MUSCULOSKELETAL WORK PRECEDING THE TKACHEV ON UNEVEN BARS

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The purpose of this study was to identify the mechanics of traditional outward facing (O) and newer inward facing (I) Tkachev on uneven bars. Images of ten straddle Tkachevs (O=5, I=5) performed at the Sydney Olympic Games, 2000 were recorded with twin video cameras (50Hz). Manual digitising and 3D DLT reconstruction techniques were combined with inertia modelling to develop customised profiles for the ten gymnasts. Inverse dynamics analyses were used to quantify hip and shoulder joint kinetics, and segmental and bar energy exchanges from the horizontal position on the downswing to bar release. There was evidence that more energy was stored in and recovered from the bar in the inward technique. The role of the hips remained similar for both skills, but a large shoulder flexion rather than extension occurred in the inward technique close to release.

KEY WORDS: Gymnastics, inverse dynamics, coaching.

INTRODUCTION:

Changes in the rules governing the bar spacing in the late 1990's have enabled female gymnasts to perform complex release and regrasp skills particularly the Tkachev either facing towards or away from the low bar when passing the high bar. Historically the Tkachev has been performed with the gymnast facing outwards (O) and travelling towards the low bar whilst clearing the high bar. Increased bar spacing has enabled females to longswing the opposite way, facing inwards (I) and travelling away from the low bar when performing the Tkachev. This change in direction highlights an issue relating to the scoring system within gymnastics. The governing body of gymnastics (Fédération Internationale de Gymnastique, FIG) seeks to ensure that the judging system is safe, objective, transparent and fair. One question which as arisen since the removal of the traditional scoring system of 10 was replaced by a composite score made up of difficultly and execution marks. These changes place greater emphasis on the performance of complex skills in order to gain extra marks. Currently the two styles of Tkachev (O and I) each have the same difficulty rating, however, although they share the same name there are mechanical differences which were highlighted by Kerwin et al. (2007). By altering the direction in which gymnasts swing around the bar, changes in angular momentum during the longswing occurred. These authors showed that this direction change presented the female gymnast with the ability to increase the release velocity and normalised angular momentum providing the opportunity to perform more complex versions of the skill (e.g. piked). More detail analysis of joint kinetics and mechanical work may help explain these differences. Previous research employing an innovative energetic analysis of Tkachevs has proposed the utilisation of bar elasticity through the muscle work at the hips and shoulders during the preceding longswing (Arampatzis and Brüggemann, 2001). They also highlighted what they termed a technical deficit in energy, particularity for women executing the Tkatchev and suggested that understanding and improving ways to overcome this deficit would be a good topic for future studies. The aim of this study was to quantify the differences in musculoskeletal work between the outward and inward Tkachevs, and to examine whether these skills are equally demanding on gymnasts.

METHOD:

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 uneven parallel bars. The optical axes of the cameras intersected at approximately 66˚ over the centre of the bars. 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 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 from 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, her 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 gymnast were customised using Yeadon's inertia model (1990), each gymnast's height and mass and using limb length scaling based on the video analysis data.

Data analysis: The reconstructed 3D coordinate data were processed with the 'ksmooth' function (MatchCad^{14}™, 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. 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 to be obtained. Knee, hip and shoulder angles and angular velocities were calculated from the linked segmental model, with the zero crossing points of the angular velocity profiles being used to determine the starts and ends of the two functional phases each for hips and shoulders (Manning et al., 2008, current poster).Inverse dynamics analysis was completed using the techniques described by Irwin and Kerwin (2007). Two types of work/energy calculations were completed. The time integral of the hip and shoulder muscle power profiles, during the functional phases of the longswing, enabled gymnast work to be calculated. Data resulting from the inverse dynamic analyses were normalised to each gymnast's body weight and height according to methods proposed by Hof (1996). Finally the methods advocated by Arampatzis and Brüggemann (2001). were used to determine total, bar gymnast energy from the horizontal position on the downswing to release. Bar forces were not measured directly and so bar deflection, and independently measured bar stiffness values were used to predict bar forces based on the methods reported by Kerwin and Hiley (2003).

RESULTS and DISCUSSION:

The joint angles profiles together with the muscle moments and powers for the hips and shoulders are presented in Figure 1. Each data set shows the mean and standard deviation (n=5) for each condition. Angles and moments have been defined so that joint closing is positive (flexion for the hips and extension for the shoulders). In Figure 1, there is a clear joint closing in the early stage of the motion and rapid joint opening as the gymnast approaches a circle angle of 300º until release at just over 400º. The power profiles show two distinctive positive phases around 270º and 360º where the gymnast is performing positive work to close the joint angles. The power profiles show two distinctive positive phases around 270º and 360º where the gymnast was performing positive work to close the joint angles. Similar double peaked power curves were reported for the outward technique by Arampatzis and Brüggemann (2001). The shoulder power curves for the outward technique were also similar to those reported by Arampatzis and Brüggemann (2001), but for the inward technique a distinctive negative phase appeared around 360º indicating vigorous shoulder opening prior to returning to a positive phase as the gymnast approached release.

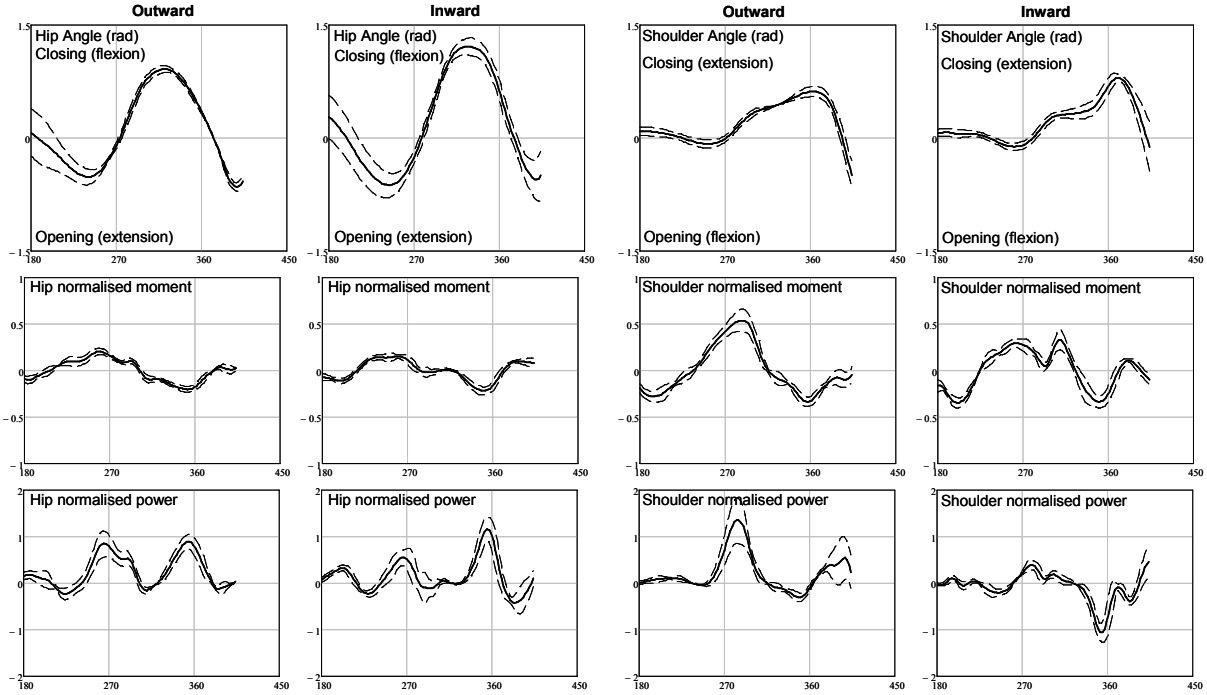

Figure 1: Joint angles and normalised muscle moments and powers (Hof, 1996) for the hips and shoulders (mean ±sd) for Outward (O) and inward (I) straddle Tkachevs on uneven bars.

Previously it has been shown the new 'inward' compared to the traditional 'outward' Tkatchev enabled gymnasts to create approximately 75% more angular momentum whilst releasing with linear velocity and release angles which were 20% greater. Therefore the purpose of this study was to examine the kinetics behind these two skills to try to identify the mechanisms responsible for these marked differences. The path of the mass centre for the outward variant was closer to the bar at the start and further away from the bar at release than for the inward version. Analysis of the energy stored in the bar showed that bar extension increased on the downswing and reduced on the upswing markedly for the inward version and reached a maximum of 60% more strain energy than for the outward version. This was seen to return to the gymnast as she approached release. The exchange of energy between the bar and gymnast has been characterised as a key feature of successful Tkatchev performance (Arampatzis and Brüggemann, 2001). Comparison of the work at the hips suggests that the outward technique requires the gymnast to contribute 20% more work than for the inward. The clear kinetic differences between the two similarly named skills highlight the fact that different coaching guidance is required. The differences in physical demands placed on the performers would dictate specific training to elicit the effective adaptations in the neuromuscular systems. Also the reduced physical demand placed on the gymnast by the newer inward technique would indicate that is more suitable as a progression to older technique or that the new technique could be developed by experienced gymnasts to create more exciting release and regrasp skills in the future. This study has highlighted that apparent similarities in the kinematics mask fundamental differences in the kinetics and expands the ideas promoted by Irwin and Kerwin (2007) when ranking progression for skill development based on musculoskeletal demands.

CONCLUSION:

The differences in physical demands placed on the performers when preparing for the Tkachev on uneven bars would dictate specific training to elicit the effective adaptations in the neuromuscular systems. Also the reduced overall physical demand placed on the gymnast by the newer inward technique would indicate that the new technique may be developed by experienced gymnasts to create more exciting release and regrasp skills in the future. This study has highlighted that apparent similarities in the kinematics mask

fundamental differences in the kinetics and expands the ideas promoted by Irwin and Kerwin (2007) when ranking progression for skill development based on musculoskeletal demands. The data presented are based on elite performers in 2000, shortly after the rule change enabling the bar spacing to be increased to 1.8 m. Looking to the future, data from more recent international competitors would add further insights into how these advanced skills have developed.

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