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Body Characteristics of Professional Japanese Keirin Cyclists: Flexibility, Pelvic Tilt, and Muscle Strength

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Abstract: OBJECTIVE: To identify muscle imbalances and pelvic tilt with implications for low back pain in Keirin cyclists. METHODS: We enrolled 16 Keirin cyclists (mean age, 32.2 ± 8.6 years) and 16 college students as controls (24.3 ± 2.3 years). We measured pelvic tilt, heel-buttock distance (HBD), iliopsoas flexibility (using the Thomas test), hamstring flexibility (using the straight-leg-raise [SLR] test), finger floor distance (FFD), and isometric and isokinetic hamstring and quadriceps muscle strength. These parameters were compared between the two groups, as well as between the right and left sides, by using the Mann-Whitney *U* test or unpaired *t* test. RESULTS: The results of this study revealed a significant anterior pelvic tilt at standing position and significantly higher HBD, SLR, and FFD in the Keirin cyclists than in the controls. The isokinetic muscle strength of the quadriceps and hamstring, and the hamstring-to-quadriceps ratio at high angular velocity were significantly greater in the Keirin cyclists. No significant differences were found between the right and left sides. CONCLUSION: This study revealed that the Keirin cyclists had an anterior pelvic tilt and imbalance in hip muscle flexibility, but the difference between the right and left sides were not significant.

Key words: Keirin, pelvic tilt, muscle flexibility, imbalance.

1. Introduction

Keirin is a track cycle racing event. Races are about 2 km long, with initial circuits at about 25 km/h, gradually increasing to about 50 km/h. The finishing speed is around 70 km/h. Overuse injuries such as that of the lower back usually occur in track cyclists because of a high repetitive load [1-3]. Therefore, injury prevention and management are necessary.

One cause of overuse injury is muscle force or flexibility asymmetry [4]. Cycling is a rare sport performed in a sitting posture, and Keirin cyclists must circle a track in one direction. Thus, muscle force or flexibility asymmetry can occur in the trunk, hip, and pelvis. As with track cycling, other sports with repetitive movements can cause muscle force or flexibility asymmetry. Rowers develop anteroposterior hip muscle flexibility asymmetry because they continuously perform in a state of hip flexion [5]. Speed skaters, and track and field athletes perform repetitive movements on a track, and develop a characteristic hip and trunk muscle asymmetry [6-8]. However, the body characteristics of Keirin cyclists have not been investigated yet. As muscle force or flexibility asymmetry could lead to overuse injury, the physical characteristics of Keirin cyclists should be clarified. Therefore, the purpose of this study was to identify possible muscle imbalances and pelvic tilt with implications for low back pain in Keirin cyclists.

2. Methods

2.1 Subjects

In this study, we enrolled 16 male professional Japanese Keirin cyclists (mean age, 32.2 ± 8.6 years; length of career as a Keirin cyclist, 11.7 ± 8.9 years) and 16 healthy men as controls (mean age 24.3 ± 2.3

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years). Table 1 shows the demographic data of the subjects. We explained the study to Keirin cyclists who had been in the profession for > 2 years and belonged to the Kyoto Keirin Federation, and to college students who were non-athletes and had not performed any excessive exercise. Those who agreed to participate in the study were recruited. Subjects with a history of neuromuscular disease or lower extremity musculoskeletal injury were excluded. Written informed consent was obtained from each participant in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1975. The study protocol was approved by the ethical committee of the Kyoto University Graduate School of Medicine (E-1892).

2.2 Pelvic Tilt

A single experienced physical therapist performed the measurements. A palpation meter (PALM, Performance Attainment Associates, St Paul, MN, USA) was used to measure pelvic tilt angle [9]. The intratest reliability of the PALM was 0.90. During measurement, the participants removed their shoes and stood in an upright position with their feet apart (approximately 10-12 cm). The landmarks for measurement were the ipsilateral anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS). The anterior pelvic tilt was measured by placement of the PALM calliper tips in contact with the ipsilateral ASIS and PSIS. The degree of deviation from the horizontal was read from an inclinometer. Positive degrees were used to describe anterior innominate tilt; and negative degrees, to describe posterior tilt in the sagittal plane. Pelvic tilt was measured for each side, and the mean values for the right and left sides were calculated and used in the analysis.

2.3 Muscle Flexibility

Heel-buttock distance (HBD), iliopsoas flexibility (using the Thomas test), hamstring flexibility (using the straight-leg-raise [SLR] test), and finger floor distance (FFD) were measured by following Kathiresan's protocol [10]. HBD was measured as an indicator of quadriceps flexibility. In this test, the subject was placed in the prone position with one knee passively bent. In this position, the distance from the heel and buttock was measured. The Thomas test was performed to measure iliopsoas flexibility. In this test, the subject was placed in the supine position, and the subject's hip and knee on one side were passively flexed. In this position, the distance from the floor to the back of the knee of the other leg was measured. The SLR test was used to measure hamstring flexibility. In the test, the subject's leg, with the knee held straight, was passively raised parallel to the edge of the table while the subject was in the supine position. The hip flexion angle was measured with a goniometer. HBD and SLR were measured for both sides. FFD was measured as an indicator of trunk and hip flexibility. FFD was defined as the distance between the fingertip and the floor when the subject bends in an upright standing position and extends the fingers toward the floor. The distance from the fingertip to the ground was measured with a tape measure, with a positive value indicating high flexibility.

2.4 Muscle Strength

An isokinetic dynamometer (Biodex System 4.0, Biodex Medical Systems Inc., USA) was used to measure muscle strength. The participants were seated correctly on the Biodex. The distal portion of the dynamometer arm was strapped proximal to the ankle

Table 1 Physical characteristics of Keirin cyclists and controls.

	Keirin	Control
	n = 16	*n* = 16
	Mean ± SD	Mean ± SD
Player age, years	32.2 ± 8.6	24.3 ± 2.3
Height, cm	176. 2 ± 3.3	171. 1 ± 4.6
Weight, kg	78.8 ± 7.5	65.3 ± 7.9
Body mass index, kg/m^2	25.4 ± 2.0	22.3 ± 2.4
Career as a Keirin cyclist, years	11.7 ± 8.9	−

joint, and the axis of the knee rotation was aligned with the lateral femoral condyle of the knee. The thigh was stabilized. The back support of the Biodex was positioned to fix the hip angle of the participants for adequate articular amplitude. The participants were secured on the seat with straps for maximal stability during the entire assessment. They performed 5 s of maximal isometric quadriceps and hamstring contractions of both legs at 90 °knee flexion (ISO), and five cycles of maximal concentric knee flexion-extension for both legs at 60 °, 180 °, and 360 ° per second (CON60, CON180, and CON360). We calculated the hamstring-to-quadriceps (H/Q) ratio from the values of these parameters.

2.5 Statistical Analyses

Differences in pelvic tilt, muscle flexibility, and muscle strength between the two groups were compared by using the Mann-Whitney *U* test (for non-normal distributions: HBD and the Thomas test) or unpaired *t* test (for normal distributions: pelvic tilt, SLR, FFD, and isometric and isokinetic muscle strength). We also compared each parameter for the right and left sides by using the Mann-Whitney *U* test or unpaired *t* test between the two groups. Statistical analysis was performed by using the SPSS version 20.0 software package (IBM Corp., Armonk, NY, USA), with a P value of < 0.05 considered as significant.

3. Results

The results of this study showed a significant anterior pelvic tilt in the Keirin cyclists as compared with the controls (8.3 ° ± 3.3 ° vs. 5.6 ° ± 2.4 °, $P < 0.01$). The HBD, SLR test score, and FFD were significantly higher in the Keirin cyclists than in the controls (HBD: 4.2 ± 4.7 cm vs. 0.5 ± 1.3 cm, $P < 0.01$; SLR: 94.1 ° ± 11.3 ° vs. 74.2 ° ± 7.4 °, $P < 0.01$; FFD: 15.2 ± 8.4 cm vs. −1.4 ± 9.5 cm, $P < 0.01$; Table 2). However, no significant difference was found in the Thomas test scores of the two groups.

The isokinetic muscle strength of the quadriceps and hamstrings were significantly higher in the Keirin cyclists. In addition, the H/Q ratios at 180 ° and 360 ° were significantly greater in the Keirin cyclists (Table 3). However, no significant differences were observed between right and left sides.

4. Discussion

In our study, the pelvic tilt of the Keirin cyclists was anterior to that of the controls. The Keirin cyclists had

Table 2 Pelvic tilt and muscle flexibility of Keirin cyclists and controls.

	Keirin	Control	*P* value
	n = 16	*n* = 16	
	Mean ± SD	Mean ± SD	
Pelvic tilt, °†	8.3 ± 3.3	5.6 ± 2.4	< 0.01*
Heel buttock distance, cm††	4.2 ± 4.7	0.5 ± 1.3	< 0.01*
Thomas test, cm††	3.8 ± 1.7	4.0 ± 1.2	0.61
Straight leg raise, °†	94.1 ± 11.3	74.2 ± 7.4	< 0.01*
Finger floor distance, cm†	15.2 ± 8.4	-1.4 ± 9.5	< 0.01*

†Continuous data are expressed as the mean ± SD (tested by the student's t-tests).
††Non parametric data are expressed as the mean ± SD (tested by the mann–whitney U-tests).

Table 3 Isometric and isokinetic muscle strength of Keirin cyclists and controls.

	Keirin	Control	*P* value
	n = 16	*n* = 16	
	Mean ± SD	Mean ± SD	
Quadriceps peak torque, Nm			
ISO†	241.6 ± 45.5	221.4 ± 49.4	0.23
CON60†	195.9 ± 20.6	172.2 ± 25.9	< 0.01*
CON180†	137.5 ± 13.3	125.4 ± 13.6	0.02*
CON360†	110.0 ± 16.0	98.8 ± 13.0	0.04*
Hamstringth peak torque, Nm			
ISO†	97.7 ± 20.2	88.7 ± 17.5	0.02
CON60†	94.6 ± 18.6	77.6 ± 12.6	< 0.01*
CON180†	81.6 ± 13.6	61.2 ± 14.0	< 0.01*
CON360†	77.1 ± 13.4	59.0 ± 12.4	< 0.01*
Hamstrings to Quadriceps ratio			
H/Q_{ISO}†	0.41 ± 0.10	0.45 ± 0.11	0.39
H/Q_{CON60}†	0.48 ± 0.08	0.44 ± 0.10	0.17
H/Q_{CON180}†	0.59 ± 0.09	0.47 ± 0.14	< 0.01*
H/Q_{CON360}†	0.72 ± 0.16	0.55 ± 0.14	< 0.01*

†Continuous data are expressed as the mean ± SD (tested by the student's t-tests).

low anterior thigh muscle flexibility but high posterior flexibility. Moreover, the Keirin cyclists had greater isokinetic quadriceps and hamstring strength and H/Q ratio at high angular velocity than the controls. However, no significant differences were observed between the right and left sides.

This study revealed that the anterior pelvic tilt was significantly greater in the Keirin cyclists than in the controls. Pelvic tilt is caused by an imbalance between the anterior and posterior pelvic muscles; the quadriceps and iliopsoas tilt the pelvis anteriorly and the hamstrings tilt the pelvis posteriorly [11]. In our study, quadriceps flexibility was significantly low and hamstring flexibility was significantly high in the Keirin cyclists. However, no significant difference in iliopsoas flexibility was observed between the two groups. Based on our results, the tightness of the quadriceps and the looseness of the hamstrings, instead of the iliopsoas, would be involved in the anterior pelvic tilt in the Keirin cyclists. Moreover, this physical characteristic is similar to those of the lower crossed syndrome (LCS) proposed by Janda [12]. In the LSC, tightness of the thoracolumbar extensors on the dorsal side crossed with the tightness of the iliopsoas and rectus femoris, and deep abdominal muscle weakness ventrally crossed with gluteus maximus and medius weakness. This pattern of imbalance creates lumbar lordosis [13]. Considering this theory, Keirin cyclists also have muscle tightening of the thoracolumbar extensors and weakness of muscles such as the abdominal, gluteus maximus, and medius, not only thigh muscle flexibility imbalance. Therefore, correcting muscle flexibility and strength are needed to improve the anterior pelvic tilt.

On the other hand, isokinetic quadriceps and hamstring strength and the H/Q ratio at high angular velocity are high in Keirin cyclists. In Keirin racing, isometric power is needed only at the start, but isokinetic power is needed for the entire race. In addition, in competitive cycling, unlike in recreational cycling, the foot is fixed to the pedal and cyclists can use the hamstrings to produce a driving force. During a Keirin race, the maximum speed of cyclists is about 70 km/h. Therefore, Keirin cyclists have hamstrings that can contract at high angular velocity. The results of this study demonstrate the muscle strength characteristics of Keirin cyclists.

Coronal body imbalances could occur in track cyclists, but no significant differences were found in our study. For sports that require repetitive asymmetrical movements such as rowing, fencing, and golf, athletes develop asymmetrical body characteristics [14-16]. Compared with these sports, track cyclists must circle in the same direction, but the cycling movement is symmetrical. Therefore, Keirin cyclists do not have asymmetrical physical characteristics on the coronal plane.

The Keirin cyclists in this study had anterior pelvic tilt due to hip muscle flexibility imbalance, but no significant difference was found between the right and left sides. Excessive anterior pelvic tilt can lead to low back pain [17]; hence, correction of muscle imbalance and improvement of anterior pelvic tilt are important. Keirin cyclists have lower quadriceps flexibility because of lack of stretching of the muscle and require muscle strength training for muscles such as the abdominal, gluteus maximus, and medius muscles, which tend to be weak in these athletes based on the LCS theory. Stretching and training to improve muscle flexibility have been conducted for healthy men or other sports athletes [18, 19], but not for Keirin cyclists. Further study to improve quadriceps flexibility and pelvic tilt in Keirin cyclists is needed.

This study has some limitations. First, the number of participants in each group was limited, and the demographic data of the control subjects were not matched to those of the Keirin cyclists. Keirin cyclists are well trained and have greater height and weight. In this study, the control subjects did not have an athletic built and had the average weight and height of Japanese. Second, the incidence of low back pain was not investigated in this study. Further study is needed to compare physical characteristics between cyclists with and cyclists without low back pain. Third, the measurements of flexibility and strength were limited to certain muscles. In order to better characterize the physical characteristics of Keirin cyclists, measurements should also be performed for other muscle groups such as the trunk muscles. In light of these limitations, the findings in this study should be considered as preliminary.

5. Conclusion

We measured pelvic tilt, muscle flexibility, and strength in Keirin cyclists and healthy men. Our study revealed that the anterior pelvic tilt in the Keirin cyclists was due to muscle flexibility imbalance, but no significant differences were found between the right and left sides.

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