fibula, 3Leg dominance as leg they would kick a soccer ball.

Figure 3: Pooled means (+sd) of the motion at thoraco-lumbar junction (A), mid lumbar (B), lumbo-pelvic junction (C), lateral lumbo-pelvic junction (D), anterior pelvic tilt (E), lateral pelvic tilt.
Table 2: Mean range of motion (+ SD) for acceleration phase. 1 is the first pedal stroke representing slow intensity, 2 and 3 are the acceleration pedal strokes, 4 is representative of fast intensity.

<table>
<thead>
<tr>
<th>Pedal stroke number</th>
<th>Flexion</th>
<th>Lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TL jn¹</td>
<td>mid Lx²</td>
</tr>
<tr>
<td>1</td>
<td>1.4</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>(0.8)</td>
<td>(0.6)</td>
</tr>
<tr>
<td>2</td>
<td>1.7</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>(1.1)</td>
<td>(0.3)</td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>(0.7)</td>
<td>(0.2)</td>
</tr>
<tr>
<td>4</td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>(0.8)</td>
<td>(0.3)</td>
</tr>
</tbody>
</table>

¹TL jn - thoraco-lumbar junction, ²mid Lx - mid lumbar spine, ³LP jn - lumbo-pelvic junction, ⁴P AP - anterior pelvic tilt, ⁵LP lat - lateral side flexion at lumbo-pelvic junction

The pelvis was laterally tilted to the left by 3.9 deg. in pedal stroke 1, which decreased slightly to 3.7 deg. in pedal stroke 2 and decreased further to 3.2 deg. in both pedal stroke 3 and 4. At low intensity cycling, maximum right lateral upward tilt of 1.8 deg. occurred at 6 o'clock, and consistent maximum left elevation of 2.1, 2.2 and 2.0 deg was each achieved at 7 o'clock for pedal stroke 2, 3 and 4 respectively (Figure 3).

MOTION OF LUMBAR SPINE

Slow

The mean flexion at the thoraco-lumbar junction at low intensity cycling followed a very shallow curve that ranged between 22.4 deg. of flexion at 12 o'clock and dipped slightly to 22.1 deg. at 5 o'clock (Figure 3). The mid lumbar flexion angle also followed a relatively flat pattern of motion ranging from 13.7 to 14.1 deg. dependent on leg position. Minimum values occurred at 12 and 6 o'clock coinciding with right and left TDC respectively, with highest values observed at 3 and 9 o'clock (Figure 3). The lumbo-pelvic angle varied by 0.6 deg. through the full pedal stroke, and followed the pattern of peak values at 1 and 7 o'clock and minimum values at 5 and 11 o'clock (Figure 3) that was slightly out of synchrony with the mid-lumbar flexion motion. The mean value for lumbar lateral flexion followed a reciprocal pattern of peak left side flexion at 12 o'clock and peak right side flexion at 7 o'clock with a range of 2.8 deg. (Figure 3).

Fast

The mean value for flexion at the thoraco-lumbar junction also followed a shallow curve that ranged between 23.8 deg. of flexion at 1 and 7 o'clock and dipped slightly to 23.4 deg. 3 and 10 o'clock (Figure 3). Mid lumbar flexion ranged from 14.6 to 15.5 deg. and followed the same leg-dependent pattern as the low intensity mean. Minimum values
Table 3: Mean range of motion (+ SD) comparing slow and fast intensities (Key as in Table 2)

<table>
<thead>
<tr>
<th></th>
<th>TL</th>
<th>mid Lx</th>
<th>LP</th>
<th>P AP</th>
<th>Lateral LP</th>
<th>P lat</th>
</tr>
</thead>
<tbody>
<tr>
<td>slow</td>
<td>x</td>
<td>1.1</td>
<td>1.0</td>
<td>1.4</td>
<td>1.7</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>sd</td>
<td>(0.4)</td>
<td>(0.5)</td>
<td>(0.7)</td>
<td>(0.8)</td>
<td>(1.5)</td>
</tr>
<tr>
<td>fast</td>
<td>x</td>
<td>1.2</td>
<td>1.2</td>
<td>1.8</td>
<td>2.6</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>sd</td>
<td>(0.6)</td>
<td>(0.3)</td>
<td>(0.7)</td>
<td>(1.2)</td>
<td>(1.4)</td>
</tr>
</tbody>
</table>

were seen at 12 and 6 o’clock and peak values at 3 and 9 o’clock (Figure 3). The lumbo-pelvic flexion angle varied by 0.8 deg. through the full pedal stroke and followed a sinusoidal curve with peak values at 1 and 7 o’clock and minimum values at 5 and 11 o’clock (103.4 and 102.6 deg. of flexion respectively) (Figure 3). Left side flexion of the lumbar spine on the pelvis was greatest just beyond TDC at 1 o’clock (2.3 deg.) and right side flexion peaked at 1.2 deg. at the 8 o’clock position. Whilst there was symmetrical movement either side of the midpoint, the midpoint did not occur on the vertical axis (Figure 3).

Acceleration Phase
The mean of thoraco-lumbar flexion varied only slightly throughout the acceleration phase, with peak values occurring at 12 o’clock throughout all pedal strokes and the minimum values occurring at different positions between 2 and 5 o’clock for different pedal strokes (Table 2). The mean pattern showed peak mid lumbar flexion at the 3 and 9 o’clock positions and minimum flexion at 6 and 12 o’clock. The amount of mid lumbar flexion increased slightly from pedal stroke 1 through to pedal stroke 4 during the acceleration phase. However, peak values of the lumbo-pelvic flexion occurred at the 1 and 7 o’clock position through all four pedal strokes and the low values for each pedal stroke occurred at the 4 and 10 o’clock positions. The peak values increased slightly for each consecutive pedal stroke during acceleration from 101.5 to 102.6 deg. and the minimum values also increased from 101.0 to 101.5 deg. (Table 2). Lumbar spine lateral flexion followed a matching reciprocal pattern of peak left side flexion at 1 o’clock and peak right side flexion at 7 o’clock for each pedal stroke. Pedal strokes 1, 2 and 4 had a range of 3.2 deg. and pedal stroke 3 had a range of 3.4 deg. (Table 2).

LUMBAR AND PELVIS MOTION

Slow
Peak lumbar flexion occurred halfway through the down stroke of the pedal cycle between 2 and 3 o’clock and again at 8 and 9 o’clock whilst peak anterior pelvic tilt occurred slightly later at 4 o’clock and 10 o’clock. At 12 o’clock the pelvis was laterally tilted to the left by 3.6 deg. and the lumbar spine was further left side flexed by 1.1 deg. As the foot descended, both the lumbar spine and pelvis shifted towards the right so that at BDC, and when the left lower limb was at TDC, the pelvis was laterally tilted to the right by 1.8 deg. and the lumbar spine was right side flexed by 1.6 deg.

Fast
The lumbar spine was flexed to its greatest extent at 1 and 2 o’clock and again at 7 and 8 o’clock (23.5, 15.5, 103.4 deg. for thoraco-lumbar junction, mid lumbar and lumbo-pelvic angles respectively). The highest anterior pelvic tilt values were found at 4 and 10 o’clock (33.7 and 33.9 deg. respectively), while greatest side flexion values for the lumbar spine occurred 1 and 2 o’clock (2.3 deg. Left) and 8 o’clock (1.2 deg. Right) that closely mirrored the peak value position for lateral pelvic tilt of 1 o’clock (4.1 deg. Left) and 7 o’clock (2.2 deg. Right).

Acceleration Phase
For thoraco-lumbar flexion, mid lumbar flexion, lumbo pelvic flexion, and anterior pelvic tilt, there was a pattern of increased flexion at 3 and 9 o’clock (23.9, 14.8, 101.8, 27.3 deg. thoraco-lumbar junction, mid lumbar, lumbo-pelvic and anterior pelvic tilt angles respectively) and low values of flexion at 12 and 6 o’clock (23.5, 14.4, 101.4, 26.0 deg. thoraco-lumbar junction, mid lumbar, lumbo-pelvic and anterior pelvic tilt angles respectively). Lateral bending of the trunk occurred slightly earlier in the pedal cycle, with peak left side flexion of between 2.1 and 2.3 deg. occurring at the 1 o’clock position. However, peak left lateral tilt of the pelvis between 2.3 and 3.9 deg. occurred at TDC although the peak value of 3.3 deg. for pedal stroke 4 was slightly later, at the 1 o’clock position. Peak right side flexion for each pedal stroke was less (0.9 to 1.1 deg.) and was found at the 7 o’clock position. Peak values of 1.8, 2.1, 2.2 and 2.0 deg. of right lateral tilt of the pelvis were observed at BDC for the low intensity pedal stroke 1 and 7 o’clock for pedal strokes during acceleration and at higher intensity cycling.
RANGE OF MOTION

Slow
The greatest range of movement of spine and pelvis segments was in the frontal plane. The lumbar spine showed an average range of 3.2 (±1.5) deg. of side flexion on the pelvis and the pelvis moved through an average range of 5.8 (±2.9) deg. of lateral tilt (Table 3). The segments which showed the least range of movement were the mid lumbar and thoraco-lumbar segments, moving through only 1.0 (±0.5) and 1.1 (±0.4) deg. respectively (Table 3).

Fast
At higher intensity cycling, the segments which showed the greatest range of movement were the frontal plane movement of the pelvis (6.8 ±3.0 deg.) and lateral flexion of the lumbar spine (4.0 ±1.4 deg.) (Table 3). The segments which showed the least range of movement were the mid lumbar and thoraco-lumbar segments (1.2 ±0.6 and 1.2 ±0.3 deg. respectively).

Acceleration
During acceleration, the segment which showed the greatest average range of movement was lateral pelvic tilt (Table 2) in each of the four pedal strokes. The largest value occurred in low intensity pedalling (6.2 deg lateral pelvic tilt) and this decreased slightly during acceleration to reach 5.7 deg. at the higher intensity. The segment which showed the least range of movement was mid-lumbar flexion (Table 2) and this was consistent through each of the four pedal strokes during acceleration. However, there was no difference in range of motion (1.3 deg.) between each pedal stroke, with only slight variation in the standard deviation for the four pedal strokes.

DISCUSSION
The purpose of this study was to describe the normal movement patterns of the lumbar spine and pelvis while cycling and to determine whether there was a difference in movement patterns between slow and fast intensities and during an acceleration phase. These findings were analysed in relation to anthropometric variables to help understanding the requirements of cycling and to identify possible risk factors involved in non specific low back injuries.

Cadence
The same gear ratio was used by each of the subjects and for all of the trials. Each subject was asked to pedal at an intensity of 50% for the slow trial and 90% for the fast trial which was self-selected without any visual cues such as cadence, speed or power. There was a variety of cadences selected with both inter- and intra-subject variability, although intra-trial variability was small, reflecting the ability of the cyclists to reliably maintain a chosen intensity.

Sagittal Plane Movement
A consistent pattern of lower limb position-dependent lumbar spine flexion occurred across all subjects. Peak flexion values for the lumbar spine and pelvis were seen between 3 and 4 o'clock, which is the point when the right lower limb is reported to generate maximum crank torque. This was mirrored at 9 and 10 o'clock when the left lower limb would be at its point of maximum force production. This motion may be a result of the abdominal muscles flexing the spine to stabilise it against the leg extension moment or may represent an inability of the extensor muscles of the spine to maintain the spine's position against the larger forces generated in the lower limb.

At the 12 and 6 o'clock positions, flexion values were minimum. At these points the right and left lower limbs are at TDC of the pedal stroke respectively and in a well-trained cyclist will represent the transition from pulling up to pushing forwards and down on the pedal. The points from 9 o'clock through to 12 o'clock are known to be the points of least force production in each unilateral pedal stroke. Whilst the right lower limb is pushing forward at TDC, the left lower limb is "scooping" through the bottom of its pedal stroke utilising the gluteal, hamstring and gastrocnemius muscles. Thus the lower limbs are producing opposing forces at vertical and horizontal crank positions which is reflected in the flexion pattern of the lumbar spine and pelvis.

Overall there was an increase in mean trunk flexion values during fast cycling compared to slower intensity cycling. This flexion was not apparent at any one point in the lumbar spine or pelvis but occurred along the spine. The pelvis showed a greater increase in flexion which is consistent with the findings of Ussabiaga et al. who found an increase in hip flexion was the largest contributor to an increased aerodynamic position. However, it is unclear whether the overall increase in flexion was due to the cyclist seeking a more aerodynamic position, as they would in a race situation at this pace, or whether there was an increase in abdominal and/or upper limb activity associated with the increased power output that could result in increased flexion. The latter reason could be an attempt to gain more force through the pedals by using more muscle groups such as increased trunk flexion in the same direction as the pedal to generate greater force production from the lower limbs. Another explanation could be a constant erecter spine force production that is not sufficient to maintain a static posture in the presence of the increased force generation through the 3 and 9 o'clock positions. Ussabiaga et al. found that there was little activity in the abdominal muscles during cycling activity and that the paravertebral lumbar muscle activity increased proportionally with cycling intensity. However the only abdominal muscle they studied was rectus abdominus and they did not look at the activity of either the oblique musculature or transversus abdominus.
Coronal Plane Movement

The pelvis and lumbar spine showed a consistent lower limb position-dependent pattern in lateral tilt away from the lower limb at the top of its stroke and towards the lower limb at the bottom of its stroke. Usabiaga et al. reported that contraction of ilio psoas during the push-pull cycle of pedalling resulted in a pattern of alternating side flexion although they found no significant change in position. In the present study there was an average lateral pelvic tilt range of 6.8° (± 3.0°) deg. which was accompanied by an additional 4.0° (± 1.4°) deg. of lateral flexion of the lumbar spine. There appears to be a combination of left lateral tilt and left side flexion at TDC and reciprocally right lateral tilt and right side flexion at BDC. However, it is unclear whether this is related to psoas activation, which would be strong at the bottom of the pedal stroke, or to upper body motion generated in an attempt to maximise power generation.

When the movement patterns were compared with anthropometric variables there appeared to be no link between seat height, as a percentage of inseam, and movement, although there was some evidence of increased movement with greater lower limb length discrepancy. Further analysis of the range of motion of each subject found that the subjects tended to fall into two groups: those that had greater motion and those that had smaller range of motion, although comparisons within a larger sample would be needed to confirm this finding and whether a relationship between motion or lack of and LPB existed.

A limitation to this study is the use of a stationary ergometer which fixes the bicycle in place and does not allow lateral sway as would occur in real-world cycling situations. However the results of this study are still relevant as a large proportion of intensity training at competitive level cycling is performed on a stationary ergometer.

CONCLUSION

Whilst cycling requires a stable lumbo-pelvic region to maximise power delivery to the pedals, the lumbar spine and pelvis does not remain static during cycling. The design of the elite cyclist’s bike seat provides a base of support and allows the necessary lower limb movement, but this mobility has been attained at the cost of lumbo-pelvic stability. The pattern of movement in both the sagittal and coronal planes is dependent on the phase of the pedalling cycle, with an increase in flexion occurring when a leg is at the anterior position of the pedal stroke (3 and 9 o’clock) and an increase in side flexion towards the leg at the bottom of the pedal stroke (12 and 6 o’clock). Although the results of this study should be viewed with caution due to the small sample of asymptomatic subjects, the motion observed may be a result of the abdominal muscles flexing the spine to stabilise it against the extension moment or the result of the larger forces generated by the leg specifically the ilio psoas muscle. This observed flexion rotation strain may overload of the passive structures of the spine such as the intervertebral disc and be a cause of non-specific chronic LBP, or may be a necessary movement to generate increases in power required during changes in cadence. Clinically 8 of the 9 subjects reported having a history of LBP in the previous 12 months and tended to fall into two groups: those with a larger range or a limited range of lumbo-sacral motion during the change in cadence. This finding supports the presence of possible underlying movement or motor control accommodation during the acceleration phase or change in cadence that predisposes the cyclist to non specific LBP. While treatment should still be based on the clinical findings, future electromyographic research may show the need to address muscles that resist or control intervertebral flexion moment during a change in cycling cadence. This might suggest that for injury prevention and/or rehabilitation of insidious low back pain in cyclists the focus should be on those muscle groups that resist side flexion and flexion of the lumbar spine such as the obliques and multifidi.

REFERENCES