HEAD STABILIZATION IN FORWARD TWISTING SOMERSAULTS

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INTRODUCTION

To date little research has been conducted in an attempt to understand how performers of complex acrobatic manoeuvres gather feedback regarding their position, orientation, and motion. It is apparent from studies in which acrobats have performed in darkness (Rezette, 1985) that the use of vision during flight assists the performance. However, it has also been found that in many acrobatic activities the rate of rotation is such that it is not possible to fix the gaze throughout the whole period of flight (Pulaski, 1981). Pulaski's data indicated that the ability to use visual information to assess one's position, orientation, and motion deteriorates with increasing head angular velocity and it becomes impossible to use visual information at angular velocities greater than 350 degrees/s. Stabilization of the head at particular times during the flight allows visual information to be used during the performance of advanced skills involving rapid rotations. Pozzo (1989) showed that in backward somersaults without twist the head was stabilized in the sagittal plane during the periods of takeoff and prelanding. There has been a paucity of research investigating head stabilization during complex manoeuvres that involve twisting motions.

Head stabilization during rotational activities may be a deliberate means of allowing the gaze to be fixed to use visual information or merely the consequence of a slowing of the rate of rotation of other body parts, particularly the trunk. Because slow rates of head angular motion may be simply due to slow rates of rate of rotation of the upper body rather than as a deliberate strategy to improve visual feedback, analysis of head motion should be conducted in conjunction with analysis of motion of the upper body.

The purpose of this study was to address the question of whether skilled,trampolinists stabilize the head during the performance of forward twisting somersaults.

METHOD

Two male and two female subjects participated in this study. Selection was based on their ability to perform forward twisting somersaults. One of these subjects was elite at international level. The remaining three subjects were elite at New Zealand national level. Prior to filming, subjects were marked with retro reflective markers so that the joint centres were clearly visible. The body landmarks were the vertex of the head, C7, both shoulders, elbows, wrists, knees, and ankles. Each subject performed five Rudis. These are forward somersaults with one and one half twists. Subjects were instructed to bounce to their usual bouncing height before commencing the skill. They were then 'called into the skill' by their coach. The trampolinists were filmed at 100 frames per second by two phase locked Photosonics 16mm cine cameras.

Each camera was positioned at a distance of 30m from the centre of the trampoline and 4m above the trampoline. Each camera was fitted with an Angenieux 12-120mm zoom lens that was adjusted so that the whole trampoline, the three dimensional calibration frame, and a space 5m above the trampoline bed and 1m below the trampoline bed were in view.

A direct linear transformation computer program (Marzan, 1975) was used to determine the three dimensional coordinates of the body landmarks. These were determined for the period corresponding to ten frames prior to last contact with the trampoline leading into the skill to ten frames after landing on the trampoline after completing the skill.

To determine the rate of rotation of the head the change in angle of the long axis of the head between successive frames was determined and differentiated with respect to time. The long axis of the head was defined as the line from the vertex to C7. Thus, the calculated rate of rotation included rotations due to flexion and extension of the head and lateral flexion and extension of the head. Rotations about the long axis of the head were not included due to their sensitivity to digitising error. The change in angle of the long axis between successive frames was given by the arc cosine of the dot product of the head unit vectors. The change in trunk long axis angle was determined in a similar manner. In this case the long axis was defined as the line from a point midway between the shoulders to the point midway between the hips.

To compare the rates of rotation, that is. the angular velocity of the head and trunk for each subject, means of the five trials of each subject and 95% confidence intervals of the true mean were determined. Because some trampolinists perform the skill more quickly than others and have less time in the air, the time axis was expressed in terms of percentiles of the period in the air (flight). This allowed comparisons between subjects in terms of their pattern of movement despite differences in the real flight time.

RESULTS

The figure shows angular velocity and 95% confidence intervals of the true mean for the flight phase of the internationally elite subject. The stick figures show the trampolinist's position at 0%, 20%, 40%, 60%, 80%. and 100% of the period of flight.

The relatively narrow 95% confidence intervals of the true mean for angular velocity of the head and trunk indicated that subjects were consistent in their movement patterns across trials.

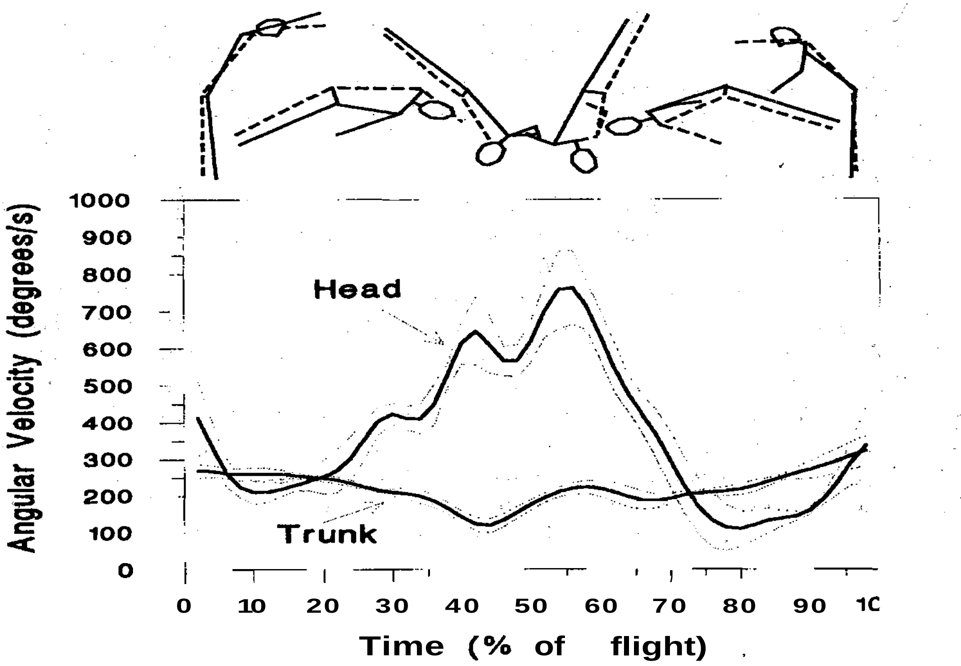

Figure. Angular velocity and 95% confidence intervals of the true mean for the most elite subject as functions of time normalised to percentiles of the fight phase.

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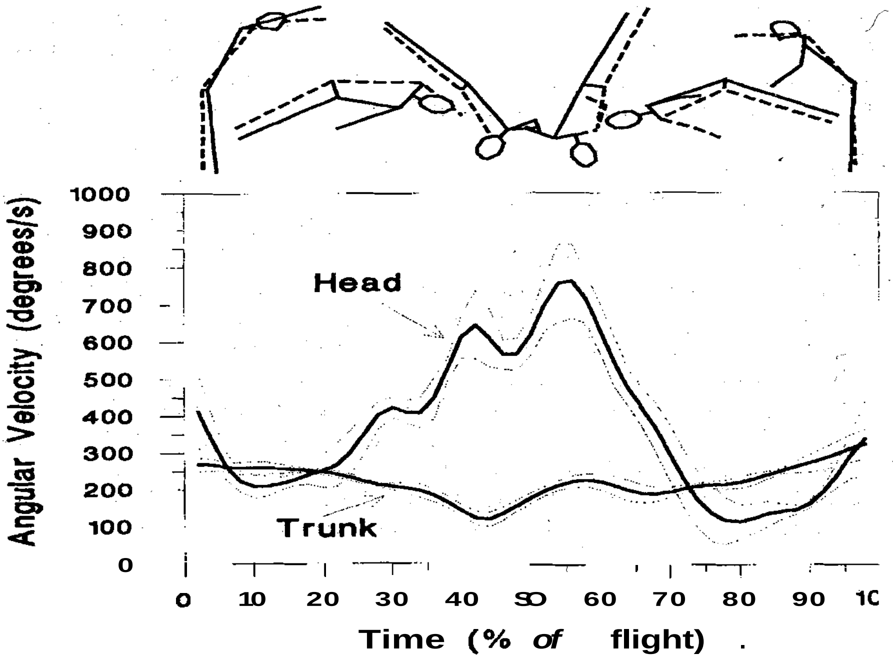

Figure. Angular velocity and 95% confidence intervals of the true mean for the most elite subject as functions of time normalised to percentiles of the flight phase.

The angular velocity of the head and trunk were significantly different at percentiles in which the 95% confidence bounds of the head and trunk were disjoint. The angular velocity of the head was very different from that of the trunk. This means that the head was moving somewhat independently and cannnot be regarded as merely an extension of the trunk segment. The generally greater angular velocities of the head than the trunk were due to considerable movement of the head with respect to the trunk. Qualitative assessment of the video recordings and inspection of the stick figures showed that the head was flexed and extended and laterally flexed and extended vigorously during the performance of the Rudi.

Peak angular velocity of the head ranged from approximately 450 degreesls to approximately 900 degreesls and was variable among subjects. However, in the case of all subjects head angular velocity was near or above 350 degreesls for periods totalling more than 50% of flight. This means that for most of the flight subjects were unable to use visual information to assess their orientation.

All subjects had two distinct periods of head stabilization. The first occurred during the first half of flight at times which were consistent within subjects but variable among subjects. Minimum head angular velocity during this first period of stabilization ranged from approximately 100 degreesls to 250 degreesls. The most elite subject achieved the first minimum head angular velocity at approximately 10% of the flight phase. The other subjects had minimum head angular velocities at approximately 20%, 34% and 42% respectively. At the times corresponding to the first minimum head angular velocity the angular velocity of the head was less than that of the trunk for three of the four subjects. However, the difference was small and statistically significant for only the elite subject shown, and then only for a very short period.

The second period of head stabilization occurred consistently among subjects between 70% and 90% of the flight phase. This corresponded to the period in which the trampolinists had completed hip flexion to stop the twist and prepare for landing. Mean head angular velocity during this time ranged from 100 degreesls to 250 degreesls and was significantly less than the angular velocity of the trunk ($p<.05$).

DISCUSSION

It was apparent that the trampolinists in this study did not elect to move the head in the same way as the trunk. That is, the head moved somewhat independently from the trunk and, for most of the flight period, had a much greater rate of rotation. This was despite the fact that the trunk angular velocities during the performance of Rudis on the trampoline were generally below the 350 degreesls 'threshold' for using visual information. The large angular velocities of the head indicated that for most of the flight the trampolinist performed the somersault and twist rotations without visual feedback.

Possible reasons why skilled trampolinists are prepared to sacrifice continuous visual feedback in return for independent head movement include: 1. The movements of the head either supplement, or are the natural response to, the trampolinist's efforts to establish and control twist rotation. 2. It may be very important to have a period in which the head rotation is slower than that of the trunk so that the quality of the visual feedback is enhanced. Having a period of fast angular motion with respect to the trunk allows the trampolinist to have a period of slow head rotation.

The timing of the second (prelanding) period of head stabilization was similar to that in the backward somersaults without twist reported by Pozzo (1989). In that study, the head was stabilized prior .to landing to below 120 degreesls for a period of approximately .15s. In this study all subjects stabilized the head to angular velocities of between 100 degrees/s and 250 degrees/s. These small angular velocities were maintained for periods ranging from .15 to .3s. Based on the study by Pulaski (1981) this was slow enough to allow the trampolinists to clearly determine their position, orientation and motion. Conversely, the trunk angular velocities were increasing during the prelanding period and were at levels close to the 350 degree/s threshold. If the head had been allowed to move as a rigid extension of the trunk it is unlikely that the trampolinists would have had visual feedback of sufficient quality to accurately assess their position, orientation, and motion when preparing to land.

CONCLUSION

It was concluded that elite trampolinists stabilize the head to use visual information when preparing to land.

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