APPLICATIONS OF MODELLING TO THE IMPROVEMENT OF SPORTS TECHNIQUE

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Models of high jumping, high bar circling, swinging on rings, tumbling, diving, twisting and balancing can give insight into the mechanics of these movements and provide a basis for coaching in order to improve performance. Such models can also be used to investigate the viability of new movements or new techniques. Training aids based on models of sports movements have the potential to speed learning and enable athletes to reach new levels of achievement.

KEY WORDS: computer simulation, training aids

INTRODUCTION:

Models of human movement may be used to gain an understanding of the underlying mechanics. In sport there is also the possibility of improving technique using the results of computer simulation models. This will be illustrated in this paper using a number of examples taken from sport.

HIGH JUMPING:

Alexander (1990) used a two-segment model to show that jump height was maximised using intermediate values of approach speed and leg plant angle. Wilson (2003) also used this model to show that jump height increases linearly with knee angle. These relationships were confirmed by Greig and Yeadon (2000) in a case study of an elite high jumper and accounted for 79% of the variation in jump height.

Tan and Yeadon (2005) used a single segment model to show that an approach with increasing curvature could account for the majority of the somersault velocity in high jumping in case studies of two elite high jumpers. Results such as these may be used to direct the coaching of high jumping on an informed basis in order to maximise the height cleared.

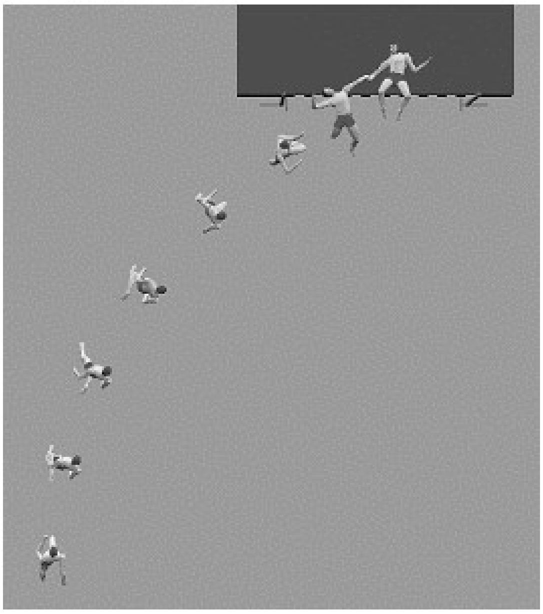

Figure 1: The curved approach in high jumping.

HIGH BAR:
Hiley and Yeadon (2003a) used a four-segment angle-driven planar computer simulation model of a gymnast on high bar to show that the change from the traditional to the scooped technique for giant circles prior to a dismount could not be accounted for on the basis of angular momentum generation. Subsequently this change was explained by an increased margin for error in timing the release arising from a flattening of the mass centre path in the scooped technique (Hiley and Yeadon, 2003b). It was also shown that the important characteristic of the scooped technique was being hyper-extended at the lowest point of the circle.
Using the same model Hiley and Yeadon (2005) demonstrated that the triple somersault straight dismount from high bar was theoretically possible in that sufficient angular momentum could be generated but was also theoretically impractical since the margin for error was too small. It was concluded that the triple piked somersault dismount and the lay-full-full tucked dismount were viable dismounts on the basis of angular momentum and margin for error. Subsequently it was shown that the triple piked dismount could be produced from optimised giant circles in which there was up to 30 ms perturbation in timing coordination (Yeadon and Hiley, 2008).
These results give focus to which aspects of giant circles should be coached and what new dismounts might be considered.

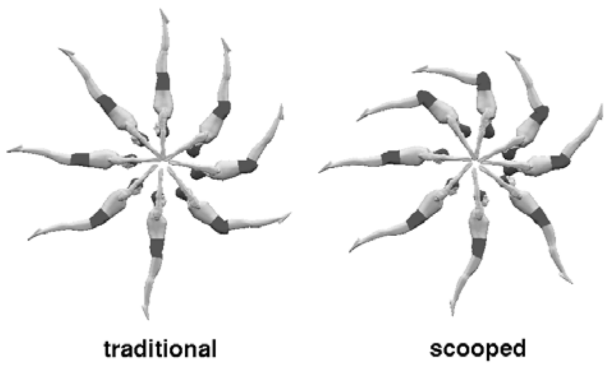

Figure 2: Two types of giant circle on high bar.

RINGS:
A five-segment 3D computer simulation model of swinging on rings was used by Brewin et al. (2000) to understand the extent to which characteristics of equipment and gymnast technique contributed to load reduction in long swings on rings. The model was also used to investigate optimal coordination for long swings to a still handstand and showed that timing errors ranged from 15 ms for minimal swing in handstand to 30 ms for other performances of Olympic competitors (Yeadon and Brewin, 2003).

Figure 3: An optimised long swing to still handstand on rings.

TUMBLING:
King and Yeadon (2003) used a five-segment torque-driven computer simulation model of tumbling to investigate to what extent a gymnast could cope with perturbations to approach characteristics and activation timings during the takeoff for a layout somersault. It was found that errors of less than 5% in perceiving approach characteristics and 7 ms in activation timings could be accommodated using adjustments during takeoff and flight.
The same model was also used to investigate whether a triple straight somersault was viable (King and Yeadon, 2004). It was shown that the prime requirement for this movement was a fast backward handspring approach (7 ms^{-1}) together with a re-optimisation of activation timings.

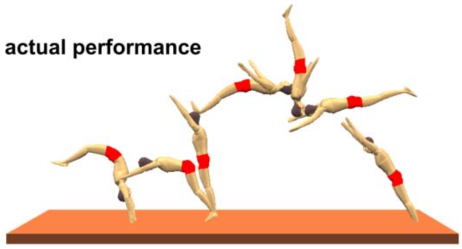

Figure 4: A matching simulation of a performance of a layout somersault.

DIVING:
Kong et al. (2006) used various activation time history profiles in an 8-segment torque-driven planar model to obtain matching simulations for forward and reverse dives. It was found that for forward dives simple activation profiles, in which extensor activations rose and then fell and flexor activations fell and then rose, allowed close agreement to be obtained between simulation and performance. For reverse dives, however, more complex activation profiles were required in order to obtain a close match.

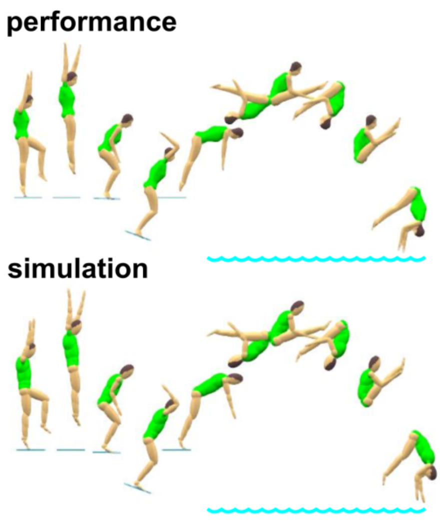

Figure 5: Comparison of performance and simulation of a forward 2 ½ piked somersault dive.

TWISTING SOMERSAULTS:
Yeadon (1993a) used a rigid body model to describe the two modes of aerial motion, namely the twisting somersault and the wobbling somersault, and to explain the instability of rotations about the axis of intermediate moment of inertia. For twists that started during contact prior to the aerial phase the effects of switching between the two modes were identified and examples given of how twist may be stopped and tilt removed (Yeadon, 1993b). Using an 11-segment angle-driven computer simulation model of aerial movement (Yeadon et al., 1990a) it was shown that twist may be initiated in the aerial phase of a somersault using asymmetrical movements of arms or hips to produce tilt and that the subsequent removal of tilt stopped the twist (Yeadon, 1993c). A method for quantifying tilt contributions to actual performances of twisting somersaults was devised (Yeadon, 1993d) and applied to quantify twisting techniques used in freestyle aerial skiing (Yeadon, 1989), springboard diving (Yeadon, 1993e), rings dismounts (Yeadon, 1994), high bar dismounts (Yeadon et al., 1990b; Yeadon, 1997) and tumbling (Yeadon and Kerwin, 1999) in competition at the 1988, 1992, 1996 and 2000 Olympic Games and the 1991 World Student Games. The simulation model was also used to show how instability about the lateral axis in multiple layout somersaults may be controlled using asymmetrical arm movements based on information supplied by the vestibular apparatus (Yeadon and Mikulcik, 1996). The feasibility of a new double twisting triple somersault dismount from high bar was also investigated using this simulation model (Hiley and Yeadon, 2005).

Figure 6: During a wobbling somersault the twist oscillates left then right.

Figure 7: During a twisting somersault the twist continues in one direction.

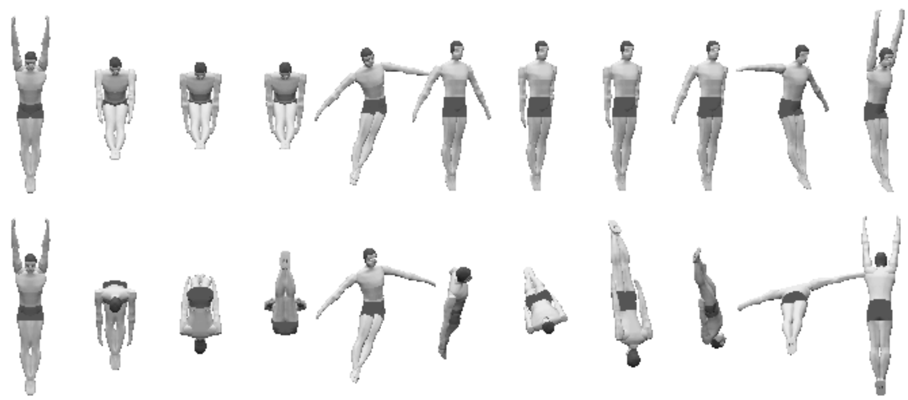

Figure 8: A double somersault with 1½ twists produced using asymmetrical hip movement.

HANDSTAND ON FLOOR:
Yeadon and Trewartha (2003) used a two-segment model of a handstand on floor to show that control is possible using wrist torque that is a function of time delayed displacement and velocity data. It was found that competitive gymnasts had feedback time delays that were too short for visual or vestibular control. It was concluded that although gymnasts may use vision and vestibular input in the learning stages they subsequently make use of long latency reflexes (100 – 150 ms) to maintain balance control.

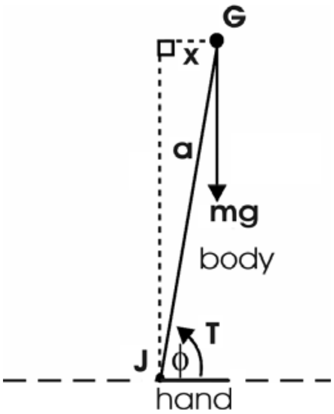

Figure 9: A planar two-segment model for controlling a handstand on floor.

GYMNASTICS TRAINING AIDS:
A model of a handstand balance on rings was used to inform the design of a training aid which allowed progressive increases in the degrees of freedom (Rosamond and Yeadon, 2008). This aid allowed the same control mechanism to be used as in the handstand on rings and performed better than other aids which tended to encourage technique resembling the handstand on floor.

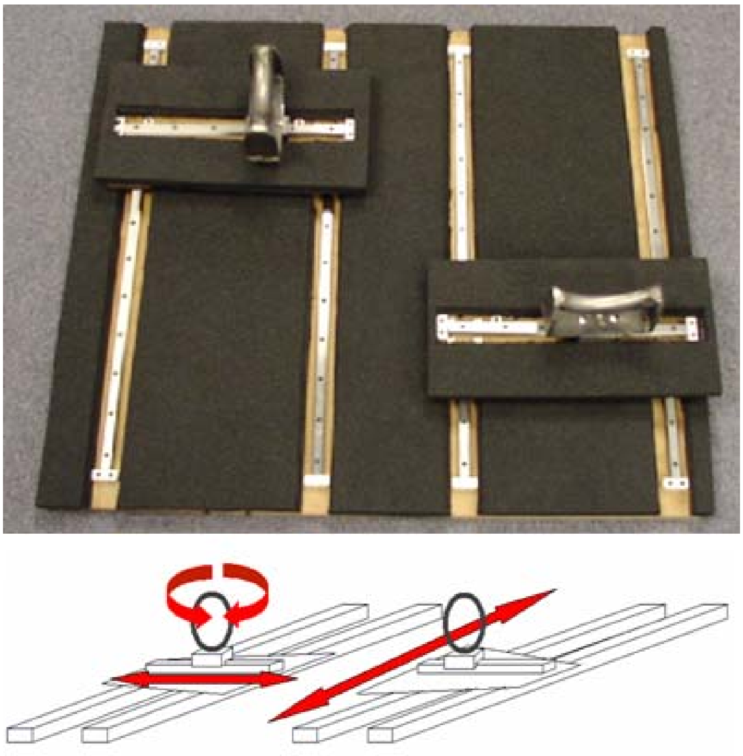

Figure 10: A training aid with six degrees of freedom for a handstand on rings.

Rosamond and Yeadon (2006) used regression equations relating the technical performance characteristics of a standing backward handspring to gymnast standing height in order to inform the design of training aid. The aid was adjustable so as to lie within the free space beneath the trajectory of a standing backward handspring and was used to teach this skill with less coach support than in traditional coaching methods.

Figure 11: A backward handspring over the prototype training aid by an experienced gymnast.

Yeadon and Knight (2006) combined a head mounted real-time virtual reality display with a twisting somersault simulation in order to train viewing techniques during aerial movement. When used by freestyle skiers it was found that experienced competitors were able to view the landing area during flight more consistently than novices. Further development of this system allows twist to be introduced into a multiple somersault using real-time monitoring of the user's arm movements. This has the potential for the user to learn the appropriate coordination during a simulated aerial phase before actually attempting the skill.

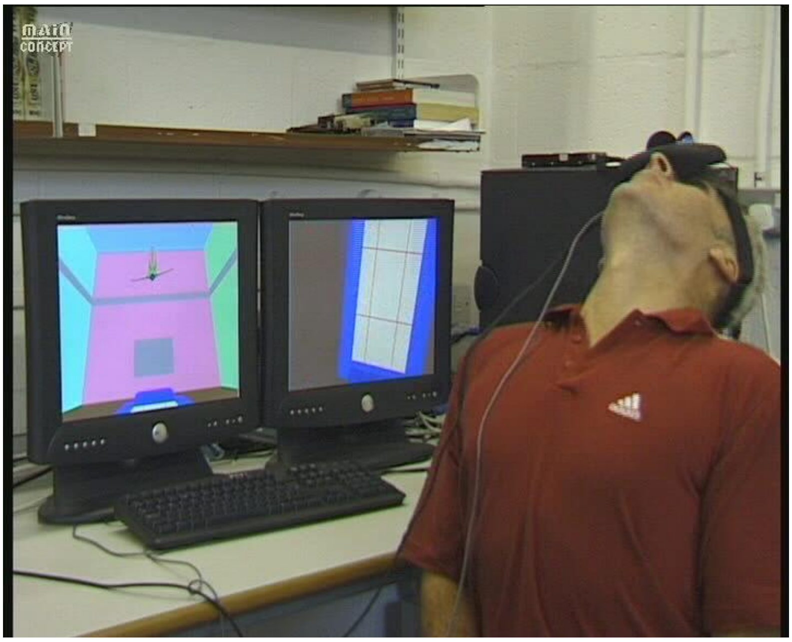

Figure 12: Interactive use of head mounted display with viewpoints of trampolinist and spectator displayed on computer screens.

DISCUSSION:

The main benefit that modeling brings to informing the coaching of technique in sport is a fundamental understanding of the mechanics of specific movements. When the underlying mechanics are understood properly then progressive schemes for skill development can be designed and insight is available when execution problems arise. Without understanding, a cookbook approach to skill development will be less effective and may give rise to the passing on of flawed explanations.

While much new technique originates from individual athletes, often unconsciously rather than deliberately, only research into sports technique can provide a sound basis for understanding, coaching, skill improvement and safe innovation. Whilst many national institutions are ready to apply knowledge gained from research into sport, few are prepared to fund such research. On the other hand an increasing number of enlightened governing bodies of specific sports are now funding research. There is a recognition that there are crucial questions, regarding injuries for example, to which the answers are currently unknown and will remain unknown unless the governing body commissions the research. Perhaps research councils will follow this lead one day by funding research in sport science and will recognise that good science depends not upon the area of application but on the questions posed and the methods used.

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