OPTIMISATION OF THE BACKWARD GIANT CIRCLE ON ASYMMETRIC BARS

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The purpose of this study was to optimise the release window in the backward giant circle performed prior to release for a double layout somersault dismount from the asymmetric bars. An additional aim was to investigate the effect of requiring the optimal technique to be robust to perturbations in timing of the changes in joint angles. A planar computer simulation model was used to maximise the release window (Hiley and Yeadon, 2005) of a female gymnast by manipulating the joint angle time histories during the giant circle prior to release. Optimisations were performed where the timing of the joint actions at the shoulder and hip were perturbed in order to obtain solutions that were robust to such perturbations. Joint angle time histories were limited by muscle data scaled from a male gymnast. Although introducing the requirement for robustness into the optimised giant circle technique reduced the size of the release windows more consistent performances were achieved.

KEY WORDS: gymnastics, simulation, optimisation.

INTRODUCTION: Backward giant circles on the asymmetric bars (a-bars) are used to generate the necessary angular momentum and flight for both release and re-grasp skills and dismounts. The technique used in the backward giant circle must incorporate a strategy to avoid the lower bar (Figure 1). Hiley and Yeadon (2005) calculated the margin for error when timing the release for double layout somersault dismounts from the a-bars. The margin for error was quantified in terms of the release window during which time the gymnast has suitable linear and angular momentum for performing the double layout somersault dismount. The release windows for the female gymnasts from the 2000 Olympics, 69 ms (Hiley and Yeadon, 2005), were generally smaller than those of the male gymnasts, 114 ms (Hiley and Yeadon, 2003a). It might be expected that gymnasts with larger release windows will be able to land their dismounts more consistently. Similarly, it might be expected that the techniques adopted by gymnasts are robust and can cope with small deviations from the desired performance. The aim of this study was to optimise the release window produced by a female gymnast in the backward giant circle prior to a double layout somersault dismount. It was also the aim to determine the effect of requiring the optimised technique of the backward giant circle to be robust to perturbations in the timing of joint angle changes.

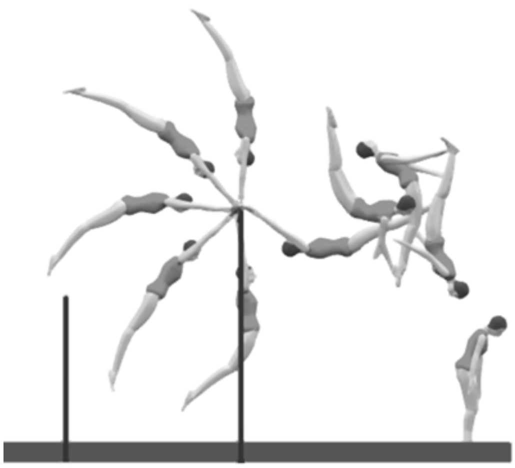

Figure 1: The backward giant circle before release for a double layout dismounts on the asymmetric bars.

METHOD: The backward giant circle preceeding a double layout somersault dismount from the Sydney 2000 Olympic Games was selected for further investigation. The release window for the performance had been calculated elsewhere (Hiley and Yeadon, 2005) and was representative of an average window (67 ms). A four segment planar model of a gymnast comprising arm, torso, thigh and lower leg segments was used to simulate the movement around the bar (Hiley and Yeadon, 2003b). The bar and the gymnast's shoulder structure were modelled as damped linear springs (Figure 2). Input to the simulation model comprised the individualised segmental inertia parameters, the stiffness and damping coefficients of the bar and shoulder springs, the initial displacement and velocity of the bar, the initial angular velocity of the arm, the initial orientation of the arm and the joint angle time histories at the shoulder and hip in the form of stepwise quintic functions.

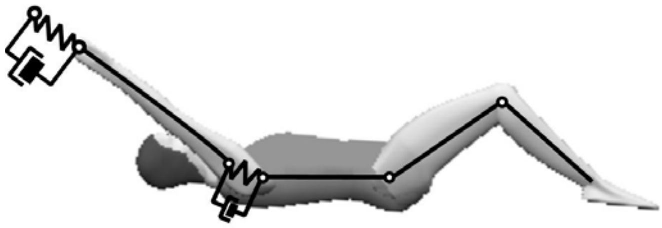

Figure 2: Four segment model of gymnast and bar.

Simulations within the optimisations were started with the model at a rotation angle of approximately 45° (from the vertical) and finished once the model had rotated to an angle of at least 270°. Initial conditions were taken from the actual performances. Two groups of optimisations were performed. In group 1 the joint angle time histories were manipulated only in terms of the timings of the actions at the shoulder and hip, with the magnitude of the angle changes being kept the same as in the actual performance. In group 2 both the angles and timings were allowed to vary. The release window was defined as the period of time during which the model possessed within ± 10% of the angular momentum determined from the actual performance, landed with the mass centre between 1.0 m and 3.0 m from the bar and had a time of flight of at least 90% of the actual flight time (Hiley and Yeadon, 2005). To investigate the effect of a requirement for robustness, the timing of the shoulder and hip actions were perturbed by ± 10 ms and ± 20 ms. 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). The score returned to the optimisation routine was the smallest release window obtained from the five simulations. The joint torque limits were determined by measuring joint torques during eccentric-concentric trials using an isovelocity dynamometer for a male National Team gymnast and fitting a function which expressed maximum voluntary joint torque in terms of joint angle and angular velocity (King and Yeadon, 2002; Yeadon and King, 2002). Joint torque limits were scaled for mass and height. In addition the peak joint torques were constrained so as not to exceed the levels used in the actual performance.

RESULTS: The results from the optimisations are presented in Table 1. The value for the actual performance is taken from the study of Hiley and Yeadon (2005). Graphics sequences of the actual performance, the optimised performance and the optimised performance robust to 20 ms perturbations for group 1 (only timings varied) and group 2 (angles and timings varied) are shown in Figure 3 and Figure 4, respectively.

Table 1 Maximised release windows (ms) obtained from optimisation

		Release Window [ms]		
Group	**Actual Performance**	**No Perturbation**	**10 ms Perturbation**	**20 ms Perturbation**
1	67	127	108	97
2	67	148	131	130

Figure 3: Graphic sequences of the (a) actual performance, (b) the optimised performance and (c) the optimised performance robust to 20 ms from group 1 (only timings varied).

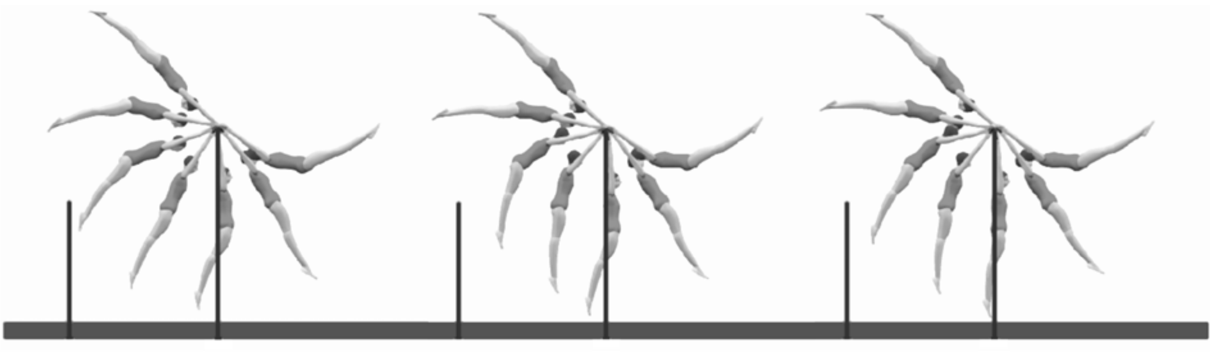

Figure 4: Graphic sequences of the (a) actual performance, (b) the optimised performance and (c) the optimised performance robust to 20 ms from group 2 (angles and timings varied).

DISCUSSION: Optimising the timings of the joint actions in the backward giant circle produced an increase in the release window (Table 1). Allowing the angles to vary (group 2) as well as the timings produced a further increase in the size of the release window. In the optimisations where the solution was required to be robust to timing perturbations the size of the release window decreased with the size of the perturbation. However, as the perturbation increased the technique became more robust. When the simulation of the actual performance was perturbed, in the same way as in the optimisations, by 10 ms, the release window ranged from approximately 57 - 80 ms. In the actual performance the level of perturbation that the technique could cope with is not really known, nor is it known whether the actual performance had already been perturbed (i.e. not performed as well as possible). It would be necessary to determine the release window from repeated trials to establish the amount of variation in the technique and the effect this variation has on the size of the release window.

When the optimal simulations that were required to be robust to 20 ms perturbations were perturbed, the range of release windows obtained were 71 – 86 ms and 122 - 131 ms for groups 1 and 2, respectively. The 20 ms robust optimisation from group 1, when perturbed, had a minimum release window comparable with the actual performance (67 ms). When the optimal simulations that were not required to be robust to timing perturbations were perturbed by 20 ms the release windows obtained ranged from 40 – 113 ms and 36 – 103 ms for groups 1 and 2, respectively. Additionally, in many of these simulations the joint torque limits were exceeded and were therefore not viable. This did not happen with the robust optimised solutions. Although the optimised techniques (no perturbation) produced larger release windows than the robust optimisations, when the technique deviated from optimal the reduction in release window was greater.

CONCLUSION: Optimisation is a powerful tool that allows the researcher to improve the performance of an individual's technique. However, care should be taken when determining such optimum techniques. In this example, a technique that requires precise timing to produce a large release window is of little use unless similar results, in terms of release window, are obtaineded when the gymnast makes small deviations from this optimal technique. It is likely that the techniques adopted by gymnasts are robust to timing perturbations so that consistent performances can be achieved.

REFERENCES:

Hiley, M.J. and Yeadon, M.R. (2003a). The margin for error when releasing the high bar for dismounts. Journal of Biomechanics, 36 (3), 313-319.

Hiley, M.J. and Yeadon, M.R. (2003b). Optimum technique for generating angular momentum in accelerated backward giant circles prior to a dismount. Journal of Applied Biomechanics, 19 (2), 119-130.

Hiley, M.J. and Yeadon, M.R. (2005). The margin for error when releasing the asymmetric bars, Journal o f Applied Biomechanics, 21, 223-235.

King, M.A., and Yeadon, M.R. (2002). Determining subject-specific torque parameters for use in a torque driven simulation model of dynamic jumping. Journal of Applied Biomechanics, 18, 207-217.

Yeadon, M.R. and King, M.A. (2002). Evaluation of a torque driven simulation model of tumbling. Journal of Applied Biomechanics, 18, 295-206.

Acknowledgement

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