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HEAD POSITIONS ARE RELATED TO THE PERFORMANCE QUALITY OF CIRCLES ON POMMEL HORSE

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Enhancing the quality of circles is critical for pommel horse performance. Previous research as well as coaching literature emphasizes the importance of body alignment such as hip angle, but little attention has been attracted to head positions. Our purpose was to investigate the head-segment kinematics and its relation to other performance variables during circles on pommel horse. Through typical kinematic and correlational analysis of 18 participants, it was revealed that the skilled gymnasts moved their head significantly more backward in the rear support phase than the less skilled counterparts. The head positions in the rear support phase were correlated with the scores and also the performance variables such as body flexion angle, shoulder extension angle, and the horizontal diameter of shoulder trajectories.

KEY WORDS: gymnastics, kinematics, correlation, coaching, rotation

INTRODUCTION: Pommel horse is one of six events in men’s artistic gymnastics, and a representative skill, called “circles” (Figure 1), is the foundation of more than 80% of skills on this apparatus. It is well understood that enhancing the quality of circles is critical for pommel horse performance. Coaching literature tells us that high-quality circles are characterized by a straight body throughout a rotation (i.e. Karácsony & Čuk, 1998), and the *Code of Points* (International Gymnastics Federation, 2010) states that “lack of body extension in circles” is an error for point deduction.

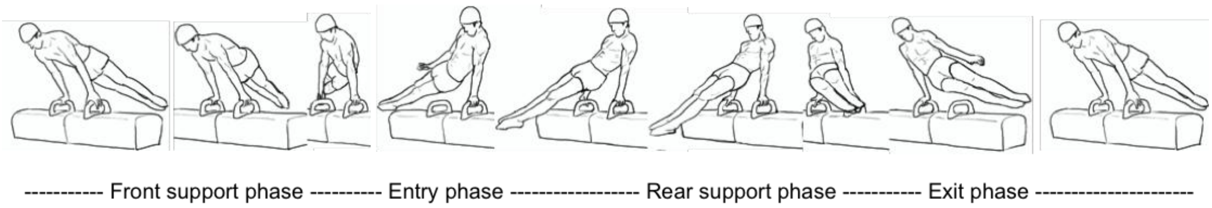

Figure 1: Circles on pommel horse.

To evaluate the quality of circles, biomechanists have examined hip angle or body angle as a measure of body extension, showing the greater body flexion in less skilled gymnasts compared to more skilled counterparts (Fujihara & Gervais, 2012a, Baudry et al., 2009). The amplitude of circles has also been evaluated using the horizontal diameter of the ankles’ excursion. This variable was first computed by Grassi et al. (2005), and it has been used in several studies for a quantitative assessment of performance (Fujihara & Gervais, 2012a, b, Baudry et al., 2009). In addition to these variables, Baudry et al. (2009) found that the diameter of horizontal shoulder excursion and the shoulder angle of extension in the rear support phase (See Figure 1 for the phase definition) could also discriminate skill level. Such findings are in line with the fact that coaching manuals often describe the importance of shoulder motions (i.e. Readhead, 1997).
Through our coaching experience, we became curious about the head position during circles. Gymnastic textbooks usually describe a desirable body alignment, hand positions, timing of hand releases and re-grasps, shoulder motions, and so forth, but the positions of the head have received less attention from coaches or researchers. According to Karácsony and Čuk

(1998), the head position reflects individual technique. Our practical observations, however, have led us to hypothesize that head orientation may have a strong relationship to the quality of circles, in particular, during the rear support phase. The ankles and head are the most distal segments from the whole-body's mass centre, which is the rotational centre of one of two rotations that comprise a circle (Fujihara, 2010). The mass of the head segment is typically estimated to be approximately 7% of body mass. Considering the distance from the centre of rotation, the influence of head positions during circles should not be considered insignificant. Head positions are likely to influence the overall dynamic balance for successful circles and to be related to key technical points such as body angles and shoulder motions. Also, some reflexes and inter-segment coordination are often associated with head movements. Considering the possible importance of head positions during circles, we believe that biomechanics can provide useful and practical information for this technical point. Therefore, the purpose of this research was to investigate the head-segment kinematics and its relations to performance variables during circles on pommel horse.

METHODS: Our previous study (Fujihara & Gervais, 2012b) can supplement information about the methodology because this study was conducted by extending the analysis of the data collected at that time.

Participants: Eighteen national-level gymnasts, including four who had international competition experiences, participated in this study. All participants were capable of performing 20 consecutive circles on two handles of a pommel horse. The mass, height and ages of the gymnasts were 47.7 ± 10.8 kg, 1.55 ± 0.11 m, and 16.2 ± 3.6 years. They had 9.4 ± 2.9 years of experience in competitive gymnastics and trained 20.3 ± 3.5 hours per week. University Ethical approval was gained for all experimental protocols, and the gymnast provided written informed consent.

Data collection and analysis: Thirteen Qualisys ProReflex cameras and two video cameras were set around a no-leg pommel horse. The origin of the global reference system was set at the centre of the top surface of the horse. The x, y, and z-axes were defined as shown in Figure 2. After a warm-up, the participants were fitted with retro-reflective markers on the anatomical landmarks suggested by de Leva (1996) and performed three sets of 10 circles on the pommel horse. Three-dimensional (3-D) kinematic data were recorded at 100 Hz. For each set of 10 circles, 7 circles (3rd – 9th) were used so that the individual mean data were computed from the data of 21 circles. The 3-D coordinate data were smoothed using a fourth-order Butterworth digital filter at the optimal cut-off frequencies (3.0 Hz – 12.2 Hz) determined by an automatic algorithm (Yokoi & McNitt-Gray, 1990). The head segment was defined as a line from a vertex (top of head) to the centre of right and left gonions, and its mass centre was estimated as a point at 59.76% from the vertex (de Leva, 1996). Hip joint centres were estimated using Halvorsen's algorithm (2003), and all other joint centres were estimated as the centres of two markers attached on the surface of each joint. Four internationally accredited judges scored the video-recorded circles. A perfect score was set at 10.0 and deductions were applied in step of 0.1 according to technical faults or execution errors. Then, the average of four scores was determined as the final score. The intra-class correlation coefficient, computed as an estimate of the inter-judge reliability, was 0.944. The top six gymnasts were classified as the expert group (scores ≥ 9.30), and the bottom six gymnasts were classified into the developing group (scores ≤ 8.50). As representative kinematic variables for performance evaluation of circles, the following variables were considered: horizontal diameters of shoulder and ankle trajectories (shoulder diameter, ankle diameter), body angle, and shoulder angle. The detailed definitions and computational description for these variables can be found in Fujihara and Gervais (2012b). The Wilcoxon-Mann-Whitney *U* test was used to compare the expert to the developing group. Head positions as related to

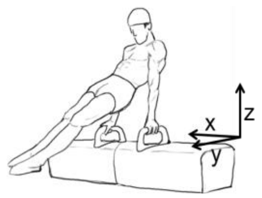

Figure 2: The direction of three axes in the global reference system with respect to performance.

performance of circles were investigated by Pearson's product-moment coefficient of correlation between the head positions and the scores as well as other computed variables. A more stringent α level (0.02) than the traditional 0.05 was selected for this study to control an inflation of the family-wise error rate due to multiple univariate statistical tests.

RESULTS and DISCUSSION:

The results showed that head positions seem to be important to the performance of circles. Figure 3 displays the horizontal trajectories of the head during circles of 18 gymnasts. The diameters of these trajectories, computed by Grassi et al.'s method (2005), were significantly different between the expert and developing gymnasts (0.37 ± 0.01 vs. 0.32 ± 0.02 body height, $P < 0.01$). In fact, these diameters were significantly correlated with the scores ($r = 0.56$, $P < 0.02$). In Figure 4, clear difference in the head positions could be visually observed especially in the rear support phase. Statistically significant difference was found in the average y-coordinates of head segment during the rear support phase between the expert and developing groups (- 0.09 ± 0.01 height vs. - 0.03 ± 0.02 height, $P < 0.01$). The average y-coordinates of the head during the rear support phase also showed a correlation with the scores ($r = -0.56$, $P < 0.02$). Those in the front support phase, however, were not correlated with the scores ($r = -0.12$). These results implied that moving the head more backward during the rear support might be an important factor to achieve high-quality circles. The average y-coordinate of the head during the rear support phase was also correlated with the discriminative kinematic variables focused on in previous studies (Baudry et al., 2009, Fujihara & Gervais, 2012a, b). The more backward a gymnast moved his head during the rear support phase of circles, the more his body was stretched ($r = -0.89$, $P < 0.001$), the greater shoulder angles were maintained ($r = -0.80$, $P < 0.001$), and the greater shoulder diameter was achieved ($r = -0.82$, $P < 0.001$) (Figure 5). These correlations do not imply any causal relationship between the variables; however, it is beneficial for practitioners to realize the existence of such patterns. For instance, it may be easier for some gymnasts to control head positions than to control body angle or shoulder angle. A coach can use a variety of instructions that can lead to the desired posture.

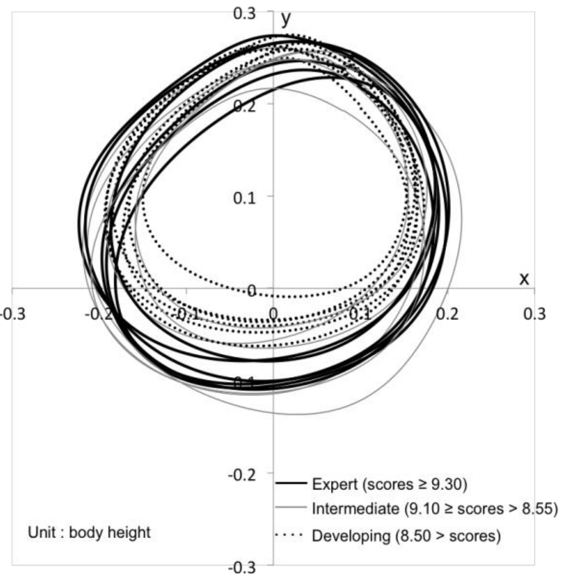

Figure 3: The horizontal paths of head during circles performed by 18 gymnasts (6 experts, 6 intermediates, and 6 developing). The displacements were normalized by the heights of gymnasts.

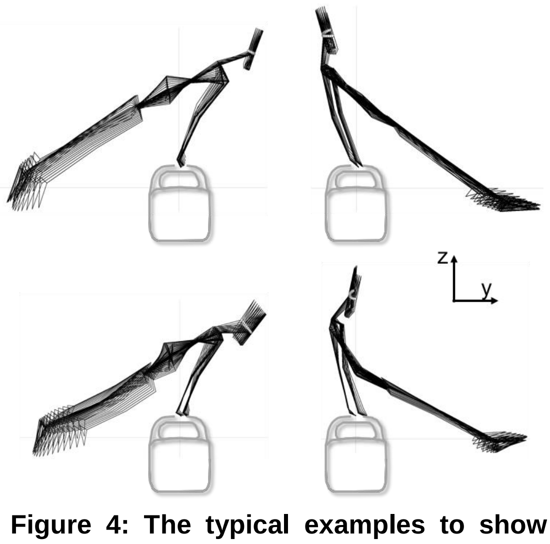

Figure 4: The typical examples to show the difference in the head positions. The stick figures were layered during the front support phase (left) and during the rear support phase (right). The top figures were circles performed by an expert, and the bottom figures were circles performed by a developing gymnast.

All five variables in Figure 5 were significantly correlated with the score, and the inter-correlations among these variables were strong except for the ankle diameter. It was not correlated with the average y-coordinate of the head during the rear support phase (*r* = -0.29). In terms of regression analysis, the ankle diameter contains unique variance to predict a score, and the other variables, including the average y-coordinate of the head during the rear support, have redundant information for score prediction. This result corroborated the research by Baudry et al. (2009) in which only two variables, the ankle diameter and body alignment, could account for the amplitude of circles.

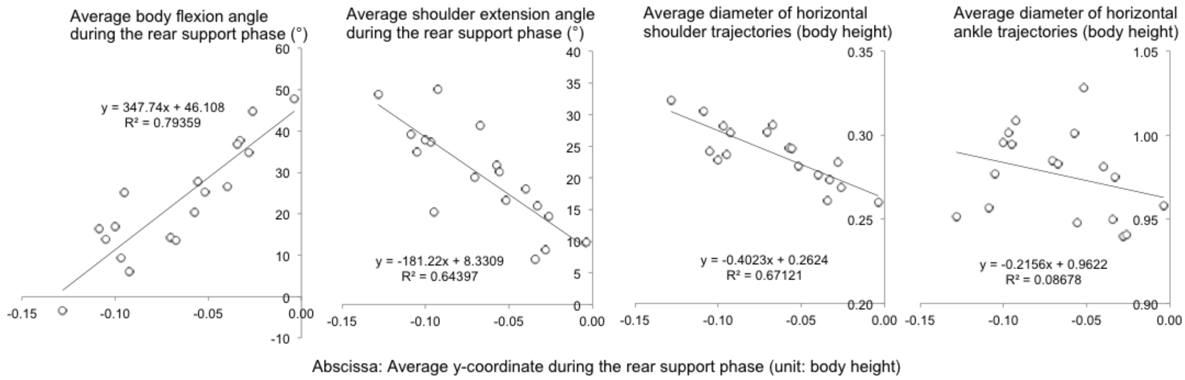

Figure 5: The relationships between the average y-coordinate during the rear support phase and four discriminative kinematic variables.

In our study, the judges also commented on the performances. Their comments were on body extension, amplitude, rhythm, leg form errors, consistency, and the timing of hip turns. Note that none of them mentioned the head positions. It was shown that the head positions during the rear support phase were related to the quality of circles. In addition, the head segment contains the visual and vestibular systems that are critical to the overall kinaesthesia during a performance. Further experiments will be necessary to determine the influence of instruction and the focus of attention on desirable motor learning. Nevertheless, the data shown in the current study provided coaches with supportive evidence for some of their practical observations and found relations among key variables of a complex skill.

CONCLUSIONS: The head segment kinematics particularly in the rear support phase provided useful information related to the quality of circles. The average y-coordinate of head during the rear support phase was correlated with the score as well as other performance variables that have been the focus of previous investigations. On a practical level, coaches and gymnasts should be aware of the relationship between the head position and performance quality.

REFERENCES:

Baudry, L., Sforza, C., Leroy, D., Lovecchio, N., Gautier, G., & Thouvarecq, R. (2009). Amplitude variables of circle on the pedagogic pommel horse in gymnastics. *Journal of Strength and Conditioning Research / National Strength and Conditioning Association, 23*(3), 705-711.

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223-1230.

Fujihara, T. (2010). Biomechanics of circles on pommel horse. *Japanese Journal of Biomechanics in Sports & Exercise, 14*(4), 155-163.

Fujihara, T., & Gervais, P. (2012a). Circles on pommel horse with a suspended aid: Influence of expertise. *Journal of Sports Sciences (30)6*, 583-589.

Fujihara, T., & Gervais, P. (2012b). Circles on pommel horse with a suspended aid: Spatio-temporal characteristics. *Journal of Sports Sciences* (30)6, 571-581.

Grassi, G., Turci, M., Shirai, Y. F., Lovecchio, N., Sforza, C., & Ferrario, V. F. (2005). Body movements on the men's competition mushroom: a three dimensional analysis of circular swings. *British Journal of Sports Medicine, 39*(8), 489-492.

Halvorsen, K. (2003). Bias compensated least squares estimate of the center of rotation. *Journal of Biomechanics, 36*(7), 999-1008.

International Gymnastics Federation. (2010). *Code of Points* FIG Men's Technical Committee (Ed.)

Karácsony, I., & Čuk, I. (1998). *Pommel horse exercises: methods, ideas, curiosities, history*. Ljubljana: University of Ljubljana and Hungarian Gymnastics Federation.

Readhead, Lloyd. (1997). *Men's gymnastics coaching manual* (2nd ed.). Marlborough, Great Britain: The Crowood Press Ltd.

Yokoi, T., & McNitt-Gray, J. L. (1990). A threshold to determine optimum cutoff frequency in automatic data smoothing using digital filter. In American Society of Biomechanics (Ed.), *Proceedings for the 14th annual meeting of the American Society of Biomechanics* (pp. 209-210). FL: University of Miami.

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