PREPARATORY LONGSWING TECHNIQUES FOR DISMOUNTS ON UNEVEN BARS

Dawn Tighe, Gareth Irwin, David G Kerwin and Marianne Gittoes

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

The purpose of this study was to quantify the biomechanical differences between two methods of performing the preparatory longswing preceding the double layout dismount. Video images of 6 female Olympic level gymnasts performing the double layout dismount (3 = straddle preparatory longswing, 3 = dished preparatory longswing) were recorded using two synchronised 50 Hz digital cameras. 3D DLT reconstructed coordinates were combined with inertia values to define discrete release variables including vertical and horizontal velocity of the mass centre, release angle and angular momentum about the gymnast's mass centre. Joint angular kinematics at the hips and shoulders were contrasted with particular reference to the hip functional phase. Based on the reported release parameters the straddle longswing could be considered preferential.

KEY WORDS: angular momentum, functional phase, artistic gymnastics

INTRODUCTION: Successful performance of an uneven bars dismount is widely acknowledged to depend upon the preparatory longswing, and more specifically, actions at the hip and shoulder i.e. the functional phases (Irwin & Kerwin, 2007). The women's bar is less stiff than the men's high bar, and as a result, the hip and shoulder functional phases exhibited by female gymnasts may vary from those seen in men's preparatory longswings. The nature of the uneven bars means that, unlike their male counterparts, female gymnasts must swing past the low bar during descent of the longswing. The proximity of the low bar has previously been identified as acting to reduce the generation of the desired release parameters such as angular momentum during the preparatory backwards longswing (Arampatzis & Brüggemann, 1999). Consequently female gymnasts are reported to either straddle their legs, or increase the angle of hip flexion in order to pass the low bar whilst conserving the build up of required release parameters such as angular momentum (Hiley & Yeadon, 2005). There is a lack of research detailing the reasoning behind the choice of technique by elite female gymnasts, and the eventual biomechanical advantages of either technique prior to release. From a coaching perspective identification of the biomechanical advantages of either technique could lead to a better understanding of the technique to teach and consequently inform the coaching process through the effective selection of the preferred preparatory longswing for the successful execution of the double layout dismount (Irwin et al., 2005). The aim of this study was to identify the biomechanical characteristics of two longswing techniques favoured by elite female gymnasts as identified in a preliminary frequency analysis. The overall purpose is to identify if either technique provides an advantage for the gymnast in generating the release parameters required for successful completion of the double layout dismount.

METHODS: Subjects: Six female Olympic level gymnasts participated in the present study, three gymnasts performed the straddled preparatory longswing and three performed the dished preparatory longswing preceding the double layout dismount. Their mean ages, heights and masses were 18 ± 3 years, 1.50 ± 0.02 m and 40 ± 6 kg (straddled technique) and 17 ± 2 years, 1.47 ± 0.05 m and 36 ± 9 kg (dished technique).

Data Collection: Two digital video cameras (Sony Digital Handycam, DCR VX1000E) were positioned 30 m and 37 m from the horizontal bar and aligned so their optical axes intersected over the centre of the uneven bars. Images, recorded at 50 Hz, of a single vertical pole, with five spheres measuring 0.10 m in diameter, was positioned in six locations surrounding the apparatus at the Sydney 2000 Olympic Games. The resulting calibration volume was 3.2 m wide, 4.3 m long and 4.2 m high. Subsequently all the routines during the qualification rounds were recorded, from which six double layout dismounts were selected for analysis.

Data Processing: VICON PEAK MOTUS 9.0 (VICON PEAK, UK) motion analysis system was used throughout the digitising process. A 16 point model was used to represent the human performer during reconstruction, with the wrist, elbow, shoulder, hip, knee, ankle and toe on both sides of the body, the centre of the gymnast's head and the mid point between the gymnast's hands on the upper bar were digitised for each camera's view. Digitisation began ten images before the gymnast reached the handstand position at the start of the preparatory longswing and concluded ten images following the gymnast's touchdown on the landing mat.

Data Analysis: The digitised coordinates were synchronised following digitisation in accordance with the method outlined by Yeadon & King (1999). Reconstruction was conducted on the preparatory, flight and landing phases, a direct linear transformation (DLT) algorithm was used to acquire 3-D coordinates as described by Abdel-Aziz & Karara (1971). Matchcad^{14TM} (Adept Scientific, UK) was used to calculate discrete and continuous performance variables including angular momentum. Segmental inertia parameters for each gymnast were obtained using Yeadon's Inertia Model (1990) customised for each gymnast based on their reported mass and height values and scaled according to their limb dimensions determined from the reconstructed video data. Linear and quadratic functions were used to fit the centre of mass (CM) trajectory data from the instant immediately following bar release to the instant prior to touchdown. The resulting regression equations were differentiated and used to predict horizontal and vertical release velocity values (Vh and Vv). Circle angle (θ_{CM}) describing the angular position of the gymnast swinging about the bar was defined as the angle made by the line joining the mass centre of the gymnast to the neutral bar position with the vertical handstand position being 90°. Joint angles were represented by vectors joining virtual points, created by averaging pairs of digitised joint centre coordinates. The shoulder joint was defined by joining the mid-elbow, mid-shoulder and mid-hip, whilst the hip comprised vectors between mid-shoulder, mid-hip and mid-knee. The functional phases were determined using the methods reported by Irwin & Kerwin, (2005). Commencement of the functional phase was defined as the instant at which the joint angular velocity (ω) passed through 0 rad/s and concluded when the respective angular velocity returned to a negative value. Closing of the shoulder and opening of the hip joints were defined as positive angular velocities. The point of release was defined as the angular position at which the bar horizontal acceleration peaked on the upswing. In order for comparisons to be made between gymnasts of varying heights and masses, angular momentum values were normalised by dividing angular momentum by moment of inertia about the transverse axis through the CM in the anatomical position and 2π to convert to units of straight somersaults per second (SS/s). Normalised angular momentum (Ln) values were multiplied by flight time to give the equivalent number of straight somersaults in the subsequent flight phase (LnFT). This dimensionless value was thus a composite score based on CM velocity and normalised angular momentum at release. All values are reported as means (±sd) for gymnasts performing either the SLS and DLS technique**.**

RESULTS: The SLS technique showed the highest Ln values at release of 1.232 SS/s, which showed a percentage difference of 6% with regards to the DLS technique. The SLS technique resulted in Vv at release of 3.70 m/s and Vh at release of 1.59 m/s, which when compared to the DLS technique show a percentage increase of 7% and 23% respectively. The hip joint and circle angle ranges were greater (41% and 58%) in the DLS technique compared to the SLS technique. In contrast the shoulder joint and circle angle ranges were smaller for the DLS (39% and 22%) than the SLS technique (Table 2).

Table 1 Release parameters for the double layout dismount performed following a straddled (SLS n = 3) and dished (DLS n = 3) longswing

Release parameter	SLS	Standard Deviation	DLS	Standard Deviation
θ_{CM} (°)	333	7	345	7
Vv (m/s)	3.70	0.03	3.42	0.43
Vh (m/s)	1.59	0.66	1.23	0.43
Ln (SS/s)	1.232	0.080	1.162	0.082
ω_{CM} (rad/s)	7.10	0.18	7.90	0.20
LnFT (SS)	1.216	0.002	1.084	0.005

Table 2 Circle and joint angles at the start and end of the hip and shoulder (shd) functional phases for the SLS and DLS techniques.

Angle (°)	Phase	SLS	Standard Deviation	DLS	Standard Deviation
Circle (Hip)	Start	276	12	268	9
	End	325	5	345	7
	Change	49	9	77	8
Circle (Shd)	Start	276	12	268	9
	End	325	5	345	7
	Change	49	9	77	8
Hip	Start	-23.7	9.6	-13.8	9.8
	End	22.6	9.5	51.5	6.7
	Change	46.2	9.6	65.3	8.4
Shd	Start	-5.2	2.9	-3.2	4.0
	End	19.6	31.3	11.9	16.7
	Change	24.9	22.2	15.1	12.2

DISCUSSION: The present study aimed to identify mechanical differences between the straddle and dished preparatory longswings commonly performed by elite female gymnasts prior to the double layout dismount. The overall purpose being to quantify differences within the generation of advantageous release characteristics between the two longswings, subsequently facilitating effective skill development of the double layout dismount. Within a preparatory longswing accurate completion of the functional phases provides a means by which angular momentum can be maximised and provides the energy source required for successful execution of the longswing and succeeding dismount (Arampatzis & Brüggemann, 1999). The hip functional phase for the DLS is initiated earlier and occurs over an increased circle angle (58%) and hip angular range (41%) (Table 2) in comparison to the SLS, this could provide an explanation for why greater peak Ln values were seen for the DLS prior to release. This conclusion is supported by the findings of Hiley & Yeadon (2005), who reported increased hyper extension to flexion during this phase of the movement to result in increased angular momentum. Following the attainment of peak Ln values both techniques exhibit a decrease from peak values prior to release. The magnitude of this decrease is greater for the DLS resulting in Ln at release of 1.162 SS/s which is 6% less than the release Ln value for the SLS (Table 1). Sufficient levels of angular momentum must be generated during the preparatory longswing and maintained until the point of release in order that the gymnast possesses the capacity to complete the rotations in the dismount successfully. Thus the SLS could be considered advantageous due to increased levels of Ln prior to release. LnFT represents a weighting factor between the release parameters which govern success of the dismount. The SLS achieved a LnFT value 11% greater than that of the DLS indicating that the SLS may be preferential for the generation of the release parameters required for completion of the double layout dismount including Vv, Vh and Ln (Table 1). Brüggemann *et al*. (1994) identified the maintenance of sufficient height and rotation to be vital in the successful completion of a dismount. Height achieved is dependant upon Vv. Results showed that Vv was 7% greater for the SLS than the DLS, and as such indicates that the SLS could be considered preferential to dismount performance based upon potential to achieve a successful flight path following release (Table1). Brüggemann *et al*. (1994) also identified the need to create a flight path which allows the gymnast to travel safely away from the bar, this occurs through the achievement of adequate release Vh. The SLS produced 23% more Vh in comparison to the DLS, therefore the SLS could also be considered preferential in allowing the gymnast to travel safely away from the bar in flight (Table 1). Irwin *et al.* (2005) proposed that the biomechanical understanding of the movement pattern of a desired skill enhances the process of skill development. As such the present study identified biomechanical differences in the generation of desired release characteristics between the two favoured longswings, thus the findings of the present study have the potential to inform coaches about the biomechanics of the straddle and dished longswing techniques and thus allow for the development of the double layout dismounts on the uneven bars, with specific regard to the generation of Ln and Vh prior to release.

CONCLUSION: The straddle technique was identified as providing increased levels of Vv, Vh, Ln and LnFT. The straddle technique could therefore be considered preferential to the dished technique. The present findings have the potential to inform the coaching process and thus allow for the development of the double layout dismount. The angular kinematics reported in relation to the functional phases suggests that further kinetic analysis is required to provide an insight into the hip and shoulder moments. Further research should aim to incorporate other factors linked to the choice of longswing technique by gymnasts including coaching background and gymnast morphology. It would also be beneficial if future studies used a large sample size and performed repeated trials to account for inter and intra subject variability.

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

Brüggemann, G.P., Cheetham, P.J., Alp, Y. & Arampatzis, D. (1994). Approach to a Biomechanical Profile of Dismounts and Release-Regrasp Skills of the High Bar. *Journal of Applied Biomechanics,*10, 291 – 312.

Hiley. M.J. & Yeadon, M.R. (2005). The Margin for Error When Releasing the Asymmetric Bars for Dismounts. *Journal of Applied Biomechanics,* 21, 223-235.

Irwin, G. & Kerwin, D. G. (2007). Musculoskeletal work of high bar progressions. Sports Biomechanics, **6**(3), 360-373.

Irwin, G. & Kerwin, D. G. (2005). Biomechanical similarities of progressions for the longswing on high bar. *Sports Biomechanics*, 4, 164–178.

Irwin, G., Hanton, S. & Kerwin, D. G. (2005). The conceptual process of skill progression development in artistic gymnastics. *Journal of Sports Sciences,* **23**(10), 1089-1099.

Yeadon, M.R. & King, M.A. (1999). A method for synchronising digitised video data. Journal of Biomechanics, 32 (9), 983-986.