OPTIMISATION TO IMPROVE CONSISTENCY IN THE TKATCHEV ON HIGH BAR

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The purpose of this study was to improve the consistency of performance of the Tkatchev release and re-grasp on high bar. A simulation model (Hiley & Yeadon, 2003) was used to optimise the technique in the giant circle leading up to release in order to maximise the size of the window within which the gymnast could release and successfully re-grasp the bar. The optimal simulation resulted in a release window considerably larger (93 ms) than the gymnast's actual performances (mean 29 ms). However, when the technique was required to be robust to small errors in timing the size of the release window was smaller. Performing the final hip and shoulder flexion and extension actions earlier and over a larger angle range than in the actual performances lead to the increase in size of release window.

KEY WORDS: simulation, optimisation, gymnastics.

INTRODUCTION:

In the Tkatchev release and re-grasp the gymnast approaches the skill from a backwards rotating swing. During release the direction of rotation must be reversed so that in flight the gymnast rotates forwards as he travels backwards over the bar to re-grasp (Figure 1). Previous research has looked at the mechanical descriptors of the preceding giant circles and the release parameters of the Tkatchev (Gervais & Tally, 1993; Brüggemann et al., 1994). Simulation models have been used to look at the differences between successful and unsuccessful performances, with attempts to identify how missed re-grasps could be corrected (Holvoet et al., 2002; Hiley et al., 2007). Holvoet et al. (2002) demonstrated that an unsuccessful Tkatchev could have been caught had the gymnast released the bar earlier than in the actual performance. In contrast, Hiley et al. (2007) found that even if the gymnast had released earlier in unsuccessful performances he still would not have been able to re-grasp the bar.

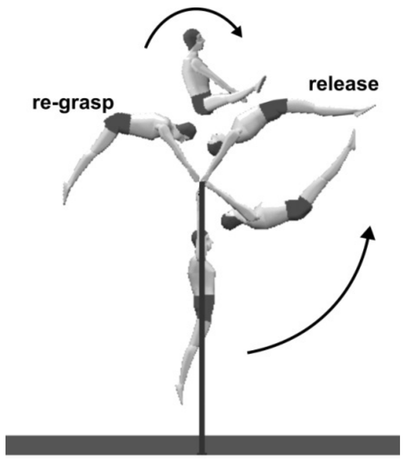


Figure 1. The Tkatchev release and re-grasp on high bar.

Hiley et al. (2007) determined the time window for release during the preceding giant circle when the gymnast had sufficient linear and angular momentum to re-grasp the bar for 10 successful and 10 unsuccessful trials. The release window for the successful trials varied from 9 – 74 ms (mean 29 ± 21 ms) and showed little consistency. In eight of the unsuccessful trials a release window of less than 5 ms was obtained (mean 3 ± 4 ms). For the unsuccessful trials it was found that the actions at the hip and shoulder joints were performed later than in the successful trials and that these trials could not have been converted into successful trials by releasing the bar earlier in the giant circle.

The purpose of this study is to use a computer simulation model to optimise the technique in the backward giant circle prior to release for a Tkatchev so as to improve the size of the release window and hence consistency of performance. In addition the effect of the requirement for solutions to be robust to perturbations in timing will be investigated. Previous research has shown the need to include aspects of robustness in the optimisation procedure to produce solutions that are able to cope with small errors in timing (Hiley and Yeadon 2008). Increasing the size of the release window with a technique that is robust to small errors in timing will lead to improved consistency of performance.

METHOD:

Matching process: One successful Tkatchev trial (release window = 29 ms) performed by a male national standard gymnast (mass = 64 kg, height 1.63 m) was chosen from the study of Hiley et al. (2007) for further analysis. A four segment model including damped linear springs for the elastic structures of the gymnast and high bar was used (Hiley & Yeadon, 2003). The model used subject-specific inertia data (Yeadon, 1990) and strength characteristics were scaled from data on an elite male gymnast using an isokinetic dynamometer (King & Yeadon, 2002). The simulation model was angle driven using joint angle time histiories in the form of Fourier series, which were matched to the recorded angle data (captured using a Vicon automatic motion capture system) during a matching optimisation. During the matching optimisation the bar and gymnast spring parameters were allowed to vary along with the initial orientation and angular momentum of the model. The model was required to produce a close match between the recorded and simulated rotation angles, bar displacements, joint angle time histories and absolute linear and angular momentum at release. Simulations ran over the last ¾ giant circle leading up to release.

Optimisation: The technique in the last ¾ giant circle was varied in order to maximise the size of the release window. The release window was defined as the period of time for which the model possessed normalised angular momentum within the range of 10 actual successful release values ± 10% of that range (Hiley et al., 2007). In order for the gymnast to be within successful catching distance of the bar, the mass centre had to lie within a sector defined by the range of actual catch positions and anthropometrically feasible positions. The release window was allowed to start before and end after the actual release time of the trial so long as the above constraints were satisfied. The path of the mass centre in flight was calculated using the mass centre location and velocity at release and the equations of motion under constant acceleration.

To investigate the effect of a requirement for robustness, the timing of the shoulder, hip and knee actions were perturbed successively by ± 5 ms, ± 10 ms, ± 15 ms and ± 20 ms. For each perturbation level five different combinations were performed for each step of the optimisation (i.e. no perturbation, shoulder and hip together both early and late, shoulder early with hip late, and shoulder late with hip early). For simplicity the knee angle was perturbed in combination with the hip angle. The score returned to the optimisation routine was the smallest release window obtained from the five simulations.

RESULTS:

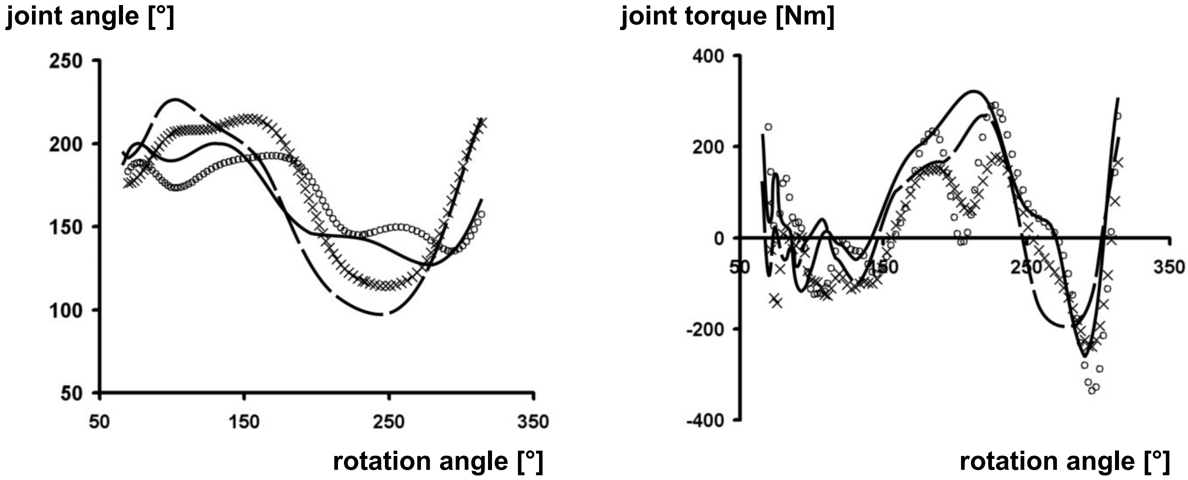
The matching simulation was able to match the whole body rotation angle to 3°, the bar displacements to 0.02 m and the joint angle time histories to 2° (rms differences) of the actual performance. The release window for the matching simulation was 34 ms. The results of the optimisations are shown in Table 1. The size of the release window decreased as the size of the timing perturbation that the optimum technique was required to be robust to increased. At a perturbation level of 10 ms the smallest release window was comparable with the mean of the actual performances.

Table 1 Release windows obtained from the actual performance and the optimisations with varing levels of perturbations (0 - 20 ms)

actual	perturbation (ms)				
performance (ms)	0	5	10	15	20
34	94	65 (68)	36 (50)	23 (48)	17 (39)

NB : the value in brackets is the mean release window from the 5 perturbation combinations

The feature common to all of the optimum simulations was the earlier phasing of the actions at the hip and shoulder joints (Figure 2a). In addition, both of these actions were performed over larger angle ranges when compared to the actual performance (Figure 2a). The joint torques used in the optimum simulations did not differ appreciably from those obtained from the matching simulation and are therefore expected to be within the gymnast's strength capability (Figure 2b).



(a) (b)

Figure 1: Histories of the (a) joint angles and (b) joint torques from an optimum simulation (solid line = shoulder, dashed line = hip) and an actual performance (circles = shoulder, crosses = hip)

DISCUSSION:

Computer simulation is a useful tool that allows the researcher to investigate changing an athlete's technique. In the present study the size of the release window was increased whilst maintaining realistic joint torques at the hip and shoulder. With a larger release window the gymnast has more chance of releasing the bar with the appropriate amount of linear and angular momentum that will result in successfully re-grasping the bar. A gymnast that has a large release window is therefore likely to have a more consistent performance.

For the gymnast used in the present study releasing the bar earlier in the unsuccessful trials, as suggested by Holveot et al. (2002), was not feasible since production of the correct amount of angular momentum did not coincide with the correct flight parameters (i.e. the gymnast had very small release windows < 5 ms). In order to improve the consistency of performance the gymnast would be required to change the technique in the backward giant circle prior to release. Performing the actions at the hip and shoulder earlier and over a larger angle range resulted in larger release windows and therefore improved consistency.

Since it is unlikely that gymnasts are able to precisely time the technique each time, it is important to include the concept of robustness into the optimisation procedure. Although it is not known how precisely gymnasts can time whole body actions it is not expected to be as low as 5 ms (especially as no trials were caught from the actual performances with release windows at this level). At a perturbation of level 10 ms all resulting release window were larger (≥ 36 ms) than the mean of the actual gymnast's successful trials (29 ms). Since the average release window of the perturbed trials was considerably larger (48 ms) it would be expected that the gymnast could successfully complete the Tkatchev on a more consistent basis using the new technique.

CONCLUSION:

Having a technique that produces a large release window and that is robust to small timing perturbations will result in a more consistent performance. In the present study the changes in technique that would result in improved consistency were within the gymnast's capability and their implementation has been recommended by the gymnast's coach (a National coach).

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Acknowledge

The authors wish to acknowledge the support of the British Gymnastics World Class Programme.