STRADDLE TKACHEV ON HIGH BAR AND UNEVEN PARALLEL BARS

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The purpose of this study was to account for the performance differences between elite male and female gymnasts when performing the straddle Tkachev. Video recordings of the straddle Tkachev performed by male (6) and female (5) gymnasts were collected from the 2000 Sydney Olympic Games. Differences were observed, particularly in the angular momentum values at release (male = -22.4 kg·m^2/s compared with female = -7.1 kg·m^2/s) and in the flight characteristics. To facilitate direct comparisons between gymnasts of different sizes, normalised angular momenta were used, with mean values for males being 1.7 greater than for females. The trajectories of the two groups of gymnasts were notably different with females releasing the bar with lower vertical velocity leading to a flatter trajectory and greater hip flexion at re-grasp.

KEY WORDS: angular momentum, men’s and women’s artistic gymnastics.

INTRODUCTION:

Release and re-grasp skills comprise a fundamental part of any high bar and uneven parallel bar routine (Gervais and Tally, 1993; Arampatzis and Brüggemann, 1999, 2001). The backward longswing is used to develop the angular momentum required for the successful performance of release and re-grasp skills (Yeadon and Hiley, 2000). In a longswing 70% of the gymnast’s work is attributed to the hip and shoulder functional phases (Irwin and Kerwin, 2006); defined as hyper extension to flexion of the hips and hyper flexion to extension of the shoulders (Irwin and Kerwin, 2005). One release and re-grasp skill favoured by gymnasts is the Tkachev (Arampatzis and Brüggemann, 2001; Holvoet *et al*., 2002), a skill characterised by the reversal in the gymnast’s angular momentum immediately prior to release. This angular momentum reversal enables the gymnast to counter-rotate around their mass centre (CM) as they pass over the bar. The main challenges of the Tkachev are therefore to release with the correct CM trajectory whilst also being able to alter of angular momentum around the CM up to release. Careful manipulation of the associated variables facilitates different body shape options to be employed by the gymnasts and consequently to attain higher tariff ratings for the skill. There are several differences between the skill when performed by males and females (FIG, 2006a; FIG, 2006b). Female gymnasts currently only perform the straddled or piked Tkachev; where as male gymnasts are able to perform more complex styles such as straight and full-twisting Tkachevs (FIG, 2006a). These differences could be attributed to a number of sources. Firstly, the *elastic characteristics* of the female upper bar are different to those of the male high bar (Kerwin and Hiley, 2003). Secondly, the inclusion of a *lower bar* obstructs the female gymnast’s descent in the traditional Tkachev (Witten *et al*., 1996) which requires variance in technique between males and females (Hiley and Yeadon, 2005; Witten *et al*., 1996). Thirdly, differences may be due to anatomical and *physiological* factors. The purpose of this study is to explain the biomechanical differences observed during the Tkachev and proceeding longswing for male and female gymnasts.

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 apparatus. The optical axes of the cameras intersected at approximately 66° over the centre of the high bar or uneven bars respectively. Both cameras captured the images at 50 Hz with a shutter speed of 1/600 s. Prior to the performances, images were recorded of two three dimensional calibration matrices; one surrounding the uneven parallel bars, comprising 20 known points (3m x 4.5m x 4m) and the other, of 40 known points, encompassing the high bar (5.2m x 6m x 3m). During the competition, images of straddle Tkachevs performed by males (n=6;

mass = 56.64 ±3.29 kg; ht = 1.62 ±0.02 m) and females (n=5; mass = 37.20 ±6.35 kg; ht = 1.46 ±0.08 m) were recorded.

Data processing: Calibration and movement data were digitised using the TARGET high resolution motion analysis system (Kerwin, 1995). The movement data were extracted from images of the preceding longswing, the release and flight phase of the straddle Tkachevs. In each image, the centre of the high bar and the gymnast's head and the 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 'ksmooth' function (MatchCad[13]™, Adept Scientific, UK) was used to process the 3D coordinate data 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). Averaging the left and right sides of the body enabled the production of a four segment planar representation of the gymnast, (arm, trunk, thigh and shank). 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. Re-grasp occurred as soon as the grip radius returned to within the previously established maximum. 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 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 at Sz_{max} (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 their 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 moment of inertia (I_{ss}) in a theoretical straight position and also by 2π to produce units of straight somersaults per second (SS/s). Comparisons between the means were made with unpaired 't' tests. Caution should be exercised in interpreting the results since the samples were small.

RESULTS & DISCUSSION:

There were clear differences between the trajectories for straddle Tkachev when performed on the high bar and the uneven parallel bars (Figure 1a). The key release and flight parameters are summarised in Table 1. Although flight time for males and females were similar, the vertical velocity at release (Vz) for males was more than double that for females; $p<0.000$). As a consequence the vertical clearance for the females was only 1/6th that of the males, ($Sz_{y=0}$ in Table 1; $p<0.000$). Females released the bar with similar release angles (θ_{cm}) and horizontal velocities (Vy) to the males but males were able to project themselves over the bar whilst the females appeared to 'drop' over the bar from comparatively similar release heights. The extra clearance over the bar displayed by the males (1.04 ±0.06) compared to the females (0.68 ±0.11) ($p=0.001$) is one of the key factors which enable males also to perform the Tkachev in a straight position.

Table 1 Release and flight parameters for the women's straddle Tkachev facing outwards relative to the apparatus and men's straddle Tkachev (mean [±sd]).

	Time$_{flight}$ (s)	**□$_{cm}$ (º)**	**Sz (m)**	***Sy$_{zmax}$ (m)**	****Sz$_{max}$ (m)**	****Sz$_{y=0}$ (m)**
Men's Straddle	0.55	49	0.72	0.12	1.09	1.04
[n = 6]	[0.03]	[9]	[0.11]	[0.11]	[0.07]	[0.06]
Women's Straddle	0.50	46	0.62	0.26	0.75	0.68
[n = 5]	[0.06]	[6]	[0.06]	[0.08]	[0.08]	[0.11]
	****L ($kg \cdot m^2/s$)**	***Ln (SS/s)**	***ω$_{cm}$ (rad/s)**	****I$_{ss}$ ($kg \cdot m^2$)**	**Vy (m/s)**	****Vz (m/s)**
Men's Straddle	-22.38	-0.40	-2.05	9.00	-1.89	2.81
[n = 6]	[2.57]	[0.07]	[0.41]	[0.75]	[0.29]	[0.36]
Women's Straddle	-7.05	-0.23	-1.29	5.16	-1.87	1.53
[n = 5]	[2.46]	[0.10]	[0.49]	[1.39]	[0.10]	[0.25]

Key: Significant differences between the means indicated by: **= *p*<0.01, * = *p*<0.05.
Time$_{flight}$ = time of flight over the bar; □$_{cm}$ = angle between gymnast's CM, bar and horizontal at release; S_z = vertical displacement of CM at release; Sz_{max} = maximum height of CM in flight; Sy_{zmax}= horizontal position of CM at Sz_{max} in flight; $Sz_{y=0}$ height of the CM as the gymnast passed over the high bar; L = angular momentum about CM, L_n = Angular momentum normalised by moment of inertia in the straight position (I_{ss}).

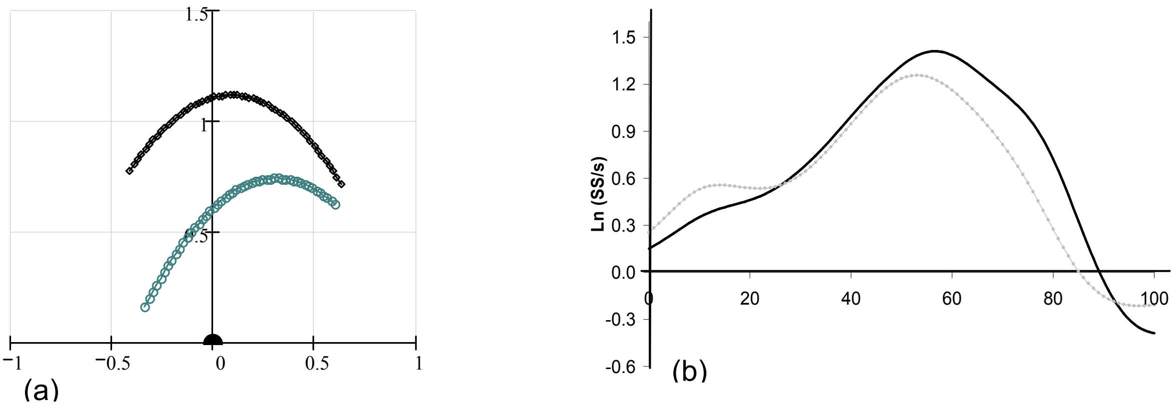

Figure 1: (a) Trajectories of CM over the high bar (0,0), for male (black) and female (grey) gymnasts performing the straddle Tkatchev. (b) Normalised angular momentum about gymnasts' mass centres during the straddle Tkachev.

The angular momentum time histories (Figure 1b) culminated in release values for men that were three times those of women (*p*=0.001). Even allowing for the fact that moment of inertia for men was almost twice that of women, the normalised angular momentum for the men remained 1.7 times that of the women (*p*=0.02). Greater angular velocity (*p*=0.04) with similar flight times provided males with the opportunity to re-grasp the bar in a higher position (0.63 ±0.09) well above the bar than for females (0.20 ±0.15) (*p*=0.002). In so doing males were able to follow the Tkachev with another complex skill. The men have at least two further advantages; there is no lower bar to obstruct their swing, and the high bar is stiffer than the uneven bar and hence able to return more energy to the gymnast.

CONCLUSION:

Apparatus construction appears to be very important in accounting for the differences between the straddle Tkachev performed by male and female gymnasts. In addition to any apparatus or technical skill characteristics already considered, the fact that male gymnasts, are relatively stronger, particularly in the shoulder girdle, than female gymnasts could also account for some of the observed differences.

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