PRACTICAL USE OF AIRBORNE SIMULATION IN AN ACROBATIC SKILL

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Introduction
In order to become national or international top level gymnasts, athletes must perform flight elements on the horizontal bar. The tkatchev is at the present time, one of the most frequently performed release-regrasp skills which may be executed during the airborne phase with piked or stretched body form. The advice given by coaches to their gymnasts on the adjustment of the critical mechanical parameters are often based more on experience and intuition than on a predictive model. The aim of this paper was to objectively predict individual improvements of a release-regrasp tkatchev skill performed on the high bar without adequate mechanical requirements. It can be expected that intra-individual studies with individual biomechanical analysis and predictive simulation, could provide interesting information on the problem of improving a acrobatic skill.

Methods

Model.
The gymnast was considered as a planar eight-link kinematic chain. The anthropometric estimates of positions of segmental centers and body center of gravity (c.g.), segmental masses and moments of inertia, have been calculated using the tables of Dempster and Gaughran (1967).

Kinematic analysis.
A 2-D video analysis was carried out during training on a series of giant swings culminating in a release-regrasp tkatchev skill performed by a French national level male gymnast (20 years, 1.65m, 58kg). Five different trials executed with adducted legs and representative of different levels of performance, were selected by the coach and four judges in order to characterize the features of failed and successful executions and also to achieve realistic input parameters. The flight trajectory of the c.g. and the segmental rotations during the airborne phase were analyzed.

Simulation.
Two failed tkatchev (A, C) were accepted to be improved so that the regrasp of the bar would be executed. A successful piked tkatchev (E) was accepted to be improved so that the backward vault would be executed with a stretched body form. A two-dimensional computer simulation model of aerial movement based on the study of Yeadon & al. (1990), was developed using the principle of conservation of angular momentum in order to calculate the effect in changes of body configuration during the flight. Adequate flight trajectories and body configurations were calculated in order to correct or to improve the failed trials.

Results.

Release properties and modified flight curves.
The corrected release positions and velocities which permitted to obtain adequate flight path of the body center of gravity, were obtained if the release happened earlier in order to achieve lower horizontal velocity and vertical position and greater vertical velocity and horizontal position of the body's center of gravity.

Airborne segmental rotations.
The rotation movement of two supra-segments linked at the hip, one being the lower limb, the other including the torso, the head and the upper limb, was analyzed related to the c.g. reference frame, during the regrasp phase of the successful piked tkatchev. Figure 1 illustrates, using each second video-fields in this reference frame, the variation of the position of the two supra-segments delimited by the hand and the hip for the upper supra-segment and
by the hip and the foot for the lower limb. The connection between the hand and the bar during the regrasp phase is drawn by the dotted line. The orientation of the upper segment appeared to be nearly constant while the lower segment rotated with a large hip extension. This constant orientation which could be interpreted as a stabilization motion of the upper supra-segment during the regrasp phase, was retained as a hypothesized joint angle and was used in the simulation process as a controlled input while the mathematical process calculated the motion of the lower segment.

Simulations (figure 2).

In the case of the failed tkatchev (A), the simulation process indicated that the translation motion of the c.g. and the time of initiation of the hip extension and the shoulder flexion during the regrasp phase were the parameters which can be correct in order to execute the regrasp of the bar. These corrections suggested that the time of the release must be initiated 0.06s earlier and that the hip extension and the shoulder flexion must begin immediately after the gymnast leaves a position vertically over the bar. The improvement of the failed and the piked tkatchev (C, E) was obtained not only with an earlier release by 0.08s but also with modified joint motions. In the case of the failed tkatchev (C), the simulation process indicated that the stabilization motion of the upper limbs which was initiated when the gymnast was vertically over the bar and maintained during the regrasp phase, was a good strategy to succeed in catching the bar. Because of the conservation of the angular momentum during the airborne phase, upper limb stabilization was possible whether the hip extension acted earlier with larger amplitude. The results indicated also that the execution of the stretched body tkatchev required an earlier release of 0.02s and a maintained hip extension of 180° when the gymnast moved away 70° relative to the horizontal axis. The consecutive movement of the upper limbs must be a reduction of the shoulder flexion.

Discussion

The analysis of the translation motion of the c.g. suggested that an earlier initiation time of release is a major problem to solve by the gymnast in order to grasp the bar. The sensitivity of the adjustment of the release time confirmed that improvement in skill, requires biomechanical model and methods in order to provide the error corrections which cannot easily be determined by visual observation. The analysis of the segmental rotations suggested that the stabilization motion of the upper limbs could be a good strategy to improve failed tkatchev. This simulated motion is in agreement with observations made by neurophysiologists (Berthoz & Pozzo, 1994) who have shown that upper segmental rotations are minimized in the sagittal plane during aerial movement in order to keep the head stable relative to the environment. This upper segment stabilization would permit the vestibular system to be used as a stable platform for the navigational inertial system. This study showed that simple computer simulation using hypothetical data based upon real data, could be an effective tool for determination of error correction and administration of feedback during the training of gymnasts performing the release-regrasp skill without adequate technical requirements.

References

FIGURE 1: Rotation movements of the two supra-segments related to the body's center of gravity reference frame.

FIGURE 2: Computer-generated sequences (1 frame over 3) of the failed 1 tkatchev (A) and the simulated movement (B) the failed 2 tkatchev (C) and the simulated movement (D) the piked tkatchev (E) and the simulated movement (F).