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OPTIMISATION OF DYNAMIC HUMAN MOVEMENT

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ABSTRACT

The use of computer simulation models to optimise performance in dynamic jumping movements by simply maximising a single performance measure such as height or somersault rotation during flight may result in theoretical simulations that are unrealistic since various factors will have been neglected. The aim of this study was to investigate the optimisation of simulated performance in tumbling and forward springboard diving takeoffs taking into consideration anatomical ranges of movement, and the need to be robust to timing perturbations.

Planar torque-driven computer simulation models of the contact phase were developed (Fig. 1) and customised to an elite athlete for each activity through calculating subject-specific inertia, strength and visco-elastic parameters based upon measurements taken on the subject. Matching simulations were obtained by varying the activation to each torque generator in the models until a good agreement between performance and simulation was found. This demonstrated that each model had sufficient accuracy to investigate optimum performance.

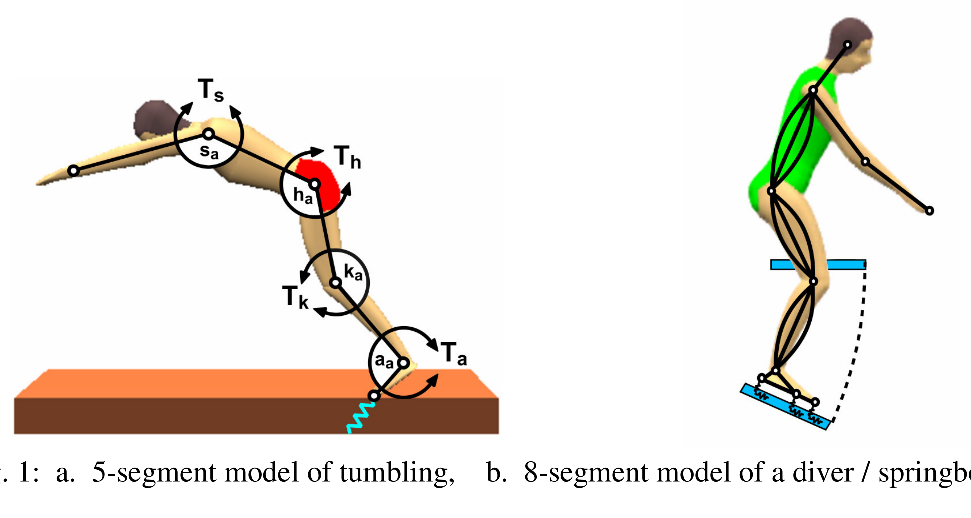

Fig. 1: a. 5-segment model of tumbling, b. 8-segment model of a diver / springboard

Optimum technique in each activity was then found by varying the activation time history to each torque generator using simulated annealing [1] in order to maximise the rotation potential at takeoff (product of angular momentum at takeoff and time of flight). To assess the effects of imposing anatomical constraints and robustness on optimisation results, three different optimisations were used: Optimisation 1 imposed no constraints or robustness; Optimisation 2 imposed anatomical constraints; and Optimisation 3 imposed both anatomical constraints and a requirement of robustness to perturbations in activation timings.

For tumbling Optimisation 1 resulted in sufficient rotation potential at takeoff for a triple layout somersault to be produced given an approach velocity of 7 ms^{-1}. Incorporating anatomical constraints had little effect on the optimised solution due to the nature of the movement. However, perturbing the activation timings of the knee and hip by ±50 ms resulted in up to 31% reduction in rotation potential. Incorporating perturbations of the activation timings for the knee and hip within the optimisation process (Optimisation 3) resulted in solutions with 1.4% to 2.3% less rotation potential at takeoff compared to Optimisation 1. With this reduced amount of rotation potential it was still possible for the model to produce a triple layout somersault and the optimum solution was insensitive to perturbations of the activation timings with all perturbations producing less than 1% change in the rotation potential at takeoff.

For forward somersault dives from the 1m springboard Optimisation 1 resulted in a substantial increase (63%) in rotation potential compared to the matching simulation which was expected to be close to a practical maximum. When anatomical constraints were used in Optimisation 2, the optimised rotation potential was 22% higher than the matching simulation. The results of Optimisation 2 are more reasonable than those in Optimisation 1 since the elite diver should have been performing close to her maximum capability and it is unlikely that minor changes in techniques would increase the rotation potential by as much as 63%. This shows that imposing anatomical constraints in the optimisation procedure has a substantial influence on the results obtained. However, the resulting simulation was not robust to perturbations of the activation timings. In Optimisation 3 the rotational potential produced was within 2% of the rotation potential for the matching simulation with the solution robust to perturbations of ±10 ms in hip and knee activation timings and without any joint constraint violations. This indicates that the achievement level in the actual performance may be accounted for by constraint and robustness considerations.

When maximising performance it is important that anatomical constraints and the robustness of the optimum solution are considered and included in the formulation of the objective function and the optimisation procedure used. Failure to do this can result in maximal solutions that are unrealistic and not achievable. In human development it is likely that the ability to always perform reasonably is just as important as the ability to excel occasionally. Such considerations of robust technique therefore have evolutionary parallels.

REFERENCES

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