HIP MOMENT PROFILES DURING CIRCLES IN SIDE SUPPORT AND IN CROSS SUPPORT ON THE POMMEL HORSE

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The purpose of this study was to analyze the hip moment profiles during Circles and to assess how gymnasts modulate their technique depending on different orientation on the pommel horse. Circles in side support and in cross support performed by six gymnasts were captured using Qualysis motion capture system. Hip joint moments were computed with the assumption that the total leg was a single rigid body. The results implied that the lateral-flexion movement at the hip joint was closely related to the important technique of both types of Circles. Cross-Circles were characterized by the greater flexor moment throughout a Circle and the smaller lateral flexor moment in the rear support phase.

KEY WORDS: Circle, Pommel horse, Hip joint moment

INTRODUCTION: Hip joint movements are one of the most critical factors of Circles, the most fundamental skill on the pommel horse in which a gymnast rotates his body horizontally alternating support from arm to arm (Fig.1). Although many textbooks describe that the whole body should be kept straight during Circles, a developing gymnast often bends his body at his hip joint to continue Circles, while keeping his knee joints straight. For this reason, the hip joint angle has been used as a discriminant variable that reflects a gymnast's level of expertise with Circles (e.g Baudry et al., 2006). Fujihara et al. (2009) asserted that lateral-flexion of the hip might be a technique unlike flexion considered a technical error. Mizushima (1998) discussed the hip rotation about the long axis, in relation to body twisting. As well as these kinematic studies, a kinetic study of the hip motions is necessary to further our analysis of Circle technique. Fujihara and Gervais (2008) observed that Circles in side support (Side-Circles, Figure1 top) and Circles in cross support (Cross-Circles, Figure1 bottom) showed different kinematic profiles due to the physical characteristics of the pommel horse. As an extension of this study, it was thought that conducting kinetic analysis using the same data set would provide a deeper insight of Circles technique. The purpose of the current study was, then, to analyze the hip moment profiles during Circles and to assess how gymnasts modulate their technique depending on the different orientation on the pommel horse.

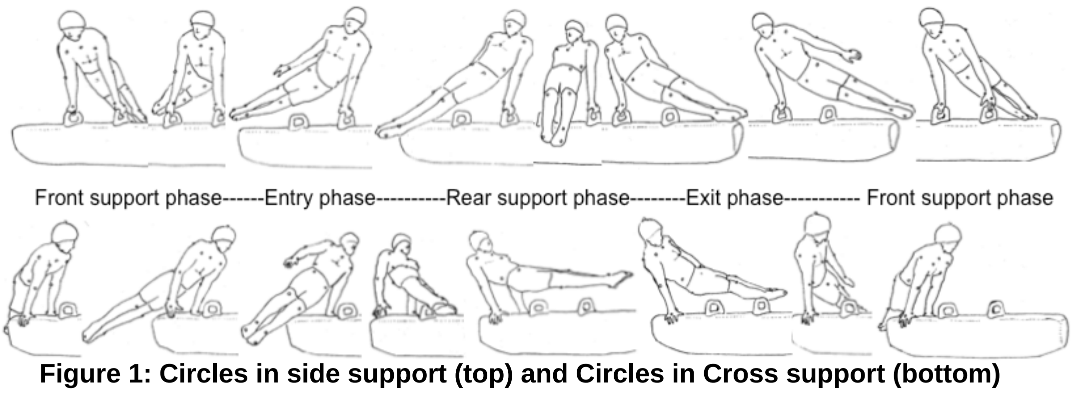

Figure 1: Circles in side support (top) and Circles in Cross support (bottom)

METHOD: Data Collection: Six gymnasts performed 3 sets of 10 Side-Circles and 3 sets of 10 Cross-Circles on a pommel horse. They were national or international level gymnasts. The first set of 10 Circles was randomly assigned as either Side-Circles or Cross-Circles, and in the subsequent sets, they performed two types of Circles alternatively. Our local ethics committee approved all experimental protocols. Prior to the experiment, each gymnast provided informed consent. Thirty seven retro-reflective markers were attached to the gymnast's body to estimate de Leva's (1996) suggested anatomical landmarks. Three-dimensional coordinates of these markers were acquired using 12 QUALISYS Proreflex motion tracking cameras operating at 120 Hz. Body mass and height were also measured.

Data Analysis: Three-dimensional coordinates data were smoothed using a fourth-order Butterworth digital filter at the optimal cut-off frequencies determined by automatic algorithm (3.67 Hz and 9.61 Hz) of Yokoi and McNitt-Gray (1990). The joint centres were estimated as the centres of two markers attached on the surface of each joint. To compute hip joint moments, all segments of the lower extremities—feet, shanks and thighs—were assumed to be a single rigid body. The moments of inertia of the total legs were computed using the parallel axis theorem based on the six segments. Note that under this assumption hip joint moments for each leg were not considered. Therefore, hip joint moment for adduction at each side of the hip, which was probably present to keep two legs together, was not taken into account. The hip joint moments were estimated by solving Euler's equations with two rigid bodies: the total leg and the lower trunk. Three local reference systems, two for the segments and one for the joint, were defined using vector cross products (Figure 2). In addition to the joint moment profiles, the joint power was computed as the product of the joint moment and the joint angular velocity, which was defined as the relative angular velocity of the distal segment with respect to the proximal segment. The joint moments and joint powers were normalized by each gymnast's body mass. For each set of 10 Circles, 7 Circles (3rd - 9th) were used so that the mean data for each variable were computed from the data of 21 Circles (7×3). The Wilcoxon matched-pairs test was used to compare Cross-Circles to Side-Circles. The effect sizes (*ES*) were computed as the differences divided by the standard deviations for Side-Circles.

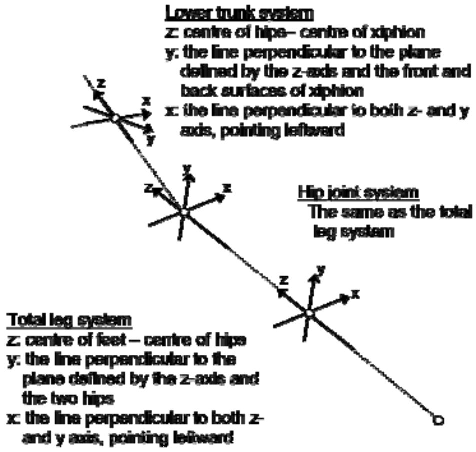

Figure 2: Definitions of the local reference systems

RESULTS: Figure 3 presents the angular velocities, joint moments, and joint powers at the hip joint during Side-Circles and Cross-Circles. For both types of Circles, the flexor moment was observed throughout a complete single Circle with mild peaks just before right-hand release, and during entry and exit phases. It should be reported, however, that the gymnast who seemed to perform the best quality Circles showed a small amount of extensor moment during the rear support phase for both Side- and Cross-Circles. In terms of flexion-extension movement, Cross-Circles was characterized by the greater flexor moments on average (0.43 vs 0.20 N·m/kg, p = 0.028, *ES* = 2.11), and the greater energy generation at the right-hand release (0.65 vs 0.10 W/kg, p = 0.028, *ES* = 3.73). In the lateral motions, the greater moments were observed for Side-Circles at the right hand contact (0.34 vs 0.10 N·m/kg, p = 0.028, *ES* = 3.06), and the left hand release (-0.64 vs -0.24 N·m/kg, p = 0.028, *ES* = 2.20). Both types of Circles showed the fast long-axial rotation of the total legs towards the right with respect to the lower trunk during the front support, but the magnitudes of the moments and powers were much smaller than those for flexion or lateral flexion.

DISCUSSION: On average, the hip flexor moment was observed throughout a Circle with several minor peaks. The patterns were not consistent among all gymnasts: each gymnast showed several peaks in different phases. Therefore, a more detailed analysis in relation to each individual technique is desirable to interpret the change in flexor moments. This is consistent with Fujihara and Fuchimoto (2006), who studied Side-Circles performed by 17 university

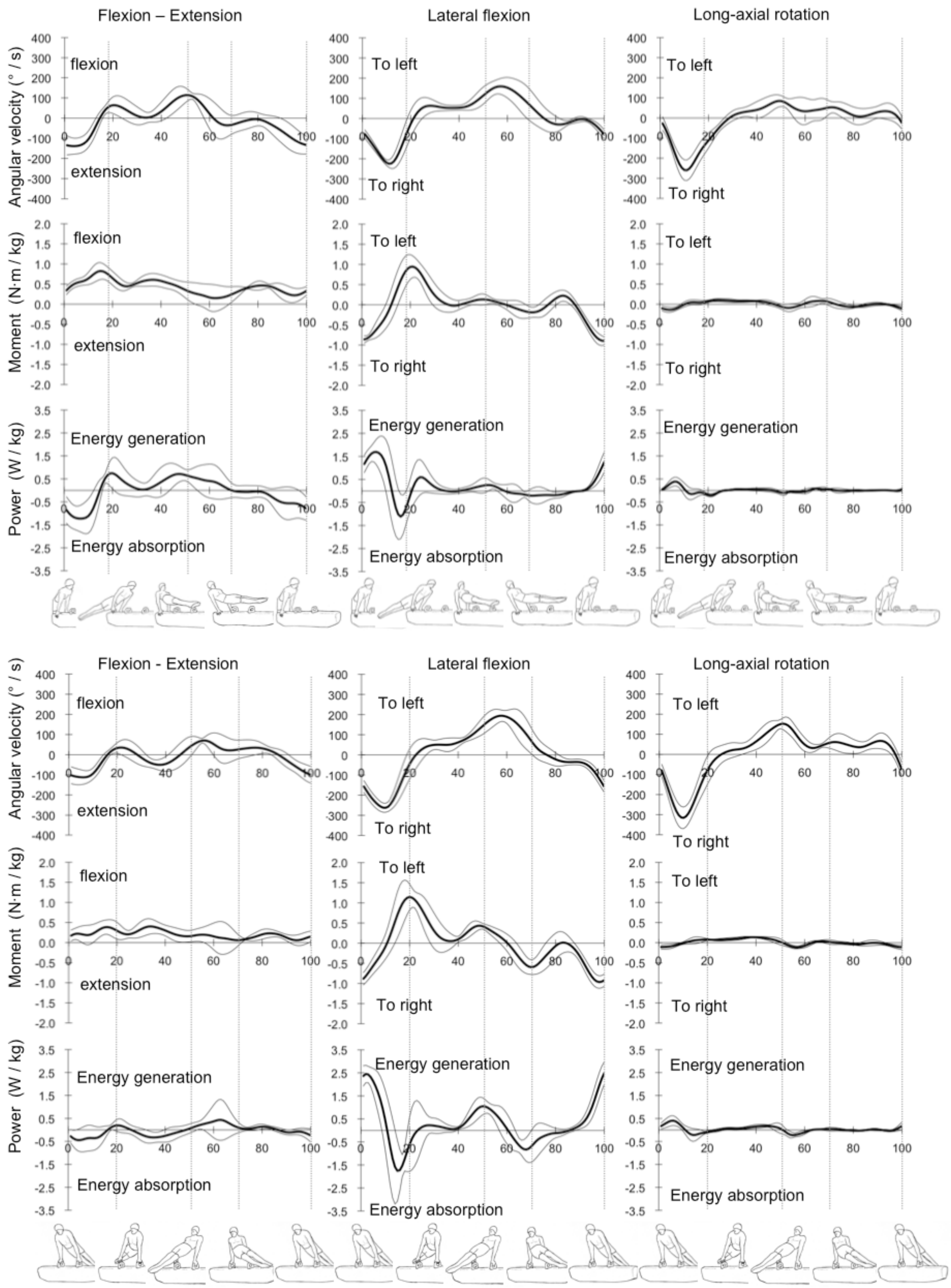

Figure 3: Angular velocities, moments, and powers at the hip joint during a single circle in cross and side support. The profiles are the averages (± one standard deviation) of 6 gymnasts (each performed 21 circles). The vertical lines and figures depict hand-contact and hand-release phases (left hand contact at 0 and 100%).

gymnasts, in the sense that no typical pattern of flexion-extension motion at the hip joint was found. As a general observation, however, the greater hip flexor moment was present in

Cross-Circles than in Side-Circles. Fujihara and Gervais (2008) reported the greater hip angle during the rear support for Cross-Circles and attributed it to the obstacle avoidance, namely, clearing the pommel horse. Although the hip flexor moment seemed to drop during the rear support, the greater moment in the preceding phases could explain the greater hip flexion in the rear support. On the other hand, a more consistent pattern was found in the lateral flexor moment among all gymnasts. Fujihara and Fuchimoto (2006) did report the general pattern of the lateral flexion motion. That is, gymnasts bended their body towards the non-supporting-hand side during the single hand support phases. Although it may not be as clear for Cross-Circles, the lateral flexor moment reached the major rightward peak at the left hand contact, the minor rightward peak at the right hand contact, the minor leftward peak at the left hand release, and the major leftward peak at the right hand release. Stated differently, the greater and smaller peaks occurred in the front support side and in the rear support side, respectively. Note that these peaks at the hand releases were eccentric work, and those at the hand contacts were concentric work. Fujihara et al. (2009) asserted that, during the double hand support phases, the upper body moved side-to-side to switch the supporting hands, and the body rotates mainly about its centre of mass. The lateral-side concentric work at the hand contacts seemed helpful to create the body rotation about the centre of mass during the side-to-side movement of the upper body. The greater side-to-side movement of the upper body for Side-Circles is perhaps one of the possible reasons for the greater magnitude seen in the lateral flexor moment.
The angular velocity of the long-axial rotation represents what is known as “twisting motion” of the hip. From the front support phase to the right hand release, a gymnast twists his hips rightward so that the front side of the legs faces up. Then, this twisted body turns in the opposite direction throughout a Circle. Both types of Circles showed this pattern, but the required moment for this motion was relatively small due to the shorter moment arm and smaller moment of inertia.

CONCLUSION: This study describes the hip moment profiles during two types of Circles. The results suggested that the lateral-flexion movement at the hip joint was an integral technique component of both types of Circles. Although more detailed analysis with individual technique is desirable, “piking” the body (flexion) appeared to be an individual adjustment to complete the skill (e.g. to keep dynamic balance or to avoid the collision with the pommel horse). It is recommended that coaches and gymnasts appreciate the importance of lateral hip motion for successful execution of Circles.

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