DYNAMICS OF SELECTED TOWER DIVE TAKE-OFFS

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The mechanics of platform diving, unlike those of springboard diving, have not been investigated to any great degree. Unlike the springboard, the platform provides no elastic energy to enhance the diver's momentum. At take-off the diver must achieve sufficient linear momentum to ensure the necessary height and distance to travel safely away from the platform and sufficient angular momentum to complete the required number of rotations about the transverse axis. Ground reaction forces (GRF) developed during contact with the diving platform and the body position of the diver at take-off define the magnitude and direction of the diver's momentum.

The nature of rotations in springboard diving has been reported by many researchers and coaches (Fairbanks, 1963; Batterman, 1968; Stroup and Bushnell, 1969). In most cases, it was felt that body lean at take-off determined the number of rotations in the dive. Golden (1984) found that body lean at take-off increases according to the number of rotations being performed. Miller (1984) found that the height obtained in springboard diving was predominantly due to the action of the lower extremities as they accelerated the trunk upwards.

Although a number of investigators have studied springboard diving, there is an apparent lack of information pertaining to platform diving. Furthermore, it seemes necessary to study the nature of increased rotations in platform diving. The purpose of this study was, therefore, to investigate the kinetics and kinematics of platform dive take-offs in which a rotation or multiple rotations occurred.

METHODS

Three young, healthy, collegiate divers served as subjects in this study after signing informed consent forms in accordance with University policy. The subjects were highly skilled (1 national, 1 international and 1 olympic) platform divers. The subjects ranged in height from 1.68 to 1.78 (X = 1.74m) and in weight from 62.6 kg to 74.4 kg (X = 69.1 kg).

The experimental set-up consisted of an A.M.T.I. force plate mounted in a specially constructed runway on a 5 m diving tower. The runway was the same height as the force plate to provide a level surface for the subjects. The force plate was interfaced to a NorthStar microcomputer via an Analogic S-100, 12-bit, analog to digital converter. Data sampling was accomplished at 1000 Hz.

In addition, a 16 mm LoCam camera was positioned normal to the movement plane at a height of 1 m above and 1 m in front of the diving tower take-off area. The focal point of the lens was positioned 25 m from the movement plane.

A 100 Hz pulsed signal applied to an internal LED timing light enabled the framing rate of 80 fps to be accurately verified. The camera shutter was set at 120/360 degrees resulting in an exposure time of 1/240 s.

Each subject was required to perform two categories of dives, forward and back, in which rotations were added. In the forward dives, the subjects were required to complete dives with 1/2, 1 1/2, and 2 1/2 rotations, in the pike position. In the back dives, they completed piked dives with 1/2, 1 and 2 rotations. Five trials of each dive and rotation category were completed. The final three dives of each group were filmed. Each dive was evaluated by a national calibre coach as to the success of the dive. One successful dive for each diver in each group was chosen for analysis.

Subject's were given as much time as they required to warm-up and practice the criterion dives. They were also given as much time as required between dives so that fatigue would not be a factor. For the forward dives, the camera was started as the subject began the next to last approach step and the force platform was triggered when a force of 1 N was exceeded. For the back dives, (which had a less distinct beginning), the camera and the force paltform were started during a verbal countdown by the investigator and prior to the initiation of the dive.

Prior to the analysis the force-time data were normalized by dividing by the subject's body weight. The data analysis consisted of the evaluation of the maximum vertical (Fz) and antero-posterior (Fy) force components and the maximum moment (Mx) about the medio-lateral axis.

Data reduction from the high speed film was accomplished using a Vanguard Motion Analyzer in conjunction with a Numonics 1224 digitizer interfaced to an Apple II+ microcomputer. For the forward dives, 5 frames prior to force plate contact until the peak of the diver's trajectory were digitized. For the back dives, digitizing began when the diver began unweighting and continued until the peak of the trajectory was reached. Coordinates of background references and eight body segment endpoints were identified and digitized for the analysis. A computer program was used to compute the angle of inclination to the right horizontal of the trunk, thigh and shank. The data were then smoothed using a low-pass digital filter with a cut-off level of 6 Hz in order to minimize measurement error. A cubic spline curve fitting technique was used to generate the angular velocities of the trunk, thigh and shank. Values for the angles and angular velocities of these segments at take-off were then defined.

RESULTS

Ground Reaction Force Data

The values for the kinetic variables for the forward and back dives are presented in Figures 1 and 2. While the vertical and antero-posterior force components levels varied from subject to subject, there was little change within subjects as rotations were added. There appeared to be a greater differential between rotations within subjects in the forward dives than in the back dives. However, no trends in any of the kinetic parameters were discernable.

Film Data

The angle of inclination of the trunk and the instantanous angular velocity of the trunk at take-off linearly changed as the number of rotations increased in both forward and back dives. In the forward dives, the trunk angle decreased 13 to 26° as the first rotation was added and 20 to 25° as the second was added. The back dives had similar changes in the trunk angle changing 13 to 22° as the first 1/2 rotation was added and 14 to 19° as the second was added. Graphical representations of the trunk angles for both forward and back dives are presented in Figures 3a and 4a. The instantaneous angular velocity of the trunk at take-off increased greatly as rotations were added to both categories of dives (Figures 5a and 6a).

Increasing the required number of rotations appeared to have little effect upon the thigh angle and its angular velocity at take-off (Figures 3b, 4b, 5b, 6b). However, the shank angle, while not substantionally changing in the forward dives (Figure 3c) increased approximately 10° for all subjects as rotations were added to the back dives (Figure 4c). The instantaneous angular velocity of the shank during back dives noticeably decreased in all subjects as rotations were added (Figure 6c).

DISCUSSION

Platform divers must, when initiating a dive with single or multiple rotations, generate a sufficient ground reacton force and positon their body at the instant of take-off such that an eccentric force is produced. It is this eccentric force that causes the rotation about the transverse axis. An eccentric force may be increased, thus causing a large total body angular velocity, by either increasing the ground reaction force, positioning the total body center of gravity further away from the force application or by doing both of the aforementioned. It was the purpose of this paper to identify kinetic and kinematic alterations that divers exhibited as a result of increasing the required number of rotations in forward and back dives.

Clearly, from the ground reaction force data, it appeared that the subjects were generating a maximum reaction force on each dive. Since there was little change in the maxima of the two force components and in the moment about the medio-lateral axis, it must be assumed that the divers were accelerating their total body center of gravity to the same extent regardless of the number of rotations in the dive.

It appeared that the divers generated sufficient angular momentum to accomplish the required number of rotations by changing the inclination of the trunk at the instant of take-off. This is in accordance with several other authors who investigated the nature of rotations on springboard diving (Golden, 1984; Miller, 1984). Since the trunk has a large mass relative to the lower extremities, by inclining it, the center of gravity is placed further from the force application. Figures 7a and 7b illustrate one subject in the take-off position in both categories of dives. In additon, the increase in angular velocity of the trunk across rotations aids greatly in completing the required dive.

It does not appear that the orientation of the thigh or shank aids in positioning the trunk in forward dives. However, in the back dives, all three divers

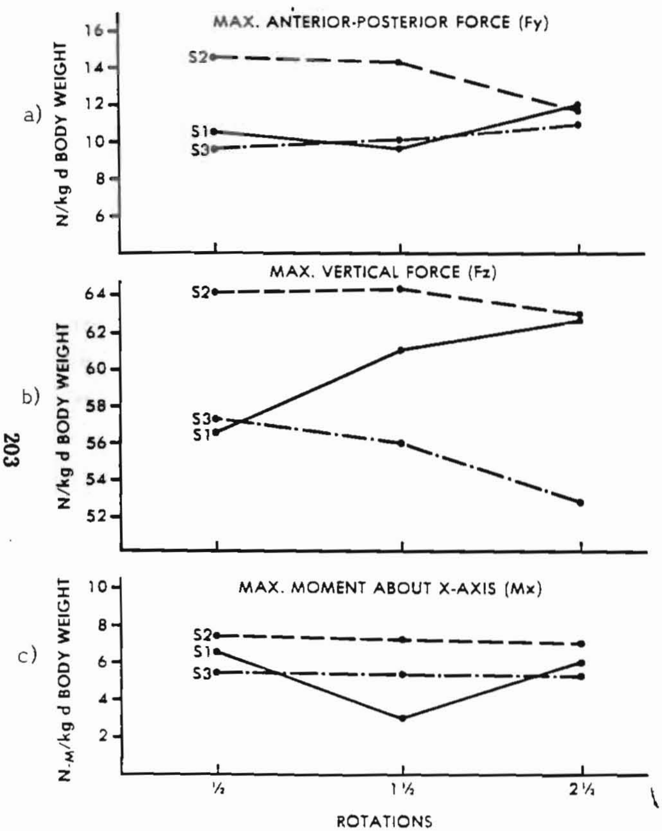

Figure 1. Ground reaction force variables for forward dives.

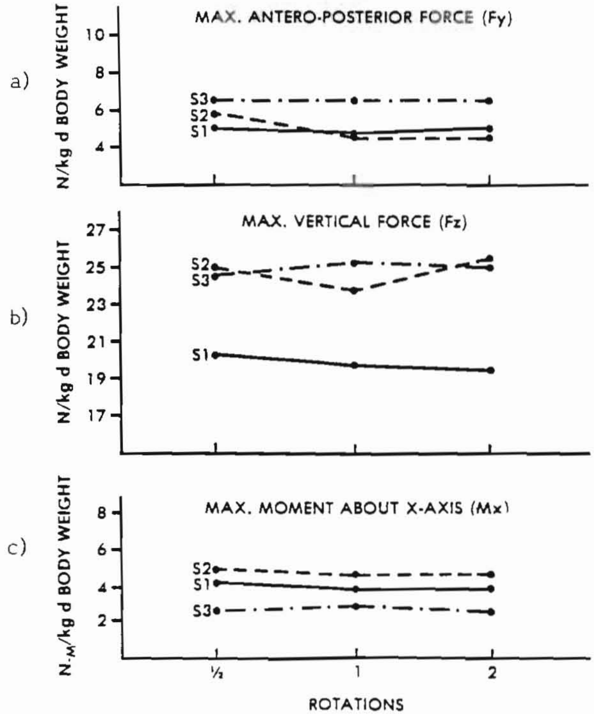

Figure 2. Ground reaction force variables for back dive.

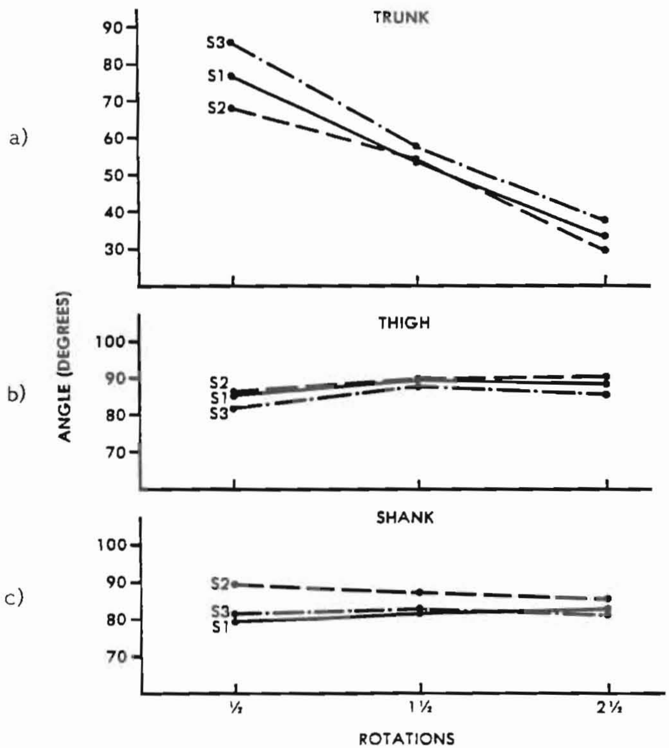

Figure 3. Body segment angles of inclination at take-off for forward dives.

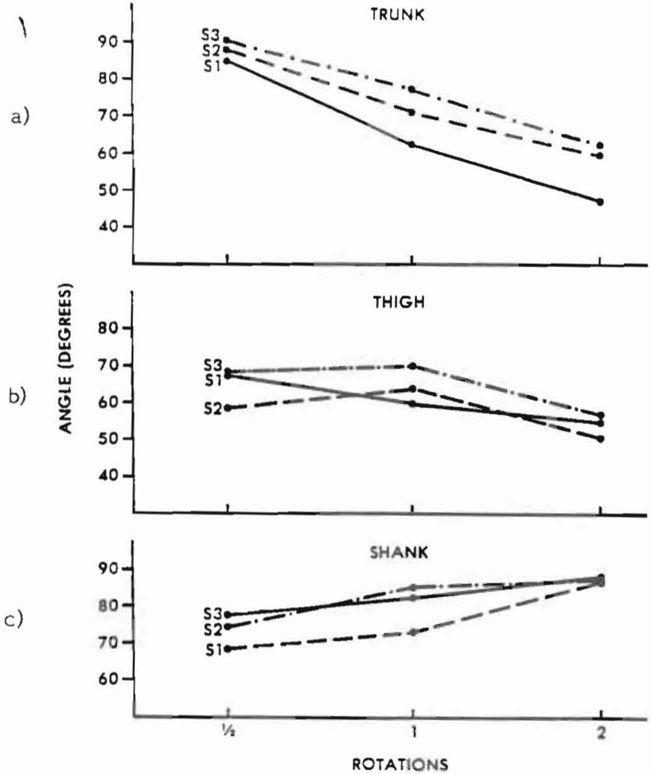

Figure 4. Body segment angles of inclination at take-off for back dives.

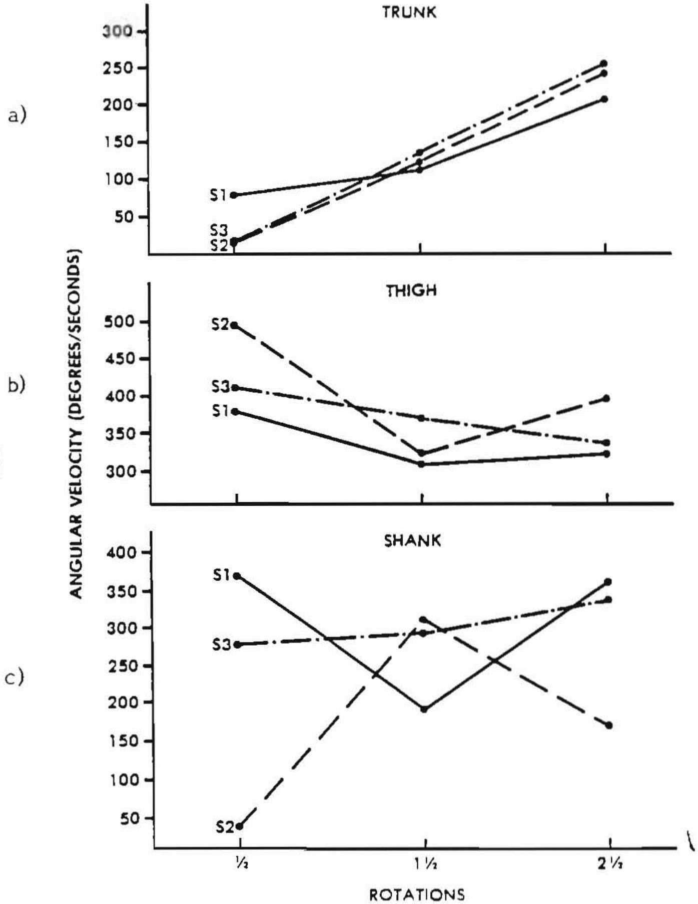

Figure 5. Instantaneous segmental angular velocities at take-off for forward dives.

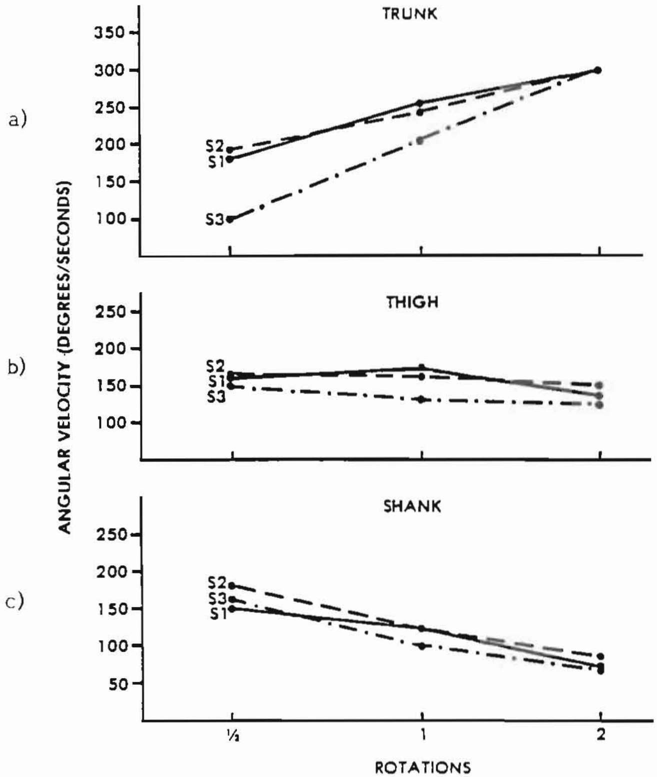

Figure 6. Instantaneous segmental angular velocities at take-off for back dives

increased the angle of the shank as rotations were added. This movement had the effect of contributing to the body lean in the direction of the rotation.

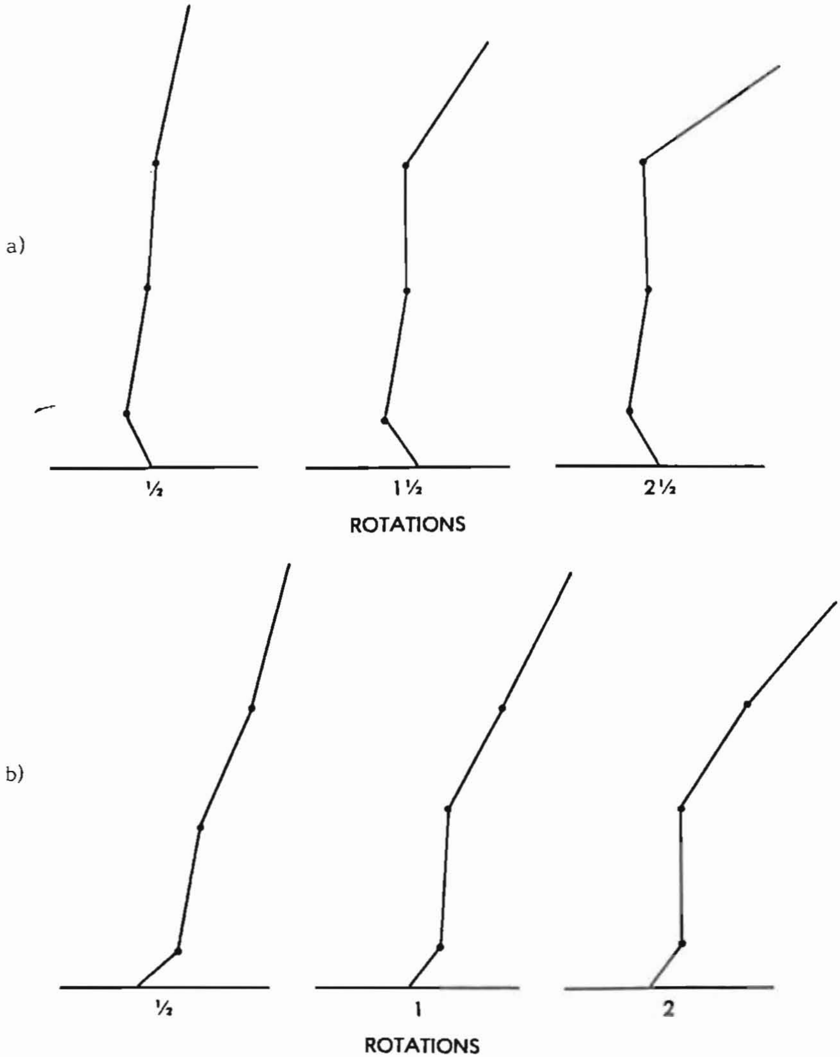

Figure 7. Segment orientations at take-off for 1 subject during a) forward dives b) back dives.

CONCLUSIONS

The results of this investigation indicated that platform divers impart maximum GRF at take-off. The magnitude of the reaction forces at take-off were found to be invariant as the number of rotations in the dives were increased. The divers increased their angular momentum at take-off by decreasing the trunk angle to the horizontal and concomitantly increasing the angular velocity of the large trunk mass.

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