BIOMECHANICS OF THE LONGSWING PRECEDING THE TKACHEV

Gareth Irwin, David Kerwin and Mark Samuels

Cardiff School of Sport, University of Wales Institute, Cardiff, Wales, UK

The aim of this study was to compare the longswing preceding the straddle, straight and full twisting Tkachev with the central aim of establishing whether a Tkachev specific longswing exists that can be used for the development of different versions of the skill. Twin video images of Tkachevs (straddle n=6; straight n=10; and full twisting n=2) were collected at the 2000 Sydney Olympics, digitised and analysed using DLT techniques. The functional phases (Irwin and Kerwin, 2005) were determined from hip and shoulder angular velocity profiles. Differences between the angular positions of the gymnasts during the functional phases highlighted that a generic Tkachev preparatory longswing did not appear to exist and that more specific preparatory drills are required to develop complex versions of this skill.

KEY WORDS: men's artistic gymnastics, high bar, functional phases.

INTRODUCTION:

The Tkachev is a distinctive release and re-grasp skill in elite gymnastics and exists in a number of variations (straddle, pike, straight, full twist) (FIG, 2006). To perform the skill, the gymnast needs to reverse the direction of rotation from the longswing during the flight phase as he passes backwards over the bar (Kerwin and Irwin, 2006). The successful completion of this skill is determined by the gymnast achieving the correct release parameters which in turn are determined by the preceding longswing (Arampatzis and Brüggemann, 2001). Longswings on high bar fall into two categories the 'general' and 'accelerated'. The accelerated longswing is a prerequisite for the successful performance of the Tkatchev, (Yeadon and Hiley, 2000; and Arampatzis and Brüggemann, 1998; Readhead, 1997). Previous research has identified that the successful completion of the longswing on the high bar is related to the functional phases, defined by a hyper extension to flexion of the hips and hyper flexion to extension of the shoulders (Irwin and Kerwin, 2005) as the gymnast passes beneath the bar. Arampatzis and Brüggemann (1999) suggested that reductions in hip and shoulder angles were used in the optimisation of angular momentum and total body energy needed for the successful execution of more complex skills. Gervais and Tally (1993) used the term 'beat swing' when investigating the contribution of this phase to the projectile determinants of the gymnast during the Tkachev. A common mode for developing the Tkatchev on high bar is through the progression from the least to the most complex version of the skill. Complexity is quantified by the FIG using an ordinal approach 'A the least difficult to 'F' the most difficult. In general, gymnasts learn the least complex straddle or pike (C), straight (D) and with full twist (E). Whilst it is apparent that the biomechanical requirements of the more complex versions of the skill will place greater demand on the gymnast, it is not apparent how this changes the preceding longswing. Based on previous research relating to the principle of biomechanical specificity in skill development (Irwin and Kerwin, 2005), it is hypothesised that there will be similarities in the spatial and temporal characteristics (Irwin and Kerwin, 2005) and musculoskeletal demand (Irwin and Kerwin, 2006) between the preceding longswing and functional phases of the straddle and the more complex versions of the Tkachev. Therefore this study aimed to examine the similarities during the preceding longswing for the straddle, straight and full twisting Tkachevs with the overall purpose of identifying whether a Tkachev specific longswing exists that can be used for the development of different versions of the skill.

METHOD:

Data collection: The data for this study were collected during the 2000 Sydney Olympic Games. Two camcorders (Sony Digital Handycam DCR VX1000E, Japan) were positioned approximately 35 m away from and 8 m above the high bar. The optical axes of the cameras

intersected at approximately 66˚ over the centre of the high bar. Both cameras captured the images at 50 Hz with a shutter speed of 1/600 s. Prior to the performances, images were recorded of a three dimensional calibration matrix comprising 40 known points encompassing the apparatus (5.2m x 6m x 3m). During the competition, images of straddle (n=6), straight (n=10) and full twisting (n=2) Tkachevs were recorded. In total data from 18 gymnasts with masses and heights 60.1 ± 4.72 kg and 1.65 ± 0.04 m were included.

Data Processing: Images of the calibration object and gymnast performing the preceding longswing and Tkachev were digitised using the TARGET high resolution motion analysis system (Kerwin, 1995). The centre of the high bar and the gymnast's head, and his 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 inertia parameters of each segment 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 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 average 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 phase was also included in this analysis. In order to accurately locate the start and end points of these 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 (Event-1), middle (Event -2) and end (Event-3) of the functional phases for the shoulders and hips for each Tkachev were calculated. When the third phase 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.

RESULTS & DISCUSSION:

Circle angles, defined by gymnast's mass centre, the neutral bar position and the right horizontal, at the start and end of the functional phases are detailed in Table 1. The start of the hip functional phase (F-1) occurred in the first quadrant for the full twisting Tkachev at 170° compared to the straight (S-1 at 218°) and the straddle (R-1, 235°) both in the second quadrant (Fig. 1). The first functional phase occurred earlier in all Tkachevs compared to the general longswing (249°), reported by Irwin and Kerwin (2005), and shown as (C-1) in Figure 1. In addition to beginning earlier in the circle, the hip angle at the start of the full twist functional phase was more hyper extended than for the straddle or straight by 16° and 13° respectively, (Table 2). The end of the first functional phase and hence start of the second occurred after the gymnast had passed under the lower vertical. Gymnasts performing the full twisting Tkachev finished earliest, followed by the straight and then the straddle. In general the change in circle angle during the first functional phase was at least 15° greater for the full twisting Tkachev compared to the other versions. Irwin and Kerwin (2005)

reported a range of 89° during the first hip functional phase of a general longswing which was smaller than for any of the Tkachevs. The changes in circle angle for the Tkachevs were greater in the first functional phase than in the second for both joints. The first functional phase started earlier for the hips than the shoulders (Table 1). The circle angle at the start of the first functional phase for the shoulders was greater for the full twist than the straddle Tkachev (ie, 46° earlier for the full twist). Irwin and Kerwin (2005) reported that the circle angle at the start of the general longswing was 252 ± 20°, further highlighting the differences between these skills. The shoulder angle during the first functional phase (shoulder hyper flexion) shows a large difference across the three versions of the Tkachev, with 13° and 17° differences between the full twisting and the straight and straddle Tkachevs respectively. Interestingly, the second shoulder functional phase occurs at a similar circle angle to the one for the hips (Table 1) and starts much earlier than for the general longswing at 362 ± 7° as reported by Irwin and Kerwin (2005).

Table 1. Circle angle (θ) and changes in circle angel ($\Delta\theta$) of the gymnast about the bar at the start and end of the functional phases for the hips (H) and shoulders (S) [mean ($\pm\delta$)]. θ_{H1} = start of hip functional phase 1, θ_{H2} = end of phase 1 and start of phase 2, θ_{H3} = end of phase 2. θ_{s1} = start of shoulder functional phase 1, θ_{S2} = end of phase 1 and start of phase 2, θ_{S3} = end of phase 2. Using similar nomenclature, $\Delta\theta_{H12}$ = change in circle angle for the hips between θ_{H1} and θ_{H2}.

	θ_{H1}	θ_{H2}	θ_{H3}	θ_{S1}	θ_{S2}	θ_{S3}	$\Delta\theta_{H12}$	$\Delta\theta_{H23}$	$\Delta\theta_{S12}$	$\Delta\theta_{S23}$
Straddle (R)	235	328	407	246	328	407	94	79	83	79
(n=6)	[6]	[10]	[9]	[6]	[10]	[9]	[15]	[10]	[15]	[7]
Straight (S)	218	316	401	228	327	402	99	85	99	75
(n=10)	[12]	[14]	[7]	[13]	[8]	[7]	[10]	[11]	[9]	[5]
Full Twist (F)	170	313	392	200	314	392	116	79	114	78
(n=2)	[8]	[6]	[6]	[4]	[3]	[6]	[14]	[9]	[7]	[1]

Table 2 Hip and shoulder angles (ϕ) and changes in hip and shoulder angles ($\Delta\phi$) of the gymnast at the start and end of the functional phases for the hips (H) and shoulders (S) [mean ($\pm\delta$)]. ϕ_{H1} = hip angle at start of hip functional phase 1, ϕ_{H2} = hip angle at the end of phase 1 and start of phase 2, ϕ_{H3} = hip angle at the end of phase 2. ϕ_{s1} = shoulder angle at the start of shoulder functional phase 1, ϕ_{S2} = shoulder angle at the end of phase 1 and start of phase 2, ϕ_{S3} = shoulder angle at the end of phase 2. Using similar nomenclature, $\Delta\phi_{H12}$ = change in hip angle between θ_{H1} and θ_{H2} (see Table 1 for nomenclature), [mean ($\pm\delta$)]

	ϕ_{H1}	ϕ_{H2}	ϕ_{H3}	ϕ_{S1}	ϕ_{S2}	ϕ_{S3}	$\Delta\phi_{H12}$	$\Delta\phi_{H23}$	$\Delta\phi_{S12}$	$\Delta\phi_{S23}$
Straddle	-37	53	-18	4	-34	21	90	71	38	55
(n=6)	[10]	[9]	[13]	[6]	[4]	[17]	[16]	[22]	[7]	[24]
Straight	-40	55	-28	17	-40	16	95	83	57	56
(n=10)	[8]	[6]	[10]	[5]	[9]	[6]	[11]	[10]	[11]	[12]
Full Twisting	-53	61	-13	21	-37	15	115	74	58	52
(n=2)	[2]	[2]	[19]	[4]	[3]	[2]	[1]	[12]	[1]	[8]

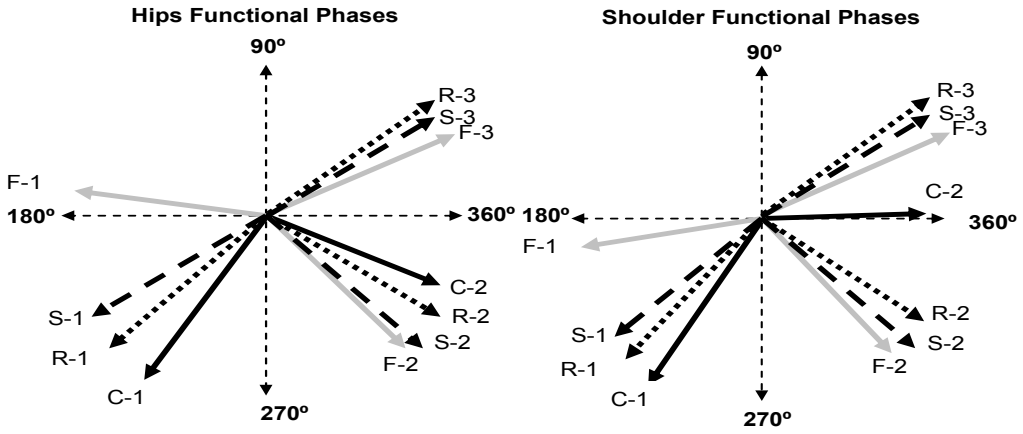

Figure 1. Circle angle at the start (S) and end (E) of the functional phases at the hip and shoulder joints for the straddle (R), straight (S) and full twisting (F) variations of the Tkachev. In addition the start and end of the functional phases of the general longswing, (CLS) reported by Irwin and Kerwin (2005) are labelled (C).

CONCLUSION:

The findings of this study have been contextualised within the concepts of biomechanical specificity and skill development in men's artistic gymnastics. Differences in the gymnast's circle angle and the hip and shoulder angles during the functional phases of the preceding longswing suggest that specific preparatory skills may be needed to develop different versions of the Tkatchev.

REFERENCES:

Arampatzis, A. & Brüggemann, G.P. (1998). A mathematical high bar-human body model for analysing and interpreting mechanical-energetic processes on the high bar. *Journal of Biomechanics*, **31**, 1083-1092.

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

Federation Internationale de Gymnastique (2006). *Code of Points, artistic gymnastics for men*. Switzerland: FIG.

Gervais, P. & Tally, F. (1993). The beat swing and mechanical descriptors of three horizontal bar release-regrasp skills. *Journal of Applied Biomechanics*, **9**, 66-83.

Irwin, G. and Kerwin, D. G. (2005). Biomechanical Similarities of Progressions for the longswing on the high bar. *Sports Biomechanics* **4** (2) 163-178.

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

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. and Irwin, G. (2006). Predicting high bar forces in the longswing. Engineering in Sport 6., Munich, Germany. (Eds. F. Eckhardt and S. Haake). International Sport Engineering Association publication, pp. 189-194. ISBN 10-0-387-31773-2.

Readhead, L. (1997). *Men's Gymnastics Coaching Manual*. Huddersfield: Crowood Press Ltd.

Yeadon, M.R. & Hiley, M.J. (2000). The mechanics of the backward giant circle on the high bar. *Human Movement Science*, **19**, 153-173.