COMPARISON OF IMPACT FORCES EXPERIENCED BY GYMNASTS PERFORMING FORWARD AND BACKWARD LANDINGS

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A natural consequence of gymnastic techniques is landing From a skill in tumbling routines. Landings cause substantial impact and potentially traumatic ground reaction forces to the spine and lower extremities. High impact forces can lead to immediate or to long-term injury from repetitive microtrauma (Caine & Lindner, 1985). Among others. Nigg. Denoth. and Neukomm (1981) and McNitt-Gray (1991) have reported vertical ground reaction forces. Findings ranged from 0.5 to 11.0 body weights (BW) in landing from various activities. Panzer, Wood, Bates, and Mason (1988) reported individual leg ground reaction force values during the landing phase of double back somersaults averaged 9.3 to 10.5 BW. Characteristics of landing strategies selected by female gymnasts during realistic gymnastics have received little study. Because a potential injury situation exists, the external forces should be measured and evaluated (Nigg, Denoth. & Neukomm, 1981). In addition, movement patterns are composed of invariant and variant features. Invariances could indicate technique strategies for movements.

The purpose of this study was to describe impact forces and performance characteristics experienced by female gymnasts performing selected forward and backward rotational landings. Specifically, the problem of this study was to identify variances and invariances in time of contact. peak impact forces, percentage of time to peak force, and mean absolute range of motion in the sagittal plane for the thigh, shank, and foot.

METHODOLOGY

Subjects (N=8) consisted of volunteer female Division II collegiate gymnasts (mean age = 20 ± 1.3 yrs; mean mass = 56.2 ± 7.8 kg; mean height = 160.0 ± 4.0 cm). Subjects were informed of all procedures and signed consent forms.

Landing kinematic and kinetic characteristics were evaluated using a force platform and high-speed film. A Kistler Model 9261A piezoelectric force platform mounted flush with the floor was used to collect the vertical force data. Sampling rate was 600 Hz for each of eight channels. Subjects were filmed with a 16 mm high-speed

LOCAM Model SI camera operating at a nominal speed of 100 fps.

The four skills used in the study were (a) round-off into a forward rebound (RFB), (b) front handspring into a front dive roll (FFD), (c) round-off into a backward rebound (RBR), and (d) round-off back handspring back tuck somersault (RBS). RFB and FFD represented forward rebounding movements, and RBR and RBS represented backward rebounding movements. Order of skill performance was randomly selected.

A gymnastic mat was placed over the force platform to permit the subjects to attenuate some force. Location of the forceplate was marked on the mat surface. The camera was placed on a tripod, leveled approximately 1.15 m above the ground, and placed approximately 6.4 m from the forceplate area. Anthropometric measures were taken, and the subject warmed-up. Skin markers were placed bilaterally on each greater trochanter, femoral condyle, tibial condyle, tibial tuberosity, calcaneous, medial and lateral malleoli, fifth metatarsal head, ASIS, sacrum, and anterior mid-pelvis. The film record included pre-contact with the force platform through rebound. Impact force sampling was initiated upon contact with the platform surface. A successful trial was one where the subject landed on the forceplate. Subjects continued performing until they performed a successful trial of each skill.

An internal timing light mechanism and a clock placed in the view of the camera were used to determine the absolute film rate for each trial. The forceplate and film record were synchronized at the first indication of load on the forceplate. The film was digitized for three frames before floor contact through three frames after liftoff. Coordinate data were filtered with a Butterworth digital recursive filter set at a rate proportional to the sampling. Ground reaction forces were normalized by body weight and expressed in Gs. The Hanavan (1964) model was used to determine segmental centers of mass. Kinematic data were analyzed using the Kansas State University Film Analysis System (Noble, Zollman & Yu, 1988).

RESULTS AND DISCUSSION

The results are presented in four figures. In each figure the first two columns demonstrate the forward rebound skills; the last two columns demonstrate the backward rebound skills.

Figure 1 shows the mean impact/rebound contact times. Mean contact times were all less than 0.17 s except the FFD (0.29 ± 0.15 s). The mean contact time for the RFB was 0.1[illegible] ± 0.02 s; for the RBR was 0.13 ± 0.02 s and for the RBS was 0.14 ± 0.02 s. The FFD not only demonstrated the longest contact time, but also the greatest variability. Mean impact/rebound contact times were slightly longer for forward than for backward landings.

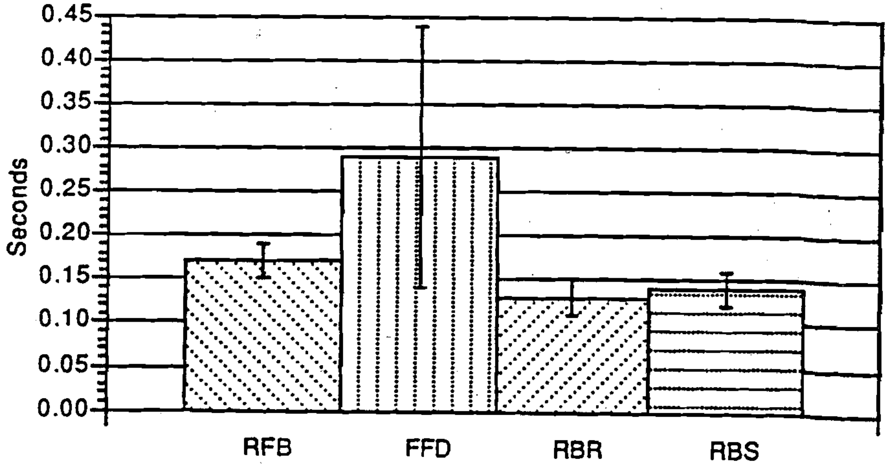

Figure 1. Mean impact/rebound contact time for each skill.

Mean percentages of time to peak forces relative to total time of impact are shown in Figure 2. Mean percentages of time to peak forces were as follows: RFB = 16.0 ± 14.6%; FFD = 13.1 ± 8.4%; RBR = 36.8 ± 13.3%; and RBS = 30.1 ± 10.9%. Time to peak force occurred sooner in the forward rebound skills than in the backward rebound skills. This finding may relate to the more vertical angle of trajectory in the forward rebound skills.

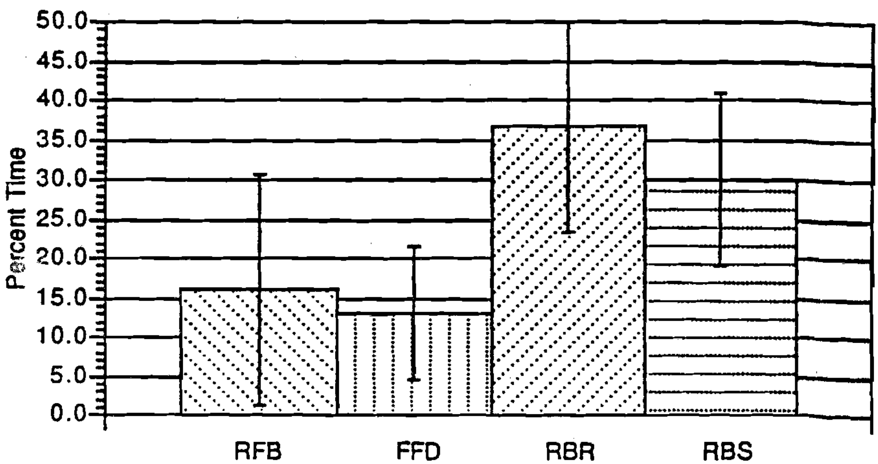

Figure 2. Mean percentage of time to peak force relative to time of impact for each skill.

Peak impact force means (see Figure 3) were as follows: RFB = 6.21 ± 0.61 Gs; FFD = 6.89 ± 2.60 Gs; RBR = 6.94 ± 0.94 Gs; and RBS = 6.94 ± 1.17 Gs. Peak impact forces for the two-footed landings were approximately the same in all four skills. Greatest variability occurred in the FFD.

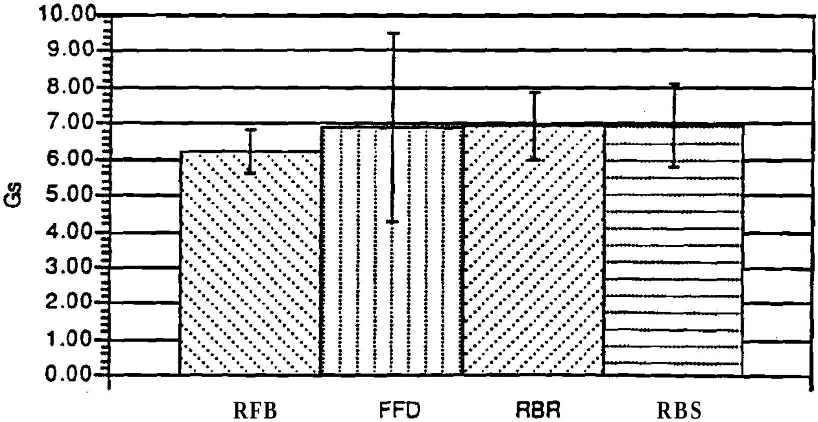

Figure 3. Mean peak impact force for each skill.

Impact force data obtained in this study were consistent with those reported by other investigators cited previously. Ground reaction forces experienced by gymnasts as used in this study.

Figure 4 depicts the mean absolute ranges of motion (ROMs), measured from right horizontal, in the sagittal plane for the thigh, shank, and foot for each skill. Mean ROMs for the thigh were as follows: RFB = 17.85 ± 8.22; FFD = 46.11 ± 17.26; RBR = 18.71 ± 8.07; and RBS = 16.04 ± 5.60. Mean ROMs for the shank and for the foot respectively were as follows: RFB = 32.52 ± 8.65; FFD = 29.83 ± 8.87; RBR = 35.16 ± 5.53; and RBS = 25.85 ± 6.42, and RFB = 33.24 ± 8.84; FFD = 42.24 ± 8.11; RBR = 28.64 ± 7.37; and RBS = 35.58 ± 7.72. ROM for the thigh was similar for all skills except for the large ROM demonstrated in the FFD. Shank ROM was reasonably consistent across all skills. Foot ROM was also consistent across all skills with the largest range occurring in the FFD.

The FFD reflected more variability than the other skills. In the FFD, the gymnasts spent more time in contact and experienced larger ROMs. Larger ROMs may be associated with the longer contact times.

CONCLUSION

In conclusion, (a) mean peak forces occurred sooner for forward than for backward landings; (b) mean impact/rebound contact times were slightly longer for forward than for backward landings; (c) minimal differences were found among the

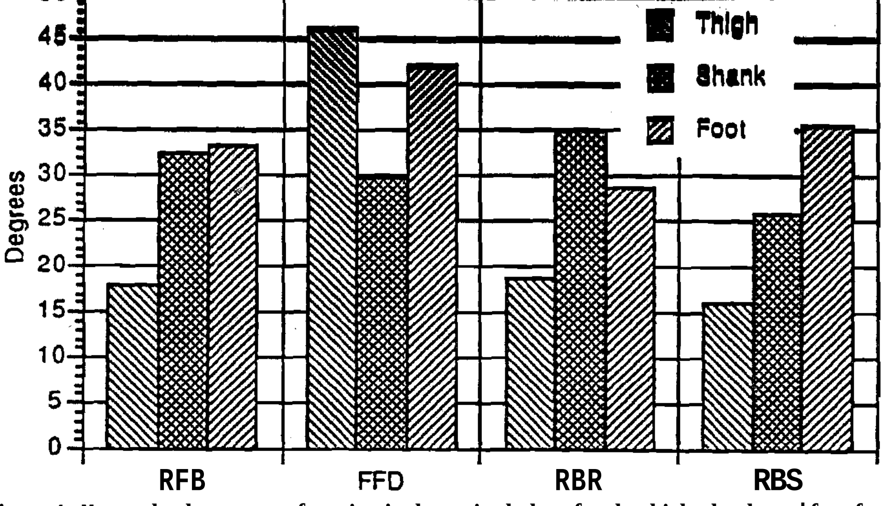

Figure 4. Mean absolute range of motion in the sagittal plane for the thigh, shank, and foot for each skill.

impact forces for forward and backward landings; and (d) minimal differences in absolute ROM for each segment were found, except for the larger thigh and foot ROM in the FFD. Future studies need larger sample sizes and three-dimensional cinematography to permit a more accurate analysis. Longitudinal studies are needed to determine a causal relationship between impact and injury.

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