DEVELOPING THE KOVACS ON HIGH BAR

Gareth Irwin, David Kerwin, Michelle Manning and Robbie Brown

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

The purpose of this study was to evaluate the tucked Kovacs as a preparatory activity for the development of the more complex straight and full twisting Kovacs. Twin video images of Kovacs (tucked n=7; straight n=3; and full twisting n=5) were collected at the 2000 Sydney Olympics. 3D_DLT analyses were used to determine joint angular kinematics and combined with customised body segment inertia parameters to determine normalised angular momenta. Angular kinematic similarities were found between the three Kovacs variants but there were large differences in normalised angular momentum between the tucked and straight Kovacs. Identifying appropriate preparatory activities is desirable to make training more effective, and in particular when trying to increase angular momentum in order to develop the straight from the tucked Kovacs.

KEY WORDS: men's artistic gymnastics, angular momentum, coaching

INTRODUCTION:

The inclusion of difficult release and re-grasp elements is paramount for the successful performance of high bar routines in gymnastics (Arampatzis and Brűggemann, 1999). The international governing body, Fédération Internationale de Gymnastique (FIG), has recently made changes to the rulings governing the sport to include a higher classification; 'F' level skills. This rewards gymnasts for the performance of more complex skills. The outcome of these changes has been evidenced by an increase in the frequency of complex skills being performed. At the 2000 Sydney Olympic Games, during the qualifying rounds, 61 Kovacs were performed compared to 22 Tkachev's and 14 Giengers. The Kovacs is a complex release and re-grasp skill, where the gymnast performs approximately 1½ backward somersaults whilst passing backwards over the high bar. The gymnast has the option of performing this skill in a tucked, piked or straight position and in some cases with a full twist around his longitudinal axis. The shape adopted by the gymnast dictates the difficulty and consequently the grading of the skill. Previous research by Brüggemann *et al.* (1994) provided an initial insight into the tucked Kovacs at the 1992 Olympic Games. This word was followed by Cuk (1995) who provided further insights into the biomechanics of the Kovacs and Kolman (full twisting Kovacs) somersault. Cuk (1995) quantified 3D kinematics of individual gymnasts performing each skill. Key biomechanical parameters that he reported included angular kinematics of the hips, shoulders and neck, and the linear kinematics of the mass centre up to and including release. Later Arampatzis and Brüggemann (1999) provided an insightful investigation by analysing the energetic processes involved in the number of skills including the Kovacs on high bar performed at the 1994 World Championships. These authors identified a number of key variables associated with the successful execution of this skill, and in particular, the angular momentum about the mass centre during the preceding longswing and at release. These authors reported a mean angular momentum of 46.1 ± 2.73 kg·m^2/s at release which allowed the continuation of rotation in the same direction post release as the preceding longswing. These authors also reported vertical velocity release (4.76 ± 0.38m/s) which provided height and time in the air, and horizontal velocity at release (-1.6 ± 0.34 m/s) providing the movement backward over the bar. Arampatzis and Brüggemann's (1999) findings showed some variations from the data reported from the earlier 1992 Olympic Games (Brüggemann *et al.,* 1994). Currently gymnastic coaches use the tucked Kovacs as a developmental or preparatory step to the more complex straight and full twisting versions. Recent research identified that preparatory skills in men's artistic gymnastics should replicate; the movement pattern (Irwin and Kerwin, 2005), inter-segmental co-ordination (Irwin and Kerwin, 2007) and musculoskeletal demands (Irwin and Kerwin, *in press*) that occur in the key phases of the final skill. Based on earlier work by Irwin and Kerwin, this study aimed to quantify the similarities in key biomechanical characteristics associated with the successful performance of the tucked Kovacs and more complex versions of the skill. The overall purpose was to evaluate the tucked Kovacs as an effective preparatory skill.

METHOD:

Data Collection: 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 tucked (n=7), straight (n=3) and full twisting (n=5) Kovacs were recorded.

Data Processing: Images of the calibration pole and movement sequences including the preceding longswing, release and flight phase of the Kovacs 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. The flight phase was identified from when the grip radius exceeded (release) and returned to within (regrasp) the maximum grip value obtained during the preceding longswing. The horizontal and vertical motion of the gymnast's mass centre (CM) during flight was fitted with linear and quadratic functions respectively. Regression values were predicted from the corresponding functions to re-define the flight phase, enabling flight time, and CM displacements and velocities at release and re-grasp to be obtained. In addition, from the flight characteristics of the CM, maximum flight height (Sz_{max}), horizontal position of CM relative to the bar at release (Sy_{zmax}) and height of the CM as the gymnast passed over the high bar ($Sz_{y=0}$) were determined. Angular momentum of each segment about its mass centre ($L_s = I_s \cdot \omega_s$) and of each segment about the whole body mass centre ($L_o = m \cdot \Omega \cdot r^2$) were summed over the four segments to obtain angular momentum of the gymnast about her body mass centre (L_c), ($L_c = L_s + L_o$). To facilitate direct comparisons between gymnasts of varying sizes, angular momentum values were normalised (L_n) by dividing L_c by his moment of inertia (I_{ss}) in a theoretical straight position and also by 2π to produce units of straight somersaults per second (SS/s).

RESULTS & DISCUSSION:

Mean absolute angular momentum at release for the straight Kovacs was approximately 30% higher than for either the tucked or full twisting versions (Table 1). Angular momentum values for the tucked Kovacs were lower than for those reported by Brüggemann *et al*. (1994) and Arampatzis and Brüggemann (1999). The difference may in part be accounted for by a higher angle of release during all of the Kovacs performed in the current study (41 to 43°) (Table 1.0) compared to 30° reported by Brüggemann *et al*. (1994). The vertical component of the tangential velocity at release was reduced as a result of this later release angle (Table 1) when compared to the values reported by Arampatzis and Brüggemann (1999) and

Brüggemann *et al*. (1994). Of the three variations, the lowest mass centre vertical release velocity was seen for straight Kovacs, indicating a reduction in flight time, which would be offset by the higher release angle.

Table 1. Values at release for absolute and normalised angular momentum (L & L_n), angular velocity (ω_{cm}), horizontal (Vh) and vertical (Vv) mass centre velocity, and CM to neutral bar angle (θ_{cm}).

	L (kg·m^2/s)	L_n (SS/s)	ω_{cm} (rad/s)	Vh (m/s)	Vv (m/s)	θ_{cm} (°)
Tucked (n=7)	40.4 [8.5]	0.7 [0.1]	8.5 [1.1]	-1.6 [0.1]	3.6 [0.3]	43 [4]
Straight (n=3)	51.3 [1.6]	0.9 [0.1]	8.7 [0.6]	-1.5 [0.1]	3.3 [0.1]	44 [3]
Full twist (n=5)	39 [4.2]	0.6 [0.1]	8.2 [1.2]	-1.4 [0.3]	3.6 [0.2]	41 [6]

From a coaching perspective the greater angular momentum found in the straight Kovacs may require a modified accelerated long swing to be developed compared to the tucked and full twisting Kovacs. Yeadon and Hiley (2000) identified the importance of the accelerated long swing in order to generate sufficient angular momentum. Similarities in the magnitude of horizontal velocity between all three Kovacs were found (-1.4 m/s to -1.6 m/s). The percentage RMS differences between normalised angular momentum for the tucked and straight; and tucked and full twisting Kovacs were 17% and 12% respectively, (Figure 2).

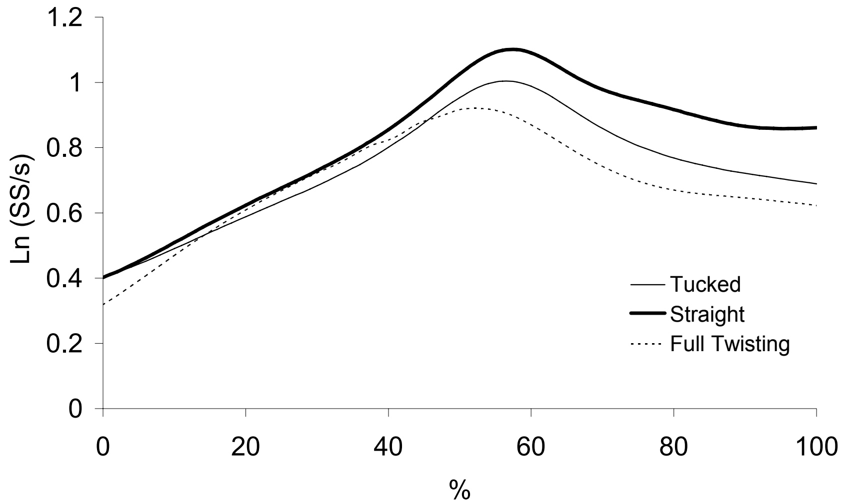

Figure 2: Normalised angular momentum profiles for the tucked, straight and full twisting Kovacs

Similarities were also found between the tucked Kovacs and the more complex versions for shoulder angle during the preceding longswing up to the point of release. In contrast shoulder angular velocity between the tucked and full twisting Kovacs showed a difference of approximately 20%. Hip joint angle differences between the tucked and straight were 8% in comparison to the full twist at 12%. The largest differences between the tucked Kovacs and the more complex versions was found for hip joint angular velocity with differences of 14.2% and 26% for the straight and full twisting Kovacs respectively. Therefore based on the training principles of specificity and previous work by Irwin and Kerwin (2005; *in press; in press*) the skills that more closely resemble the movement pattern and musculoskeletal loading of the final skill will be most effective. As such from the findings of the current study it would appear that the tucked Kovacs is a good preparatory activity for the specific developmental of the shoulder angle for both the straight and full twisting version and the hip angle for the straight Kovacs. However the hip angular velocity during the tucked Kovacs does not require a similar movement pattern to either the straight or full twisting Kovacs. The major differences were found in the angular momentum during the preceding longswing and at release. From a coaching perceptive the gymnast must produce greater angular momentum at release; this is initiated through the preceding longswing. Different types of preceding longswing may exist for the performance of these skills. It is interesting to note that the 'power' or 'scooped' accelerated longswing is never performed prior to this skill. Looking to the future, a closer investigation into the functional characteristics of the preceding longswing may provide some explanation for these differences.

CONCLUSION:

With the exception of hip angular velocity, the angular kinematics in the preceding longswing, were similar for the tucked Kovacs and the two more complex versions of this skill. Normalised angular momentum during the preceding longswing and at release differed considerably between the tucked, straight and full twisting Kovacs. This study highlights the need to considerer more specific preparatory activities that would promote the development of the correct angular momentum. Consideration of other factors such as musculoskeletal loading and inter-segmental co-ordination during the preceding longswing may provide some of these answers.

REFERENCES:

Abdel-Aziz, Y.I., and Karara, H.M. (1971). Direct linear transformation from the comparator coordinates into object space coordintes in close range photogrammetry. *In the proceedings of the Symposium on Close Range Photogrammetry*. Falls Church, VA: American Society of Photogrammetry.

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

Brüggemann, G. P., Cheetham, P., Alp, Y., and Arampatzis, D. (1994). Approach to a biomechanical profile of dismounts and release and regrasp skills of the high bar. *Journal of Applied Biomechanics,* 18(4), 332-344.

Cuk, I. (1995). Kolman and pegan saltos on the high bar. In *ISBS 1995: Proceedings of XIII Symposium of Biomechanics in Sport* (edited by T. Bauer), pp. 118-122. Lakehead University: Thunder Bay, Ontario.

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. (2007). Inter-segmental co-ordination of high bar progressions. *Sports Biomechanics*. 6(2), 129-142.

Irwin, G., and Kerwin, D. G. (*in press*). Musculoskeletal demands of progressions for the longswing on high bar. *Sports Biomechanics*. September 2007.

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.

Yeadon, M.R. (1990). The simulation of aerial movement. Part III: A mathematical inertia model of the human body. *Journal Biomechanics,* 23, 67-74.

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

Acknowledgements:
The authors would like to thank the IOC Medical Commission for their support during the data collection and also the colleagues at Loughborough University for their assistance with the collection of the video data.