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CONTROL OF THE TAKEOFF PHASE IN ONE METRE SPRINGBOARD FORWARD DIVES

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INTRODUCTION

In springboard diving consistency of body orientation at water entry is necessary for a good dive and is likely to be dependent on the consistency of conditions at takeoff. Elite divers may be expected to be very consistent in the springboard touchdown conditions at the end of the hurdle phase. If open loop control is used the joint angle variability during springboard contact will be solely a function of the variability at touchdown. On the other hand if feedback or feedforward control is used, the joint angle variability will arise mainly from technique adjustments made in each individual dive. Sayyah et al. [1] found that rotation potential at takeoff (angular momentum x flight time) had low variability. The aim of this study was to investigate whether the low rotation potential variability can be attributed to the low variability at touchdown or whether a diver makes configurational adjustments during contact to reduce the rotation variability at takeoff.

METHODS

Two-dimensional video analysis was used to calculate orientation and configuration angles of 12 forward pike dives and 12 forward 2½ somersault pike dives, performed by an international diver. Body orientation was calculated as a weighted mean of trunk and leg orientations with the trunk weighted twice as much as the legs. Diver-specific segmental inertia parameters were calculated from anthropometric measurements using a mathematical inertia model [2]. A simulation model [3] of a diver and springboard during board contact (Fig 1) was used to obtain matching simulations and to calculate the rotation potential for each dive.

Simulations were used to determine (a) the variation in conditions at mass centre lowest point arising from variation in touchdown conditions and (b) the rotation potential variability at takeoff arising from the variability in conditions at mass centre lowest point. The variability in mass centre horizontal velocity and trunk angular velocity at mass centre lowest point was calculated for each of the two dives from the 12 matching simulations. This was compared with the variability at the lowest point determined from simulations of perturbed initial touchdown conditions. The initial values of mass centre horizontal velocity, vertical velocity and trunk angular velocity were allowed to vary by ± one standard deviation as calculated from the 12 trials. For each of the 12 matching simulations 8 combined perturbations of the three initial variables were used to drive the perturbed simulations, and the standard deviations of the 8 values of mass centre horizontal velocity and of trunk angular velocity at mass centre lowest point were calculated. From these mean standard deviations of horizontal velocity and angular velocity were calculated for each of the 12 trials.

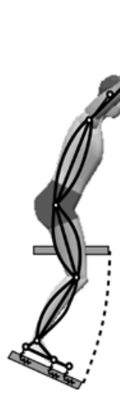

Fig 1: Planar simulation model of a springboard and an eight-segment diver. Wobbling masses are included in the trunk, thigh and shank segments, and visco-elastic spring-dampers are acting at the heel, ball and toe representing the foot-springboard interface.

A similar analysis was conducted using simulations with the four combined perturbations of ± one standard deviation of horizontal velocity and trunk angular velocity at mass centre lowest point as initial conditions to calculate the simulated variation in rotation potential at takeoff.

For each of the two dives a two-tailed one-sample t-test was used to investigate whether the mean standard deviation in the horizontal velocity at the lowest point, as determined using the simulations with perturbed initial touchdown conditions, was different from the standard deviation of the lowest point horizontal velocity of the matching simulations. This was repeated for the trunk angular velocity at the lowest point.

For each of the two dives a one-tailed one-sample t-test was used to investigate whether the mean standard deviation of the rotation potential at takeoff for the simulations with perturbed lowest point conditions was greater than the standard deviation of the rotation potential at takeoff of the matched simulations.

RESULTS AND DISCUSSION

For both dives the mean standard deviation of the horizontal mass centre velocity at the lowest point arising from the simulations with touchdown perturbations was greater than ($p < 0.001$) the standard deviation obtained from the matched simulations. This implies that the diver made adjustments during board depression to control the horizontal velocity. The mean standard deviation of the trunk angular velocity at the lowest point arising from the perturbed simulations was less than ($p < 0.001$) the standard deviation obtained from the matched simulations. This larger variation of angular velocity in the recorded performances is likely to be a consequence of the adjustments made to control the horizontal mass centre velocity.

The control mechanism for the joint angle changes during board depression is likely to be feedforward adjustments based on an estimation of the touchdown conditions during the hurdle flight [4] together with feedback adjustments after touchdown similar to those made in standing balance [5].

When the simulations of both dives were started with perturbations from the lowest point of the mass centre the mean standard deviation of the rotation potential at takeoff was greater than ($p < 0.02$) the standard deviation of the matched simulations. This implies that the diver made adjustments during the board recoil phase to control the rotation potential at takeoff.

The primary mechanism for generating angular momentum during the board recoil phase is hip flexion which reached maximum variability shortly after the lowest point and then decreased towards takeoff (Fig 2). The mechanism for generating vertical velocity is the timing of the knee extension which showed maximum variation late in the recoil phase for the 2½ pike somersault dives and showed large variation until late in the recoil phase for the pike dives. The control mechanism for the adjustments in the board recoil phase is likely to be feedforward rather than feedback with a modification to the pre-planned joint angle configurational time histories being based on the information received during the board depression phase.

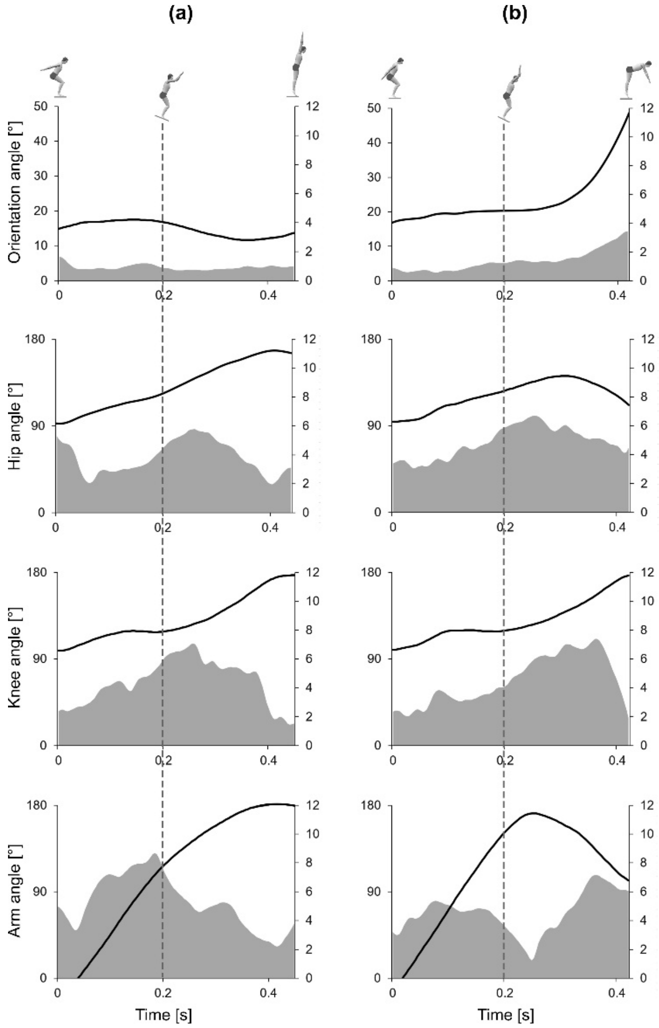

Fig 2: Mean (thick black line) and standard deviation (shaded grey) time histories of orientation, hip, knee and arm angles during the takeoff phase of (a) 12 forward pike dives and (b) 12 forward 2½ somersault pike dives. The vertical dashed line shows the average time at mass centre lowest point.

CONCLUSIONS

Springboard divers make adjustments during board depression to control the horizontal mass centre velocity at mass centre lowest point and make adjustments during board recoil to control the rotation potential at takeoff.

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