BIOMECHANICS OF LONGSWINGS PRECEDING TKACHEV ON UNEVEN BARS

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Changes in the rules governing the separation of uneven bars have allowed female gymnasts to perform the Tkachev in both directions. The aim of this study was to compare the similarities in the preparatory longswing during the outward (O) and inward (I) Tkachevs. Video recordings of the Tkachevs (O=5, I=5) were collected from the 2000 Sydney Olympic Games. A 37° greater range of movement was found at the hips during the I Tkachev. In the more conventional O technique changes in the hip angle were smaller (23°) and occurred over a greater circle angle. This study has identified differences in what appear to be very similar skills. Further inter-segmental coordination and joint kinetic analyses may provide insight into the performance of these release and regrasp skills.

KEY WORDS: Gymnastics, kinematics, functional phases.

INTRODUCTION:

Artistic gymnastics is a continuously evolving sport developing constantly through changes in apparatus, developments of the scoring system and introduction of more complex skills. On the uneven bars, female gymnasts have been faced with a change from the traditional scoring system and an increase in bar spacing in the last ten years. With the importance of more complex elements to increase a routine's difficulty value, the inclusion of flight elements from release and regrasp has become mandatory for elite level performances. The Tkachev is one of the most common flight elements in gymnastics (Holvoet *et al*., 2002) with success being determined by the release parameters that in turn are governed by the preceding longswing (Arampatzis and Brüggemann, 2001). Research has identified that underpinning the success of the longswing is a rapid hyper extension to flexion at the hips and a hyper flexion to extension at the shoulders; recently termed the functional phase (Irwin and Kerwin, 2006). The functional phase facilitates the musculoskeletal work required for successful completion of the ascent phase and correct release parameters for release and re-grasp elements (Arampatzis and Brüggemann, 1999; Irwin and Kerwin, 2006). Irwin and Kerwin (2006) reported that 70% of muscular work was found to occur during the functional phase. Female gymnasts have traditionally had to negotiate the low bar on the decent phase of the preparatory longswing causing a loss of energy and delayed maximum hip angle reducing angular momentum (Arampatzis and Brüggemann, 1999; Hiley and Yeadon, 2005). With developments of the apparatus allowing an increase in bar spacing in the late 1990's, gymnasts have altered the direction of the longswing and therefore the direction of the Tkachev. This reverse in direction removes the restriction during the downswing but introduces a potential change in technique on the upswing (Kerwin *et al*., 2007). The development of the Tkachev from a coaching perspective is often based on the location of the hang phase described as maximum hip extension which is then followed by a 'tap' through to hip flexion (Tsuchiya *et al*., 2004). Building on from Kerwin *et al.* (2007) and employing the functional phase definitions of Irwin and Kerwin (2005), this study aimed to compare the similarities in the preparatory longswing during the inward and outward straddled Tkachev on uneven bars. This will inform coaches of where the hang phase occurs and determine kinematic differences between these apparently similar skills.

METHOD:

Data collection: During the 2000 Olympic Games data were collected by two camcorders (Sony Digital Handycam DCR VX1000E, Japan) positioned approximately 35 m away from and 8 m above the uneven bars. The optical axes of the cameras intersected at approximately 66° over the centre of the bars. Both cameras were set with a shutter speed of 1/600 s and a frequency of 50 Hz. Images were recorded prior to the performances of a

three dimensional calibration matrix comprising 20 known points encompassing the apparatus (3m x 4.5m x 4m). During the competition, images of straddle Tkachevs performed outwards (n=5) and inwards (n=5) from the apparatus were recorded.
Data processing: Calibration and movement images were digitised from each camera's view using the TARGET high resolution motion analysis system (Kerwin, 1995). The movement data comprised images for the preceding longswing, the release and flight phase of the Tkachev. In each sequence the centre of the high bar and the gymnast's head, right and left wrists, elbows, shoulders, hips, knees, ankles, and toes were digitised. An 11 parameter direct linear transformation (Abdel-Aziz and Karara, 1971) was implemented to calibrate the cameras and reconstruct the coordinate data. The segmental inertia parameters of each gymnast were customised using Yeadon's inertia model (1990), limb lengths determined from the video analyses and each gymnast's height and mass.
Data analysis: The reconstructed 3D coordinate data were processed with the 'ksmooth' function (MatchCad[13]™, Adept Scientific, UK) with the parameter 's' set to 0.10. This routine has similar characteristics to a Butterworth low-pass digital filter with the cut-off frequency set to 4.5 Hz (Kerwin and Irwin, 2006). The left and right sides of the body were averaged to produce a four segment planar representation of the gymnast, (arm, trunk, thigh and shank). The instants of release and re-grasp were defined by quantifying 'grip radius' as the linear separation between the 'mid-wrists' and the centre of the high bar. Release was considered to have occurred once the grip radius exceeded the maximum value obtained during the preceding longswing. The angular position of the gymnast about the bar was defined by the mass centre to neutral bar location. In order to compare within and between gymnasts all data were interpolated in 1° intervals throughout the circle angle using a cubic spline function (MatchCad[13]™). A circle angle was defined as 90° when the gymnast was in a handstand position and continued to 450° as he returned to handstand. The previously defined 'functional phases' by Irwin and Kerwin (2005) were used, with the start and end points described by maximum hip extension to flexion and maximum shoulder flexion to extension. Due to the fact that the Tkachev ended with the gymnast performing a hyper flexion of the shoulder and hyper extension of the hips a third event was also included in this analysis. In order to accurately locate the start and end points of the phases, the zero crossing points in the hip and shoulder angular velocity time histories were used for each gymnast. Average circle angles for the gymnast at the start (1), middle (2) and end (3) of the functional phases for the shoulders and hips for each Tkachev were calculated. These three phases coincide with those reported by Arampatzis and Brüggemann (2001). In the third phase when the angular velocity of the joint did not reach zero prior to release, the gymnast's circle angle at release was reported. Joint angles and changes in joint angles at the shoulders at hips for each functional phase were determined. Shoulder extension and hip flexion indicate closure of the respective joint angles and are reported as positive values.

RESULTS & DISCUSSION:
The functional phases for the shoulders and hips started and ended earlier in the outward compared to the inward Tkachev (Figure 1). Circle angles were similar for events 1 and 3 however, event 2 occurred noticeably earlier for the outward than the inward Tkachev. This significant difference is highlighted in the $\Delta\theta Cs_{23}$ score (Table 1).
The change in hip angle during the Δ_{H12} is 37° less during the outward (72°) than the inward (109°) (Table 1). Earlier hip extension has been reported to influence the angular momentum for this skill (Hiley and Yeadon, 2005). Kerwin *et al*. (2007) confirmed this finding that changing the direction of the skill from outward to inward further increased angular momentum.
Outward hip angle changes are smaller than the rotation angle changes in comparison to the inward Tkachev. The change in hip angle in the outward Tkachev is 75% of that needed for the inward and occurs whilst the gymnast rotates though an 11% larger circle angle.

Table 1 Circle angle of the gymnast about the bar (θC), changes in circle angle (ΔθC), relative joint angles (θ) and changes in joint angle (Δθ) at the start and end of the shoulder (S) and hip (H) functional phases (FP) (mean [±δ]]). 1= start of FP 1, 2= end of FP 1 and start of FP 2, 3= end of FP 2

ShoulderS	θC_{S1} (°)	θC_{S2} (°)	θC_{S3} (°)	$\Delta\theta C_{S12}$ (°)	$\Delta\theta C_{S23}$ (°)	θ_{S1} (°)	θ_{S2} (°)	θ_{S3} (°)	$\Delta\theta_{S12}$ (°)	$\Delta\theta_{S23}$ (°)
OUTWARD	254	338	405*	84	74	3	37	3	34	34
n=5	[13]	[8]	[1]	[11]	[9]	[5]	[9]	[11]	[8]	[5]
INWARD	265	362	414*	97	54	-3	43	18	46	25
n=5	[13]	[6]	[13]	[11]	[16]	[5]	[4]	[13]	[2]	[14]
HIPS	θC_{H1} (°)	θC_{H2} (°)	θC_{H3} (°)	$\Delta\theta C_{H12}$ (°)	$\Delta\theta C_{H23}$ (°)	θ_{H1} (°)	θ_{H2} (°)	θ_{H3} (°)	$\Delta\theta_{H12}$ (°)	$\Delta\theta_{H23}$ (°)
OUTWARD	245	305	405*	60	107	-22	50	-32	72	82
n=5	[11]	[5]	[1]	[9]	[6]	[5]	[3]	[5]	[4]	[4]
INWARD	250	319	414*	69	95	-38	71	-34	109	105
n=5	[10]	[10]	[12]	[10]	[14]	[11]	[6]	[19]	[15]	[22]

* denotes release

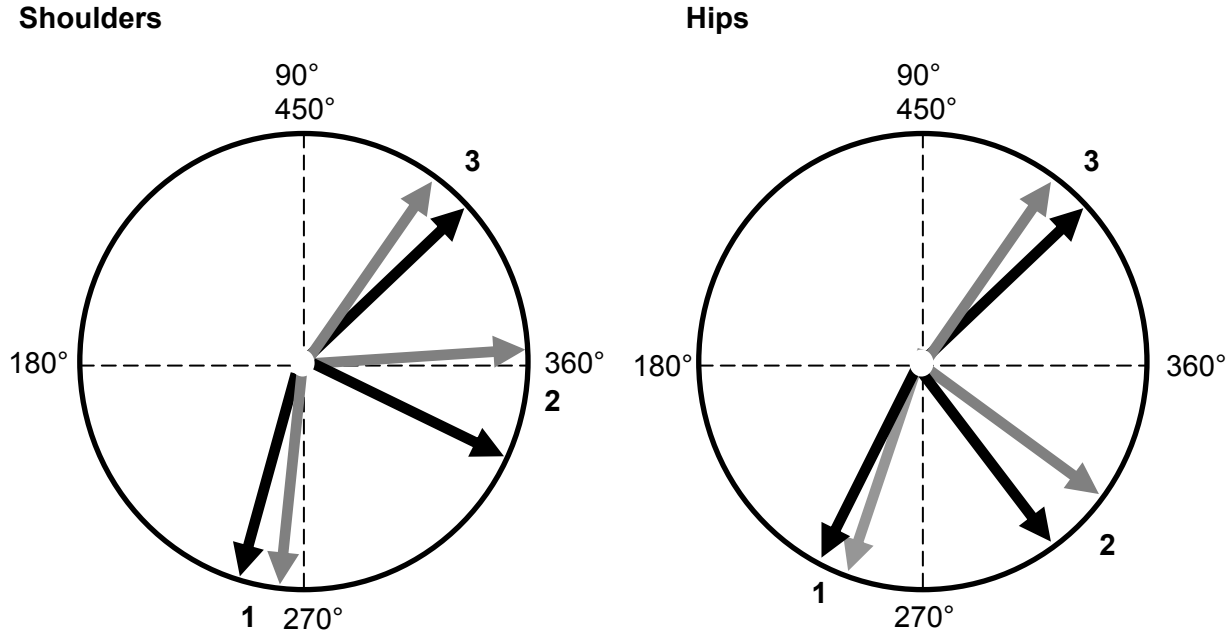

Figure 1: Circle angle at each stage (1, 2 and 3) of the functional phases at the shoulder and hip joints for the outward (black) and inward (grey) variations of the straddle Tkachev on the uneven bars

CONCLUSION:

This study aimed to compare the preparatory longswing during inward and outward straddle Tkachevs. Initiation and completion of the functional phases at the hips and shoulders were similar between the two variants of the skill. There were differences in circle angle in the mid phase for hips and shoulders with the outward beginning and ending earlier than the inward. Currently both skills are both scored equally within the judging criterion of the Fédération Internationale de Gymnastique (FIG), but the notable benefits in release parameters resulting from the inward variant (Kerwin et al., 2007) suggest that the two skills are mechanically different. The more recently introduced inward technique offers a greater range of movement, particularly at the hip. The larger shoulder opening at a slightly later release angle of the inward Tkachev, together with the hip characteristics, offers gymnasts the opportunity to create improved release conditions and potentially more advanced flight skills.

The relationship between joint kinematics and the creation of angular momentum was highlighted by Hiley and Yeadon (2005). These changes in circle angle and differences in the joint kinematics are important for coaches in developing these skills. Also, the information may help provide the FIG with more objective information about the classification of these skills. Looking to the future, inter-segmental co-ordination and joint kinetic analysis may provide further insights into the mechanics underpinning successful performance of the female Tkachev.

REFERENCES:

Abdel-Aziz, Y. I. & Karara, H. M. (1971). Direct Linear Transformation from Comparator Coordinates into Object Space Coordinates in Close-range Photogrammetrey (ASP Symposium on Close-range Photogrammetry) 1-18. *American Society of Photogrammetry,* Falls Church, VA.

Arampatzis, A. & Brüggemann, G.P. (1999). Mechanical energetic processes during the giant swing before dismounts and flight elements on the high bar and uneven parallel bars. *Journal of Biomechanics*, 32, 811-820.

Arampatzis, A. & Brüggemann, G.P. (2001). Mechanical energetic processes during the giant swing before Tkatchev Exercise. *Journal of Biomechanics*, 34, 505-512.

Hiley, M.J. & Yeadon, M.R. (2005). The margin for error when releasing the asymmetric bars for dismount. *Journal of Applied Biomechanics*, 21, 223-235.

Holvoet, P., Lacouture, P. & Duboy, J. (2002). Practical use of airborne simulation in release-regrasp skill on the high bar. *Journal of Applied Biomechanics,* 18, 322-344.

Irwin, G. & Kerwin, D. G. (2005). Biomechanical Similarities of Progressions for the longswing on the high bar. *Sports Biomechanics,* 4, 163-178.

Irwin, G. & Kerwin, D. G. (2006). Musculoskeletal work of high bar progressions. In Proceedings of XXIV International Symposium on Biomechanics in Sports (Eds. H. Schwamsder, G. Strytzenberger, V. Fastenbauer, S. Lindinger, & E. Muller), (pp 83 – 86). Salzburg, Austria.

Kerwin, D.G. (1995). Apex/Target high-resolution video digitising system. In J. Watkins (ed.), *Proceedings of the Sports Biomechanics section of the British Association of Sports and Exercise Sciences* (pp1-4), Leeds: BASES.

Kerwin, D.G. & Irwin, G. (2006). Predicting high bar forces in the longswing. In Engineering in Sport 6 (Eds. F. Eckhardt and S. Haake), *International Sport Engineering Association publication* (pp. 189-194). Munich, Germany.

Kerwin, D. G., Irwin, G. & Exell, T. (2007). Outward and inward Tkachevs on uneven parallel bars. In Proceedings of XXVth International Symposium on Biomechanics in Sports. Ouro Preto, Brazil, 427-430.

Tsuchiya, J., Murata, K. & Fukunaga, T. (2004). Kinetic analysis of backward giant swing on parallel bars. *International Journal of Sport and Health Science,* 2, 211-221.