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Activity characteristics and movement patterns in people with and people without low back pain who participate in rotation-related sports

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Abstract

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).

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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.

A number of different factors, including high and low levels of activity, low muscular fitness, altered movement patterns, changes in muscle activation patterns, increased body mass index, low education and smoking, are frequently associated with an increased risk of having low back pain (LBP).[1–9] However, not everyone with LBP demonstrates every identified risk factor, nor does everyone with an identified risk factor develop LBP.[1,5,6,8,10] Understanding the complex relationship between LBP and risk factors may be improved through examining the combined effect of identified risk factors. A common principle of tissue mechanics is that individual risk factors sum to create a greater cumulative risk.[11–14] This principle may be particularly useful in understanding how multiple risk factors contribute to chronic or recurrent non-specific LBP. The current study examines the relationship between LBP (chronic or recurrent) and the combination of two risk factors: (1) relative contributions of different types of activities to overall activity level, and (2) altered lumbopelvic movement patterns during active limb movement tests.

Physical activity levels can be assessed in many different ways. The use of multiple methods may contribute to contradictory findings in the literature on the association between physical activity and LBP.[15–18] A meta-analysis by Lin and colleagues supports the common assumption that lower overall activity levels are associated with chronic LBP.[18] In contrast, there is also evidence to suggest that participation in certain types of athletic activity increases the risk of LBP.[19,20] This seemingly conflicting evidence on LBP risk can be understood when activity level is defined to include both daily functions and sporting activities. However, there has been no report of how the relative contribution of different types of activities performed throughout the day relate to a LBP problem.[17,21] The current study examines habitual activity levels, including sport activities and daily functions, among people who all 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.[22–24] 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.[25] 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. [25,26] 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.[25,26] 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 during a clinical examination.[22–25] When these tests are modified to decrease the lumbopelvic motion, people report a decrease in LBP symptoms during the limb movement test.[24,27] 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.[12]

Rotational forces occurring in the transverse plane are applied to the lumbopelvic region during participation in rotation-related sports. Rotation-related sports (RRS) are defined as sports requiring repeated lumbopelvic rotation, e.g., tennis or golf. Repeated lumbopelvic rotation during RRS 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 RRS demonstrated greater and earlier lumbopelvic rotation during limb movement tests than people without LBP who did not participate in a RRS.[9] Thus, it is unclear if people with LBP who play a RRS 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 non-athletes suggests the activities people participate in may alter joint ranges of motion, postural sway, and postural stability.[28–33] For example, throwers demonstrate differences in shoulder range of motion between the dominant and non-dominant shoulder,[30,31] and dancers demonstrate differences in hip range of motion compared to non-dancers.[32,33] The greater and earlier lumbopelvic rotation demonstrated during limb movement tests by people with LBP, who play a RRS, 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 a 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 RRS. 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 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 one 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 two lower limb movement tests. Motion analysis was used to measures 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 RRS recreationally at least 1–2 hours per week were enrolled in the study. A RRS was defined as a sport that put repeated rotational demands on the trunk and hips during most of the activity (e.g. tennis, racquetball, golf). Twenty-five subjects reported no history of LBP. Fifty-two subjects reported a history of at least 12 months of either (1) chronic LBP, defined as symptoms present on at least half the days in a 12-month period in single or multiple episodes, or (2) recurrent LBP, defined as symptoms present on less than half the days in a 12-month period, occurring in multiple episodes over the year.[34] 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 a 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

Self-Report Measures—All subjects completed self-report measures including (1) a demographic, sport-related, and LBP history questionnaire,[35] (2) a verbal numeric pain rating scale,[36] and (3) the Baecke Habitual Activity Questionnaire (BHAQ).[37] 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.[35] The BHAQ provides a score for overall activity level as well as subscores for activity level during (1) sport, (2) work, and (3) non-sport, 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.[37] The total BHAQ score is the sum of the three subscores (range: 3–15).[37] 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 non-sport leisure subscores (AveWorkLeisure).

Laboratory Measures—Subjects performed two active lower limb movement tests in prone: knee flexion and hip lateral rotation. Knee flexion and hip lateral rotation were examined because: (1) both tests provoke symptoms in people with LBP,[22,38] and (2) we have previously reported differences between people with and people without LBP in movement patterns demonstrated during knee flexion and hip lateral rotation.[9] Methods for kinematic analyses for both clinical tests have been described previously.[9] 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 one trial of each test on the right and left leg separately at a self-selected speed.

Data were collected using a six-camera, three-dimensional, motion capture system (EVaRT, Motion Analysis Corporation, Santa Rosa, CA, USA). Angular displacement (degrees) and velocity (degrees/second) 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.[38]

Statistical Analyses

All data analyses were performed using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA). Statistical significance was defined as a two-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

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test for differences between groups on three activity-related variables of the BHAQ (total score, sport subscore, and the composite AveWorkLeisure subscore). A mixed model analysis of variance test was used to assess the difference between activity level during sport activities and daily functions. The between groups factor was group, with two levels, people with LBP and people without LBP. The within groups factor was activity subscores, with two levels, sport and AveWorkLeisure.

Laboratory Measures—Because previous data suggest no differences in limb or lumbopelvic motion between the left and right limb,[9] left and right trials of the movement variables were averaged. Independent samples t-tests were used to examine differences between the two groups with regard to (1) maximum angle of knee or hip movement (2) maximum angle of lumbopelvic rotation and anterior tilt, and (3) 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 RRS, amount of strength or endurance training, frequency of play, session duration, primary RRS, or most frequent stroke/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 non-sport 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=0.01, Table 3). When activity level during sports (sport subscore) was compared to activity level during daily functions (AveWorkLeisure composite subscore) the analysis of variance revealed an interaction effect between group and activity (F=6.55, P=0.01; Figure 1). Compared to 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>0.05 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 RRS. 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 non-sport leisure) compared to people without LBP. Interestingly, despite participants reporting a worsening of LBP symptoms with their RRS 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 RRS 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 levelbetween sports and daily functions than people without LBP. The findings of the current study suggest that a discrepancy in the *nature* of activities, i.e. 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 (PST).[14] The PST describes how the physical stress level 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, rate) of the stress associated with sport participation were similar for the two 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 RRS participation may be greater for people with LBP than people without LBP. The result would be that the high velocity, high magnitude trunk movements performed during a RRS 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.[14]

There are potential alternative explanations for the greater discrepancy between activity level during sport activities and daily functions in people with LBP compared to 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 two 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., RRS) 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 suggests 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, which 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.[39] 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. One group of researchers[9] reported that people with LBP who participated in a RRS demonstrated greater and earlier lumbopelvic motion during lower limb movement tests than people without LBP who did not participate in a RRS. In contrast, in the current study all people participated in a RRS and there were no significant differences in movement patterns demonstrated during limb movement tests between people with and people without LBP (Table 4). Interestingly, a comparison to findings from the previous study[9] demonstrates that regardless of LBP people in the current study who participated in a RRS demonstrated greater maximal lumbopelvic rotation with knee flexion (LBP/RRS: 3.28° ± 1.76°, No LBP/RRS: 3.30° ± 1.69°) and hip rotation (LBP/RRS: 5.75° ± 3.00°, No

LBP/RRS: 6.22° ± 2.75°) than the people without LBP who did not play a RRS in the previous study (lumbopelvic rotation angles: knee flexion: 2.32° ± 1.48°, hip rotation: 4.47° ± 2.55°).[9] Also, people who played RRS 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 RRS. In the current study people who played RRS demonstrated earlier lumbopevlic rotation during knee flexion (LBP/RRS: 0.25 ± 0.21, No LBP/RRS: 0.30 ± 0.18) and hip rotation (LBP/RRS: 0.21 ± 0.81, No LBP/RRS: 0.20 ± 0.13) in comparison to people without LBP who did not play a RRS 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 RRS 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.[28,29,40,41] 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.[40,41] Schmit et al[28] 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 compared to non-gymnasts.[29] Similarly, people who consistently participate in a RRS may develop movement patterns as an adaptation to the sports activity. The cross-sectional nature of these studies limits the ability to determine whether a causal relationship exists between RRS 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 LBP,[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,[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.[37] A second limitation is the generalizability of the findings to people who perform repetitive activities other than a RRS. In the current study we recruited people who play a RRS at least 1–2 days per week in order 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 daily functions (work and non-sport leisure) than people without LBP. People with and people without LBP who play RRSs 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 a LBP problem in people who play a RRS.

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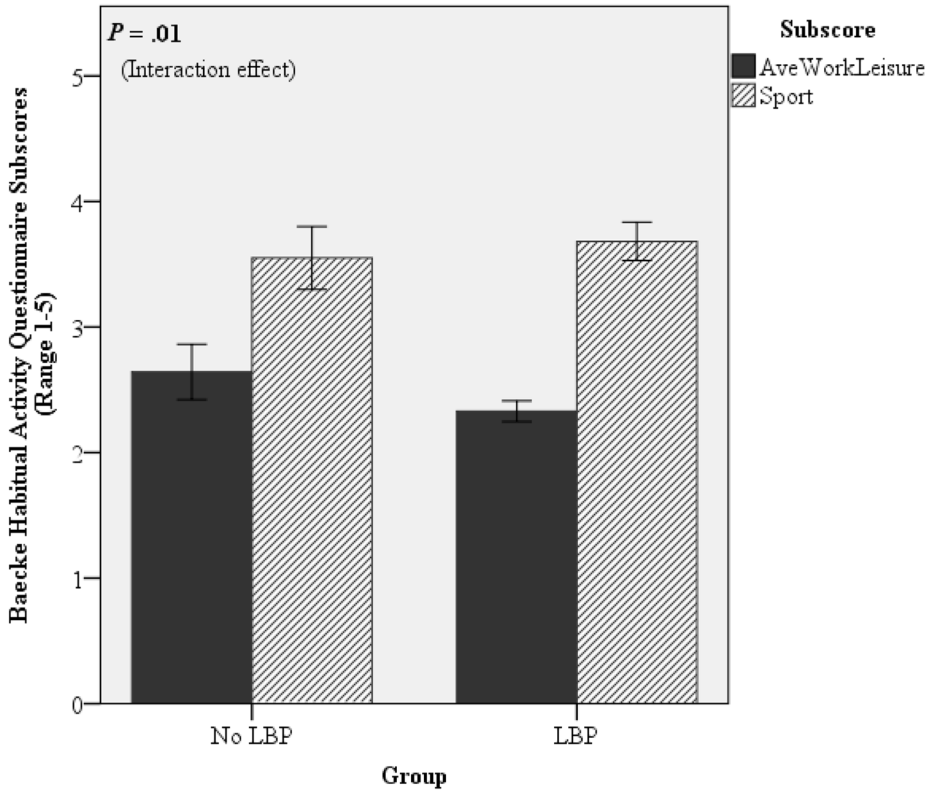
P = .01
(Interaction effect)
Subscore
AveWorkLeisure
Sport
Baecke Habitual Activity Questionnaire Subscores (Range 1-5)
0
1
2
3
4
5
No LBP
LBP
Group

Figure 1.

TABLE 1

Demographics of people with and people without chronic or recurrent low back pain who participate in rotation-related sports.

Characteristic	People without LBP (N = 25)	People with LBP (N = 52)	Statistical Value, Degrees of Freedom, P-value
Age (y)	25.5 ± 6.7	28.5 ± 8.2	t = 1.73, df = 57.67[a], P = 0.09
Body mass index (kg/m^2)	25.2 ± 3.5	24.9 ± 3.5	t = 0.41, df = 75, P = 0.68
Sex (%)	Male: 76 Female: 24	Male: 64 Female: 36	χ^2 = 1.21, df = 1, P = 0.27
Hand dominance (%)	Right: 92 Left: 8	Right: 94 Left: 6	χ^2 = 0.14, df = 1, P = 0.71
Family history of LBP (%)	Yes: 24 No: 76	Yes: 37 No: 63	χ^2 = 1.21, df = 1, P = 0.27
Level of activity associated with occupation[b] (%)	Low: 88 Medium: 12 High: 0	Low: 92 Medium: 6 High: 2	χ^2 = 1.36, df = 2, P = 0.51
Type of LBP (%)	NA	Chronic: 40 Recurrent: 60	NA
duration of LBP (y)	NA	6.6 ± 5.4	NA
Number of acute flare-ups in previous 12 Months[c]	NA	7.1 ± 3.8	NA

Abbreviation: LBP, low back pain

Values expressed as means ± standard deviation or as otherwise indicated.

[a]Equal variances not assumed

[b]The Baecke Habitual Physical Activity Questionnaire [37] includes a subscale in which the person rates the activity level associated with his 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 months of either (1) chronic LBP, defined as symptoms present on at least half the days in a 12-month period in a single or multiple episodes, or (2) recurrent LBP, defined as symptoms present on less than half the days in a 12-month period, occurring in multiple episodes over the year.[34]

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TABLE 2

Sport participation of people with and people without chronic or recurrent low back pain who participate in rotation-related sports.

Variable	People without LBP	People with LBP	Statistical Value, Degrees of Freedom, P-value
Participation in			
Individual RRS (y)	8.4 ± 4.5	10.7 ± 7.8	t = 1.34, df = 73, P = 0.18
Team RRS (y)	3.7 ± 4.5	4.3 ± 5.5	t = 0.47, df = 72, P = 0.64
Strength training (y)	5.5 ± 5.1	6.2 ± 6.0	t = 0.49, df = 73, P = 0.63
Endurance training (y)	5.6 ± 5.7	8.0 ± 6.6	t = 1.56, df = 73, P = 0.12
RRS frequency (times per week)	2.8 ± 1.6	3.1 ± 1.7	t = 0.73, df = 74, P = 0.47
Duration of each RRS session (min per session)	78.3 ± 31.2	91.0 ± 39.4	t = 1.38, df = 74, P = 0.17
Primary RRS (%)	Tennis: 63 Racquetball: 29 Squash: 4 Golf: 0 Badminton: 4	Tennis: 46 Racquetball: 38 Squash: 12 Golf: 4 Badminton: 0	χ = 6.91, df = 6, P = 0.33
Most frequent stroke or swing with RRS (%)	Forehand: 88 Backhand: 8 Serve: 4 Forehand and Backhand: 0 Iron shots: 0 Driving: 0	Forehand: 77 Backhand: 6 Serve: 2 Forehand and Backhand: 11 Iron shots: 2 Driving: 2	χ = 4.46, df = 5, P = 0.49

Abbreviations: LBP, chronic or recurrent low back pain; RRS, rotation-related sport

Values expressed as means ± 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.

Characteristic	People without LBP	People with LBP	Statistical Value, Degrees of Freedom, P-value
Total score (range 3–15)[a]	8.84 ± 1.24	8.34 ± 0.73	t = 1.84, df = 32.3[b], P = 0.08
Sport subscore (range 1–5)[a]	3.55 ± 0.61	3.68 ± 0.55	t = 0.96, df = 75, P = 0.34
AveWorkLeisure composite subscore (range 1–5)[c]	2.64 ± 0.54	2.33 ± 0.30	t = 2.73, df = 31.4[b], ***P* = 0.01**

Statistically significant differences are in bold ($P \leq 0.05$)

Abbreviation: LBP, chronic or recurrent low back pain

Values expressed as mean ± standard deviation

[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

TABLE 4

Means and standard deviations for movement pattern variables calculated during active limb movements in people with and people without chronic or recurrent low back pain.

	People without LBP	People with LBP
Knee Flexion		
Maximal knee flexion angle	94.32° ± 28.38°	107.87° ± 69.67°
Maximal lumbopelvic rotation angle	3.30° ± 1.69°	3.28° ± 1.76°
Maximal anterior pelvic tilt angle	3.90° ± 2.00°	3.42° ± 2.02°
Timing of lumbopelvic rotation	0.30 ± 0.18	0.25 ± 0.21
Timing of anterior pelvic tilt	0.30 ± 0.18	0.25 ± 0.21
Hip Lateral Rotation		
Maximal hip lateral rotation angle	46.79° ± 5.40°	44.52° ± 6.47°
Maximal lumbopelvic rotation angle	6.22° ± 2.75°	5.76° ± 3.00°
Timing of lumbopelvic rotation	0.20 ± 0.13	0.21 ± 0.18

P>0.1 for all comparisons

Abbreviation: LBP, chronic or current low back pain

Values expressed as mean ± standard deviation