Activity Characteristics and Movement Patterns in People With and People Without Low Back Pain Who Participate in Rotation-Related Sports

Ruth L. Chimenti, Sara A. Scholtes, and Linda R. Van Dillen

Many risk factors have been identified as contributing to the development or persistence of low back pain (LBP). However, the juxtaposition of both high and low levels of physical activity being associated with LBP reflects the complexity of the relationship between a risk factor and LBP. Moreover, not everyone with an identified risk factor, such as a movement pattern of increased lumbopelvic rotation, has LBP. **Objective:** The purpose of this study was to examine differences in activity level and movement patterns between people with and people without chronic or recurrent LBP who participate in rotation-related sports. **Design Case:** Case-control study. **Setting:** University laboratory environment. **Participants:** 52 people with chronic or recurrent LBP and 25 people without LBP who all play a rotation-related sport. **Main Outcome Measures:** Participants completed self-report measures including the Baecke Habitual Activity Questionnaire and a questionnaire on rotation-related sports. A 3-dimensional motion-capture system was used to collect movement-pattern variables during 2 lower-limb-movement tests. **Results:** Compared with people without LBP, people with LBP reported a greater difference between the sport subscore and an average work and leisure composite subscore on the Baecke Habitual Activity Questionnaire ($F = 6.55, P = .01$). There were no differences between groups in either rotation-related-sport participation or movement-pattern variables demonstrated during 2 lower-limb-movement tests ($P > .05$ for all comparisons). **Conclusions:** People with and people without LBP who regularly play a rotation-related sport differed in the amount and nature of activity participation but not in movement-pattern variables. An imbalance between level of activity during sport and daily functions may contribute to the development or persistence of LBP in people who play a rotation-related sport.

**Keywords:** rehabilitation, athlete, LBP
daily functions, among people who participate in a sport associated with an increased risk of LBP.

One factor that contributes to LBP symptoms associated with activity may be the lumbopelvic movement patterns used while performing sport activities and daily functions. A movement pattern is evident when the same lumbopelvic motion, such as rotation, is demonstrated during a variety of tasks—for example, kicking or reaching—that provoke LBP symptoms. A limb-movement test is a standardized method of examining the lumbopelvic movement pattern and LBP symptoms with a simple upper or lower extremity movement. During the limb-movement test, a person is asked to isolate a component of an extremity motion, which is used during activities that are associated with an increase in LBP symptoms. For example, the test of active knee flexion performed in prone replicates one component of the motion used during a serve or walking down stairs. People with LBP often demonstrate lumbopelvic motion and report reproduction of LBP during limb-movement tests in a clinical examination. When these tests are modified to decrease the lumbopelvic motion, people report a decrease in LBP symptoms during the limb-movement test. Considering the limb-movement-test findings, a repeated pattern of lumbopelvic motion with limb movements during daily tasks has the potential to contribute to an accumulation of mechanical stress in tissues of the lumbopelvic region. For example, the mechanical stress in the lumbopelvic region absorbed during a given task is likely to increase during movements of greater speed or greater magnitude of rotation. This increase in mechanical stress may potentially exceed the threshold of tissue maintenance and result in LBP symptoms.

Rotational forces occurring in the transverse plane are applied to the lumbopelvic region during participation in rotation-related sports. Rotation-related sports are defined as sports requiring repeated lumbopelvic rotation—for example, tennis or golf. Repeated lumbopelvic rotation during rotation-related-sport participation may contribute to a pattern of increased or earlier lumbopelvic rotation during daily functions. A prior study reported that people with LBP who played a rotation-related sport demonstrated greater and earlier lumbopelvic rotation during limb-movement tests than people without LBP who did not participate in a rotation-related sport. Thus, it is unclear whether people with LBP who play a rotation-related sport demonstrate a movement pattern that is specific to people with LBP or is an adaptation to the rotation-related activity. Prior literature examining differences between athletes and nonathletes suggests that the activities in which people participate may alter joint ranges of motion, postural sway, and postural stability. For example, throwers demonstrate differences in shoulder range of motion between the dominant and nondominant shoulders, and dancers demonstrate differences in hip range of motion compared with nondancers. The greater and earlier lumbopelvic rotation demonstrated during limb-movement tests by people with LBP who play a rotation-related sport may be an adaption to the increased amount and frequency of rotational movement required to play the sport. This movement-pattern adaptation, when combined with other factors such as a low activity level during daily functions, may contribute to an LBP problem.

The purpose of the current study was to examine activity levels related to sport participation and daily function, as well as movement patterns in people with and without LBP who regularly play a rotation-related sport. We hypothesized that the groups would differ in the relative amount and nature of activities contributing to a person’s overall physical activity level. However, due to their similar sports participation, we hypothesized that they would demonstrate similar lumbopelvic movement patterns during lower-limb-movement tests.

Methods

Design

A case-control study design was used to examine differences in activity level and movement patterns between people with and people without LBP at a single point in time. The independent variable used to define groups was the presence or absence of LBP. The dependent variables collected to describe these groups were subscores of the Baecke Habitual Activity Questionnaire, responses to items of a sport-related questionnaire, and the amount and timing of lumbopelvic motion during 2 lower-limb-movement tests. Motion analysis was used to measure characteristics of the lower-limb-movement tests of knee flexion performed in prone and hip lateral rotation performed in prone.

Subjects

Seventy-seven people who participated in a rotation-related sport recreationally at least 1 to 2 hours per week were enrolled in the study. A rotation-related sport was defined as a sport that put repeated rotational demands on the trunk and hips during most of the activity (eg, tennis, racquetball, golf). Twenty-five subjects reported no history of LBP. Fifty-two subjects reported a history of at least 12 months of either chronic LBP, defined as symptoms present on at least half the days in a 12-month period in single or multiple episodes, or recurrent LBP, defined as symptoms present on less than half the days in a 12-month period occurring in multiple episodes over the year. In addition, all subjects with LBP reported an increase in LBP symptoms during or after participation in their sport. People were excluded from the study if they reported a history of spinal fracture or surgery. They were also excluded if they reported any of the following conditions: spinal stenosis, osteoporosis, disc pathology, significant lower extremity impairment, a systemic inflammatory condition, current pregnancy, or other serious medical condition. An informed-consent statement approved by the Washington University School of Medicine Human Studies Committee was read and signed by all subjects before enrolling in the study.
Procedures

All subjects completed self-report measures including a demographic, sport-related, and LBP history questionnaire, a verbal numeric pain-rating scale, and the Baecke Habitual Activity Questionnaire (BHAQ). The demographic, sport-related, and LBP history questionnaire included categorical and continuous measures of sport-specific activity that may contribute to the development or persistence of LBP. The questions were modeled after an assessment of lifetime sporting activities described by Videman and colleagues. The BHAQ provides a score for overall activity level, as well as subscores for activity level during sport, work, and nonsport leisure activities. Each subscore is reported on a 5-point scale, with 1 representing the lowest level of activity and 5 the highest level of activity. The total BHAQ score is the sum of the 3 subscores (range 3–15). Because our primary interest was in comparing the relative contribution of sporting activities and daily functions to overall activity levels, we calculated a composite subscore to quantify activity level with daily functions. The composite subscore was the average of the work and nonsport leisure subscores (AveWorkLeisure).

In the laboratory, subjects performed 2 active lower-limb-movement tests in prone: knee flexion and hip lateral rotation. Knee flexion and hip lateral rotation were examined because both tests provoke symptoms in people with LBP and we have previously reported differences between people with and people without LBP in movement patterns demonstrated during knee flexion and hip lateral rotation. Methods for kinematic analyses for both clinical tests have been described previously. Briefly, for both tests subjects were positioned in prone with the hip in neutral abduction/adduction and neutral femoral rotation. At the start of the knee-flexion trials, both lower limbs were fully extended; at the start of the hip lateral-rotation trials, the knee of the tested limb was flexed to 90°. The subjects performed 1 trial of each test on the right and left leg separately at a self-selected speed.

Data were collected using a 6-camera, 3-dimensional motion-capture system (EvaRT, Motion Analysis Corp, Santa Rosa, CA, USA). Angular displacement (degrees) and velocity (degrees/s) of movement across time were calculated for the limbs and the lumbopelvic region relative to the initial starting position. Limb and lumbopelvic motion were examined from start to maximal angle of limb movement. Lumbopelvic anterior tilt represents rotation of the pelvis in the sagittal plane. Lumbopelvic rotation represents rotation of the pelvis in the transverse plane. In addition to examining maximal angles for lumbopelvic anterior tilt and rotation, a timing variable was calculated for both lumbopelvic motions. Timing of lumbopelvic motion was calculated as the difference in time between the start of the limb movement and the start of the lumbopelvic motion. The time difference was normalized to each subject’s self-selected movement speed by dividing by the total limb-movement time.

Statistical Analyses

All data analyses were performed using SPSS 17.0 for Windows (SPSS Inc, Chicago, IL, USA). Statistical significance was defined as a 2-tailed P value ≤0.05 for all analyses.

Self-Report Measures. Descriptive statistics were calculated for relevant subject characteristics. Self-report variables were analyzed using independent-samples t tests and chi-square test for independence as appropriate. Independent-samples t tests were used to test for differences between groups on 3 activity-related variables of the BHAQ (total score, sport subscore, and the composite AveWorkLeisure subscore). A mixed-model analysis of variance was used to assess the difference between activity level during sport activities and daily functions. The between-groups factor was group with 2 levels: people with LBP and people without LBP. The within-group factor was activity subscores with 2 levels: sport and AveWorkLeisure.

Laboratory Measures. Because previous data suggest no differences in limb or lumbopelvic motion between the left and right limbs, left and right trials of the movement variables were averaged. Independent-samples t tests were used to examine differences between the 2 groups with regard to maximum angle of knee or hip movement, maximum angle of lumbopelvic rotation and anterior tilt, and timing of lumbopelvic rotation and anterior tilt during the limb-movement tests of knee flexion and hip lateral rotation.

Results

Self-Report Measures

There were no differences between groups in age, body-mass index, sex, hand dominance, family history of LBP, or occupation (Table 1). There were also no differences in number of years of participation in individual or team rotation-related sport, amount of strength or endurance training, frequency of play, session duration, primary rotation-related sport, or most frequent stroke or swing used (Table 2).

There were no differences in total activity level or sport between people with LBP and people without LBP as reported on the BHAQ (Table 3). When work and nonsport leisure-activity levels were combined to examine the average level of activity with daily functions, people with LBP reported being less active than people without LBP (P = .01; Table 3). When activity level during sports (sport subscore) was compared with activity level during daily functions (AveWorkLeisure composite subscore), the analysis of variance revealed an interaction effect between group and activity (F = 6.55,
### Table 1 Demographics of People With and People Without Chronic or Recurrent Low Back Pain (LBP) Who Participate in Rotation-Related Sports

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Without LBP (n = 25)</th>
<th>With LBP (n = 52)</th>
<th>Statistical value, degrees of freedom, ( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>25.5 ± 6.7</td>
<td>28.5 ± 8.2</td>
<td>( t = 1.73, \text{df} = 57.67^a, P = .09 )</td>
</tr>
<tr>
<td>Body-mass index (kg/m²)</td>
<td>25.2 ± 3.5</td>
<td>24.9 ± 3.5</td>
<td>( t = 0.41, \text{df} = 75, P = .68 )</td>
</tr>
<tr>
<td>Sex (%)</td>
<td>Male,76; female, 24</td>
<td>Male, 64; female, 36</td>
<td>( \chi^2 = 1.21, \text{df} = 1, P = .27 )</td>
</tr>
<tr>
<td>Hand dominance (%)</td>
<td>Right, 92; left, 8</td>
<td>Right, 94; left, 6</td>
<td>( \chi^2 = 0.14, \text{df} = 1, P = .71 )</td>
</tr>
<tr>
<td>Family history of LBP (%)</td>
<td>Yes, 24; no, 76</td>
<td>Yes, 37; no, 63</td>
<td>( \chi^2 = 1.21, \text{df} = 1, P = .27 )</td>
</tr>
<tr>
<td>Level of activity associated with occupationb (%)</td>
<td>Low, 88; medium, 12; high, 0</td>
<td>Low, 92; medium, 6; high, 2</td>
<td>( \chi^2 = 1.36, \text{df} = 2, P = .51 )</td>
</tr>
<tr>
<td>Type of LBP (%)</td>
<td>NA</td>
<td>Chronic, 40; recurrent, 60</td>
<td>NA</td>
</tr>
<tr>
<td>Duration of LBP (y)</td>
<td>NA</td>
<td>6.6 ± 5.4</td>
<td>NA</td>
</tr>
<tr>
<td>Number of acute flare-ups in previous 12 mo²</td>
<td>NA</td>
<td>7.1 ± 3.8</td>
<td>NA</td>
</tr>
</tbody>
</table>

Note: Values expressed as mean ± SD or as otherwise indicated.

\( ^a \) Equal variances not assumed.

\( ^b \) The Baecke Habitual Physical Activity Questionnaire\(^37\) includes a subscale on which the person rates the activity level associated with his or her occupation on a 3-point scale. Examples of low-level activities include office work, teaching, or studying. Examples of medium-level activities include factory work, plumbing, or carpentry. Examples of high-level activities include dock work or construction work.

\( ^c \) All LBP subjects reported a history of at least 12 mo of either chronic LBP, defined as symptoms present on at least half the days in a 12-mo period in a single or multiple episodes, or recurrent LBP, defined as symptoms present on less than half the days in a 12-mo period, occurring in multiple episodes over the year.\(^34\)

### Table 2 Sport Participation of People With and People Without Chronic or Recurrent Low Back Pain (LBP) Who Participate in Rotation-Related Sports (RRS)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Without LBP</th>
<th>With LBP</th>
<th>Statistical value, degrees of freedom, ( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participation in individual RRS (y)</td>
<td>8.4 ± 4.5</td>
<td>10.7 ± 7.8</td>
<td>( t = 1.34, \text{df} = 73, P = .18 )</td>
</tr>
<tr>
<td>Participation in team RRS (y)</td>
<td>3.7 ± 4.5</td>
<td>4.3 ± 5.5</td>
<td>( t = 0.47, \text{df} = 72, P = .64 )</td>
</tr>
<tr>
<td>Strength training (y)</td>
<td>5.5 ± 5.1</td>
<td>6.2 ± 6.0</td>
<td>( t = 0.49, \text{df} = 73, P = .63 )</td>
</tr>
<tr>
<td>Endurance training (y)</td>
<td>5.6 ± 5.7</td>
<td>8.0 ± 6.6</td>
<td>( t = 1.56, \text{df} = 73, P = .12 )</td>
</tr>
<tr>
<td>RRS frequency (times/wk)</td>
<td>2.8 ± 1.6</td>
<td>3.1 ± 1.7</td>
<td>( t = 0.73, \text{df} = 74, P = .47 )</td>
</tr>
<tr>
<td>Duration of each RRS session (min/session)</td>
<td>78.3 ± 31.2</td>
<td>91.0 ± 39.4</td>
<td>( t = 1.38, \text{df} = 74, P = .17 )</td>
</tr>
<tr>
<td>Primary RRS (%)</td>
<td>Tennis, 63; racquetball, 29; squash, 4; golf, 0; badminton, 4</td>
<td>Tennis, 46; racquetball, 38; squash, 12; golf, 4; badminton, 0</td>
<td>( \chi^2 = 6.91, \text{df} = 6, P = .33 )</td>
</tr>
<tr>
<td>Most frequent stroke or swing with RRS (%)</td>
<td>Forehand, 88; backhand, 8; serve, 4; forehand and backhand, 0; iron shots, 0; driving, 0</td>
<td>Forehand, 77; backhand, 6; serve, 2; forehand and backhand, 11; iron shots, 2; driving, 2</td>
<td>( \chi^2 = 4.46, \text{df} = 5, P = .49 )</td>
</tr>
</tbody>
</table>

Note: Values expressed as mean ± SD unless otherwise indicated.

### Table 3 Results From the Baecke Habitual Activity Questionnaire for People With and People Without Chronic or Recurrent Low Back Pain (LBP)

<table>
<thead>
<tr>
<th>Score</th>
<th>Without LBP</th>
<th>With LBP</th>
<th>Statistical value, degrees of freedom, ( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total score (range 3–15)(^a)</td>
<td>8.84 ± 1.24</td>
<td>8.34 ± 0.73</td>
<td>( t = 1.84, \text{df} = 32.3^b, P = .08 )</td>
</tr>
<tr>
<td>Sport subscore (range 1–5)(^a)</td>
<td>3.55 ± 0.61</td>
<td>3.68 ± 0.55</td>
<td>( t = 0.96, \text{df} = 75, P = .34 )</td>
</tr>
<tr>
<td>AveWorkLeisure composite subscore (range 1–5)(^c)</td>
<td>2.64 ± 0.54</td>
<td>2.33 ± 0.30</td>
<td>( t = 2.73, \text{df} = 31.4^b, P = .01 )</td>
</tr>
</tbody>
</table>

Note: Statistically significant differences are in bold (\( P \leq .05 \)). Values expressed as mean ± SD.

\( ^a \) Activity level as reported on the Baecke Habitual Activity Questionnaire.\(^37\) A higher value indicates greater activity. The total score is the sum of the sport, work, and leisure subscores.

\( ^b \) Equal variances not assumed.

\( ^c \) Average of the work and non-sport leisure subscores.
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Table 4 Movement-Pattern Variables Calculated During Active Limb Movements in People With and People Without Chronic or Recurrent Low Back Pain (LBP), Mean ± SD

<table>
<thead>
<tr>
<th>Variable</th>
<th>Without LBP</th>
<th>With LBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee flexion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>maximal knee-flexion angle</td>
<td>94.32° ± 28.38°</td>
<td>107.87° ± 69.67°</td>
</tr>
<tr>
<td>maximal lumbopelvic-rotation angle</td>
<td>3.30° ± 1.69°</td>
<td>3.28° ± 1.76°</td>
</tr>
<tr>
<td>maximal anterior pelvic-tilt angle</td>
<td>3.90° ± 2.00°</td>
<td>3.42° ± 2.02°</td>
</tr>
<tr>
<td>timing of lumbopelvic rotation</td>
<td>0.30 ± 0.18</td>
<td>0.25 ± 0.21</td>
</tr>
<tr>
<td>timing of anterior pelvic tilt</td>
<td>0.30 ± 0.18</td>
<td>0.25 ± 0.21</td>
</tr>
<tr>
<td>Hip lateral rotation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>maximal hip lateral-rotation angle</td>
<td>46.79° ± 5.40°</td>
<td>44.52° ± 6.47°</td>
</tr>
<tr>
<td>maximal lumbopelvic-rotation angle</td>
<td>6.22° ± 2.75°</td>
<td>5.76° ± 3.00°</td>
</tr>
<tr>
<td>timing of lumbopelvic rotation</td>
<td>0.20 ± 0.13</td>
<td>0.21 ± 0.18</td>
</tr>
</tbody>
</table>

Note: $P > .1$ for all comparisons.

$P = .01$; Figure 1). Compared with people without LBP (sport subscore, 3.55 ± 0.61; AveWorkLeisure composite subscore, 2.64 ± 0.54), people with LBP reported a greater difference in activity levels between sports and daily functions (sport subscore, 3.68 ± 0.55; AveWorkLeisure composite subscore, 2.33 ± 0.30, Table 3).

Laboratory Measures

There were no differences between groups in movement-pattern variables measured during the limb-movement tests of knee flexion or of hip lateral rotation ($P > .05$ for all comparisons; Table 4).

Discussion

The purpose of the current study was to examine activity levels related to sport participation and daily function, as well as movement patterns, in people with and without LBP who regularly play a rotation-related sport. We hypothesized that people with and without LBP would...
differ in the relative amount and nature of activities contributing to an overall physical activity level but would demonstrate similar lumbopelvic movement patterns during lower-limb-movement tests. Consistent with our hypothesis, people with LBP reported lower activity levels with their daily functions (AveWorkLeisure composite subscore of work and nonsport leisure) than people without LBP. Despite participants’ reporting a worsening of LBP symptoms with their rotation-related-sport activity, people with LBP were as active in their sport as people without LBP. Also consistent with our hypothesis, people with and people without LBP who played a rotation-related sport demonstrated similar movement patterns during the tests of knee flexion and hip lateral rotation. Thus, the primary difference between groups was that people with LBP had a greater difference in activity level between sports and daily functions than people without LBP. The findings of the current study suggest that a discrepancy in the nature of activities—a greater difference in activity level between sport activities and daily functions—that contribute to overall activity level concurrent with an altered lumbopelvic movement pattern may increase a person’s risk for LBP.

The potential effect of this combination of factors to increased risk for LBP is consistent with the principles outlined in the physical stress theory. The physical stress theory describes how the level of physical stress on a tissue is a sum of the direction, time, and magnitude of the stress applied to the tissue. In the context of our study, the primary direction (rotation) of the stress on the lumbar tissues and the time-related characteristics (duration, repetition, and rate) of the stress associated with sport participation were similar for the 2 groups (Table 2). However, because there was a larger discrepancy in activity levels between sport activities and daily functions in people with LBP, the relative magnitude of stress with rotation-related-sport participation may be greater for people with LBP than for people without LBP. The result would be that the high-velocity, high-magnitude trunk movements performed during a rotation-related sport may be more likely to exceed the maintenance range of the trunk tissue in people with LBP than in people without LBP, contributing to a cascade of events that result in LBP symptoms.

There are potential alternative explanations for the greater discrepancy between activity level during sport activities and daily functions in people with LBP than in people without LBP found in the current study. It is possible that people with LBP simply choose occupations that require less activity throughout the day. In the current study, however, there was no difference in the nature of the occupations between the 2 groups (Table 1). Both groups reported occupations associated with low to moderate activity levels. It is also possible that people with LBP limit their activity throughout the day to avoid LBP symptoms yet continue to engage in an activity they enjoy (i.e., rotation-related sport) even though they experience mild to moderate LBP symptoms during the activity. Although this is a plausible option, it does not negate the importance of the findings of the current study. Whether people are less active during daily functions because of habit or pain avoidance, our data suggest that it may be important to maintain a balance between activity level during sport participation and daily functions. This recommendation may be particularly relevant for workers with sedentary jobs, who composed 91% of our sample (Table 1). A study of municipal employees reported that people with more sedentary jobs chose to participate in more physically challenging activities outside of work than people with physically demanding jobs. Thus, having a sedentary job may put a person at more risk for LBP because of the discrepancy in the relative contributions of different types of activity to the person’s overall activity level.

Symptoms of LBP also have been related to movement patterns demonstrated during limb-movement tests. In a previous study, Scholtes et al demonstrated that people with LBP who participated in a rotation-related sport demonstrated greater and earlier lumbopelvic motion during lower-limb-movement tests than people without LBP who did not participate in a rotation-related sport. In contrast, in the current study all the subjects participated in a rotation-related sport, and there were no significant differences in movement patterns demonstrated during limb-movement tests between people with and people without LBP (Table 4). A comparison with findings from Scholtes et al demonstrates that regardless of LBP, people in the current study who participated in a rotation-related sport demonstrated greater maximal lumbopelvic rotation with knee flexion (LBP/rotation-related sport, 3.28° ± 1.76°; no LBP/rotation-related sport, 3.30° ± 1.69°) and hip rotation (LBP/rotation-related sport, 5.75° ± 3.00°; no LBP/rotation-related sport, 6.22° ± 2.75°) than the people without LBP who did not play a rotation-related sport in the previous study (lumbopelvic-rotation angles: knee flexion, 2.32° ± 1.48°; hip rotation, 4.47° ± 2.55°). Also, people who played rotation-related sports demonstrated a shorter time difference between the start of the limb motion and the start of the lumbopelvic rotation than people without LBP who did not play a rotation-related sport. In the current study people who played rotation-related sports demonstrated earlier lumbopelvic rotation during knee flexion (LBP/rotation-related sport, 0.25 ± 0.21; no LBP/rotation-related sport, 0.30 ± 0.18) and hip rotation (LBP/rotation-related sport, 0.21 ± 0.81; no LBP/rotation-related sport, 0.20 ± 0.13) than did people without LBP who did not play a rotation-related sport in the previous study (timing of lumbopelvic rotation: knee flexion, 0.39 ± 0.33; hip rotation, 0.31 ± 0.26). These data suggest that the increased and earlier lumbopelvic rotation demonstrated by people who participate in a rotation-related sport for a similar amount of time per week may be more related to the sporting activity than the presence or absence of LBP symptoms.

The relationship between sport activity and movement patterns proposed in our study is consistent with previously described models and research reports. It has been proposed that activities performed repeatedly...
throughout the day, whether activities of daily living, occupational tasks, or higher-level tasks such as fitness and sport, may produce changes in movement patterns.\textsuperscript{40,41} Schmit et al\textsuperscript{42} proposed that ballet dancers demonstrate better postural control than track athletes as a result of their balance-focused classical ballet training. Gymnasts have been reported to demonstrate greater postural stability than nongymnasts.\textsuperscript{59} Similarly, people who consistently participate in a rotation-related sport may develop movement patterns as an adaptation to the sport activity. The cross-sectional nature of these studies limits our ability to determine whether a causal relationship exists between rotation-related-sport activity and movement patterns. These studies do, however, provide additional evidence to support the importance of these theoretical concepts and the need for further investigation using a prospective, longitudinal study design.

One limitation of the current study is the use of the BHAQ, a self-report measure, as the measurement tool for habitual activity level. Although the BHAQ has been reported to be a reliable tool for different populations including those with LBP,\textsuperscript{42–44} its validity in measuring habitual activity level has not been consistently reported. A number of different methods have been used to validate the BHAQ\textsuperscript{43–45}; however, there is no single measure that is comparable to the intention of the BHAQ, which is to examine habitual activity levels over a period of time rather than activity level or energy expenditure during a particular task.\textsuperscript{37} A second limitation is the generalizability of the findings to people who perform repetitive activities other than a rotation-related sport. In the current study we recruited people who play a rotation-related sport at least 1 or 2 days per week to model the relationship between participation in an activity that requires repeated movement in the same direction and a lumbopelvic movement pattern. Further investigation would be necessary to determine whether LBP is associated with a discrepancy in activity levels in individuals who perform other types of repetitive activities such as work.

**Conclusions**

People with chronic or recurrent LBP report a greater difference in activity levels between sport activities and the majority of their daily functions (work and nonsport leisure) than people without LBP. People with and people without LBP who play rotation-related sports recreationally demonstrate similar movement patterns during lower-limb-movement tests. The discrepancy between the relative amount and nature of the physical activities contributing to an overall activity level, along with a repetitively used pattern of movement, may together contribute to the development or persistence of an LBP problem in people who play a rotation-related sport.

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