KINEMATICS AND KINETICS OF SWING LEG IN CURVED SPRINT RUNNING

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The purpose of this study was to demonstrate kinematics and kinetics of left and right swing legs in curved sprint running. Nine male sprinters and decathletes participated in this study. Participants run 60 m on a curved path and their motion was recorded by a motion capture system. The joint angle, angular velocity, moment and power of both swing legs were calculated. For the statistical test, a statistical parametric mapping was used. There were no kinematic and kinetic differences in the hip joint. However, asymmetries were found in the knee joint. Runners may just move swing legs same as for straight running/sprinting.

KEYWORDS: curved sprinting, swing leg.

INTRODUCTION: When running on a curved path, the centripetal force acts on runner's body. This force affects the running velocity and running techniques (Alt, Heinrich, Funken, & Potthast, 2015; Churchill, Salo, & Trewartha, 2015; Ishimura, Tsukada, & Sakurai, 2013; Stoner & Ben-Sira, 1978). In addition, biomechanical asymmetries between left and right support legs have been found in curved sprint running (Alt et al., 2015; Churchill et al., 2015; Ishimura & Sakurai, 2010, 2016). Recently, the mechanism of curved running is becoming clear. However, researchers have focused on support phase and legs. The reason would be that the centripetal force acts only during support phases and through support legs. Meanwhile, many researchers have investigated the mechanism of straight running. Some studies have focused on the swing leg kinematics and kinetics (Nagahara, Matsubayashi, Matsuo, & Zushi, 2017; Schache et al., 2011). However, to our best knowledge, little is known about the swing leg in curved running. From the perspective of coaching, the swing leg mechanism is important. If kinematics and kinetics of swing leg in curved running are investigated, this would contribute to improved understanding of the mechanism of curved running. Moreover, it would help coaches and athletes to develop curved running performance and technique. Thus, this study aims to determine kinematics and kinetics of left and right swing legs in curved sprint running.

METHODS: A total of 9 male sprinters and decathletes (Mean ± SD: 20.8±0.1 years: 1.73±0.05 m, 67.5±6.5 kg) volunteered for the study. All participants had no lower extremity injuries. Informed consent was obtained from all, and the protocol was approved by the institutional research ethics committee. After their own warm-up exercise, participants wore lycra cap, shirts, tights and their own spike shoes. Forty-one retro-reflective markers (diameter: 14 mm) were placed on body landmarks selected from a previous study (Ishimura & Sakurai, 2013). All participants were asked to perform 3 × 60m sprints on the curved path (lane 4: average radius: 43.51m) of outdoor track with sufficient inter-trial intervals. The running time of the latter 30m was recorded with a photocell system (PhotoGate, BROWER Timing Systems Inc., Draper, USA), and one trial with fastest running time was chosen for further analysis. 3-D positional data of the markers were recorded using a motion capture system (250 Hz) with 19–20 infrared cameras (10 Vicon-MX13 and 9–10 Vicon-MX-T20, Oxford Metrics Inc., Oxford, UK). This system was established at a distance of 40 m to 55 m from the beginning of the 60-m course. Data collection was conducted in 3 days and, therefore, the number of cameras was different among days. Obtained raw positional data were smoothed using Singular Spectrum Analysis techniques with window length $L = n/10$ and first 3 principal components for data reconstruction (Alonso, Castillo, & Pintado, 2005; Ishimura & Sakurai, 2012). Segment and joint coordinate systems were set on each participant legs (thighs, shanks and feet) and pelvic to calculate joint kinematics and kinetics (angle, angular velocity, moment and power).

Segmental inertial parameters were taken from the body segment parameters of Japanese athletes (Ae, Tang, & Yokoi, 1992). All variables were calculated as average of two swing phases. Each swing time was normalized to 100%. A statistical parametric mapping (SPM), specifically a Hotelling's T^2 test (α=0.05) were used to assess the 3-D (3-component) time varying (1D) vectors of the hip and knee joint. When warranted, post hoc paired t tests were conducted between left and right legs (Donnelly et al., 2017; Pataky, Robinson, & Vanrenterghem, 2013). All SPM analyses were implemented using the open-source spm1d code (version0.4, www.spm1d.org) in Matlab (R2018a, The Mathworks Inc, Natick, MA).

RESULTS: Kinematics and kinetics of the left and right hip (Figure 1) and knee (Figure 2) joints were highly similar for the majority of swing phase. The critical threshold SPM{T^2} of 98.798 and 109.668 were exceeded for the 3-D hip joint moment and power, respectively. Post hoc analysis did not show kinematic and kinetic differences between the left and right swing legs. The critical threshold SPM{T^2} of 60.063 and 90.844 were exceeded for the 3-D knee joint angle and moment, respectively. Post hoc paired t test indicated the differences during 0-11% and 85-93% for the knee adduction/abduction angle, 41-45% for the knee adduction/abduction moment and 0-6% for the knee internal/external rotation moment.

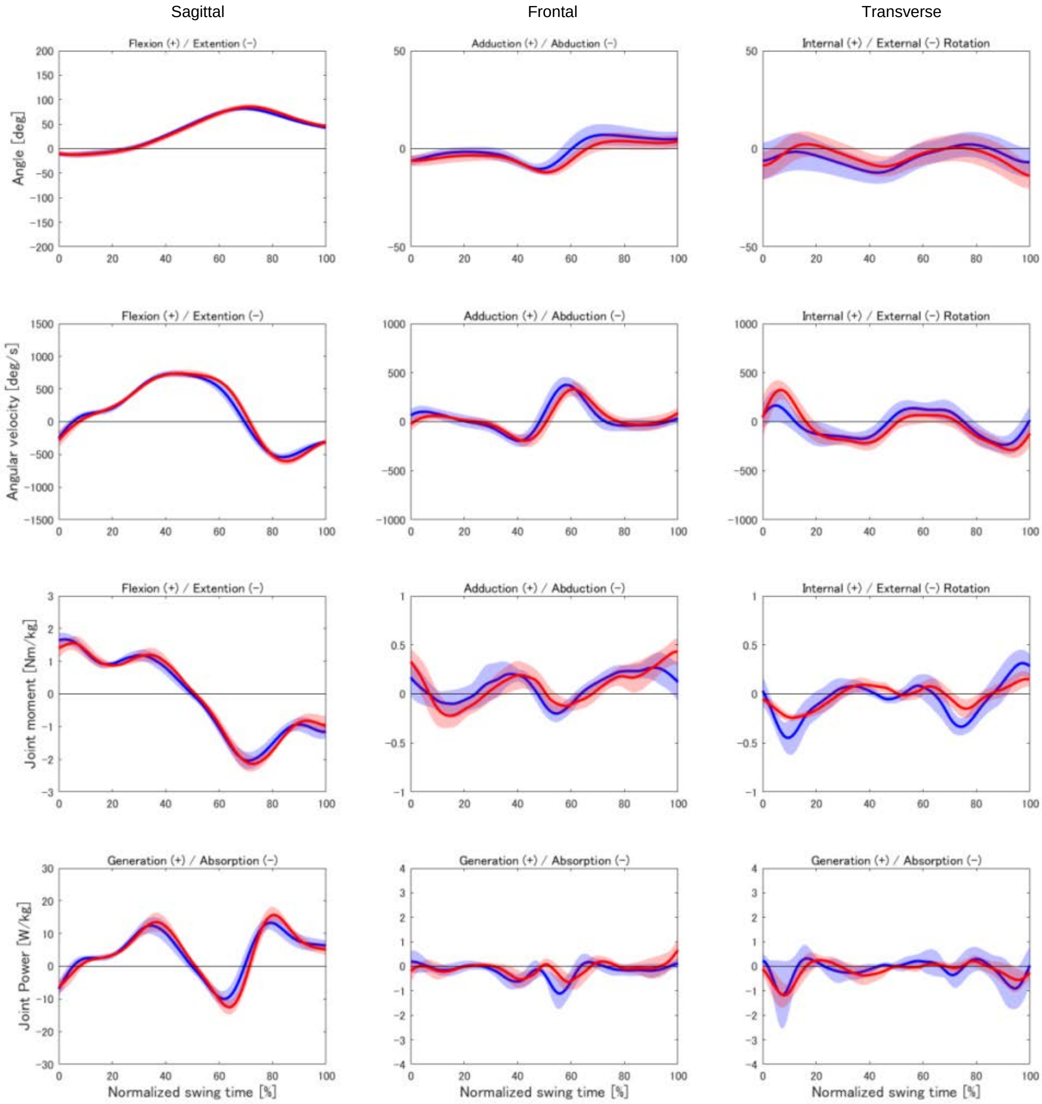

Figure 1: Means (lines) and standard deviations (shades) of angle, angular velocity, joint moment and joint power of hip joint. Blue and red indicate left and right swing leg, respectively.

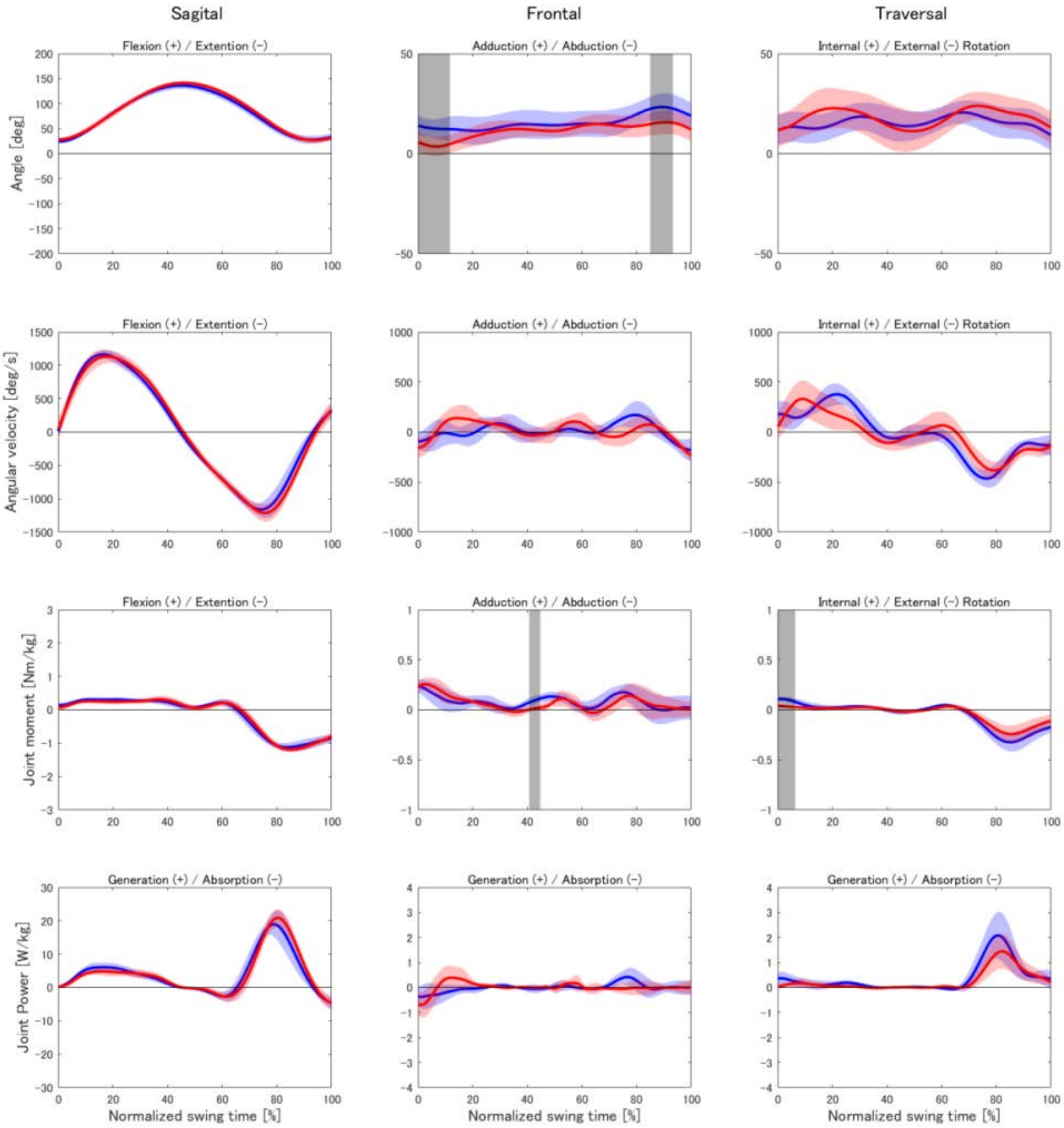

Figure 2: Means (lines) and standard deviations (shades) of angle, angular velocity, joint moment and joint power of knee joint. Blue and red indicate left and right swing leg, respectively. Gray vertical bars show the significant difference in post hoc SPM{t}.

DISCUSSION: This study demonstrated the swing leg kinematics and kinetics in curved sprint running. The patterns of joint angle, angular velocity, moment and power demonstrated here were quite similar to those for straight sprinting in previous studies (Nagahara et al., 2017; Novacheck, 1998; Riley et al., 2008; Schache et al., 2011). Surprisingly, there were no statistical differences between left and right of hip joints (Figure 1). The asymmetries between left and right were found only in the knee joint angle and moment (Figure 2). These results may show that there is no technical adaptation for swing legs in curved running/sprinting. In curved running/sprinting, runner's body inclines toward the centre of path. In the curved running/sprinting, therefore, runners may just move swing legs the same as in straight running/sprinting.

CONCLUSION: The joint kinematics and kinetics of swing leg (hip and knee) in curve running were revealed. These parameters were quite similar to straight sprinting. Moreover, the asymmetries were shown only in the knee joint. Therefore, we could conclude that runners may just move swing legs in curve running the same as in straight running/sprinting.

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