LANDING CHARACTERISTICS OF DOUBLE BACK SOMERSAULTS ON THE FLOOR

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This study examined the biomechanical characteristics of double back somersault landings at the beginning, during, and end of floor exercises performed by ten male gymnasts at the World Gymnastic Championships 1994 in Brisbane. Kinematic data was captured at 50 Hz through 2-D videorecordings during competitions. Analysis of the data revealed, that the displacement from maximum CM height before the landing (2.16 ± 0.15 m) to CM height at landing (0.87 ± 0.15 m) was 1.29 m. The minimum CM height was 0.67 ± 0.13 m. The vertical and horizontal impact velocities were -4.97 ± 0.32 and 2.11 ± 0.36 m/s. The mean knee angles at landing (touch-down) were 153 ± 6° and at minimum CM height were 98 ± 19°, a 55° knee angle displacement during landing over 0.096 ± 0.03 sec duration. The mean angles between CM to toe and the horizontal at landing (touch-down) were 69 ± 22'. The mean angles between trunk and the horizontal and thigh to the horizontal at landing (touch-down) were 21 ± 13' and 92 ± 9°, respectively. Selected parameters of the results presented in this study may be used to form a representative biomechanical profile for floor landings.

Introduction

The data in the biomechanical literature on landings in gymnastics during competition is limited. During competition gymnasts must comply with specific performance guidelines that require them to bring the velocity of the body to zero with a single placement of the feet (Brueggemann, 1994, McNitt-Gray et al., 1993). Landings performed by elite gymnasts during major competitions represent one of the more extreme conditions under which the body must provide adequate force absorption. As a result, landings following advanced skills occur at high velocities and subsequently result in high impact forces. Gymnasts must also meet the specific landing performance requirements imposed by the rules of the sport. The current FIG code of points (Zschocke, 1993) is the official judge's manual for the evaluation of gymnasts' performances and specifies landing errors on each of the events. Situations such as environment (surface) and skill (performance) relate to landing ability (Brueggemann, 1990). The relative contributions of the body segments, soft tissue and bones, vary depending on localized fatigue, task constraints, or fitness of the muscles responsible for the eccentric muscle action controlling the joint flexion (McNitt-Gray et al., 1993).

(Adrian and Cooper 1989) state that when a body falls, its vertical force, kinetic energy, and momentum are directly related to the distance through which it falls, due to the exponential effect of gravity. (Alp and Brueggemann 1993) measured the pressure distribution and the acceleration of the foot and shank during landing after gymnastic dismounts. Maximum foot and tibia peak acceleration was registered at approximately 40g. (McNitt-Gray et al. 1993) examined the reaction forces at the mat/floor interface.

Concerning landings after drop jumps from different heights, ranging from 3.9 to 11 BW. Significant differences, $p < .05$, were reported in peak vertical force, time to peak vertical force, landing phase time, and lower extremity kinematics across different drop heights (McNitt-Gray, 1991; McNitt-Gray et al., 1993). There were no significant differences to vertical impact peak between soft and stiff mats (McNitt-Gray et al., 1993). On the other hand, lower extremity kinematics showed significant difference between mats with varying composition. These results indicate that changes in drop height and mat composition may lead to changes in landing strategies for female gymnasts.

Subjects

Landing performances of ten male gymnasts at the World Gymnastic Championships 1994, Brisbane, participating in "qualification competitions", and "individual all round competition" (competition II), were chosen as subjects.

Equipment and Data Capture

Landing performances on floor were filmed during competitions with two genlocked PAL video cameras from the catwalks above the floor of the Brisbane Entertainment Centre. The competition area was lit by high power television lighting. All signals were cabled to a control room for EBU time-coding and recording. During subsequent digitization, time synchronization of paired camera views was based on the on-screen time code (field-accurate). To obtain the three-dimensional data from dual two-dimensional views the PEAK calibration frame was recorded at various intervals during each filming day. This occurred usually before and after each session. Three calibration frame positions were used on the floor: central floor position, between centre of floor and corner, and corner of floor.

Data Analysis

Analysis of the tapes were performed using a Peak-5 video data acquisition system. The two dimensional coordinates of a 21-point body model were manually digitized (effective half-pixel resolution 1024x1024). The coordinates were filtered with a Butterworth low pass digital filter (Winter, 1990), with an 'optimal' cut-off frequency determined independently for the X and Y coordinates of each body point. This was done from the residuals by the Jackson 'knee' method (Jackson, 1973), with the 'prescribed limit' set to 0.1. Total body centre of mass (TBCM) position was determined based on estimated segment centre of mass positions and proportions of total body mass, according to (Dempster 1955).

The two 2-D views of the calibration frame were used to construct a DLT (Abdel-Aziz & Karara, 1971), which was then used to calculate the 3-D coordinates of the gymnasts from the digitized 2-D coordinates. Digitisation generated positional data which when combined with temporal data generated kinematic parameters on the three axes as well as resultant (Miller & Nelson, 1973).

Results and Discussion

One of the most frequently used components of a floor exercise are the landings which can occur anywhere during the exercise. Analysis of the data revealed, that the displacement from maximum CM height before the landing (2.16 ± 0.15 m) to CM height at landing (0.87 ± 0.15 m) was 1.29 m. The vertical and horizontal impact velocities were -4.97 ± 0.32 and 2.11 ± 0.36 m/s. The mean knee angles at landing (touch-down) were 153 ± 6° and at minimum CM height were 98 ± 19°, a 55° knee angle during landing over 0.10 seconds. The videorecordings of the individual landing performances were carefully reviewed to qualitatively investigate the completion of the second salto of the double back somersault before the landing. The better performances showed a reasonable extension of the body or a kick out before the landing, and the landing was actively anticipated through proper feet placement. Poor performances resulted in a slow second salto extending the hip and knee joints hurriedly into the landing surface. The mean angles between CM to toe and the horizontal at landing (touch-down) were 69 ± 22". The mean angles between trunk and the horizontal and thigh to the horizontal at landing (touch-down) were 21 ± 13, and 92 ± 9°, respectively.

Parameters	Mean	sd
Max. CM height during dismount (somersault) flight (m)	2.16	0.15
CM height at touch-down (m)	0.87	0.15
CM height at minimum (m)	0.67	0.13
CM vertical velocity at impact (m/s)	-4.97	0.32
CM horizontal vel. at impact (m/s)	2.11	0.36
Duration from max. CM height to touch-down (sec)	0.44	x
Duration of CM at touch-down to minimum (sec)	0.096	0.03
Angle CM to ground contact and the horiz. at touch-down (deg)	69	22
Knee angle at touch-down (deg)	153	6
Minimum (deg)	98	19
Trunk to horizontal touch-down (deg)	21	13
Minimum (deg)	22	22
Thigh to horizontal touch-down (deg)	92	9
Minimum (deg)	56	14

Table 1. Means and Standard Deviations of Selected Landing Parameters for the Floor Landing Performances.

Double back somersaults, which have linear and angular momentum before take-off, are very difficult to control during landings. Small minimum hip angles (109") and small minimum knee angles were recorded (98'). This result suggests that the gymnasts adjust to the landing impact by absorbing the landing forces over a long period of time. The increase in landing phase time due to maximum CM height before the landing observed is consistent with the trend observed by McNitt-Gray (1991). For the technically well executed double back somersaults, the extended position of the joints at touch-down

provided the subject with the option of using a large range of joint motion during the landing phase. This may create a large safety margin, particularly, if the subjects need to modify their strategy during the landing. For example, if the hip joint is flexed prior to touchdown, as in landing a double back somersault lacking sufficient rotation, less hip joint motion is available during the landing phase. If insufficient hip range motion is available, the knee joint is expected to play a greater role. The flexible landing surface makes it an increased challenge and subsequently more difficult for the gymnasts to "stick" the landing. Therefore, in order to minimize the stress placed on the musculo-skeletal system during landings, the gymnast must effectively dissipate the large forces encountered during the landing phase. Examination of the video recordings indicate that landing techniques employed by the gymnasts differ within the group.
This research project, which was conducted under real conditions, may provide thoughts for modification of competition landings that provides safer and more controlled landings.

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