TAKE-OFF CHARACTERISTICS OF DOUBLE BACK SOMERSAULTS ON THE FLOOR

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Backward take-offs are one of the most important and frequently used components of a floor routine in artistic gymnastics and can occur at any point of a routine. The purpose of the study was to investigate the biomechanical characteristics of dynamic take-offs in double backward somersaults performed by ten male and eight female gymnasts on the floor at the World Gymnastics Championships in Brisbane, 1994. Data was captured at 50 Hz by two video cameras which permitted the calculation of 3D kinematic data. Analysis of the data for both male and female gymnasts revealed, that the most important performance factor determining somersault height was the vertical velocity of the CM, at 4.2 m/s for males and 3.54 m/s for females at take-off. The horizontal velocity at touch-down was 4.32 and 4.05 m/s and decreased to 3.21 and 2.30 m/s at take-off and the mean take-off period was 130 and 120 ms, respectively for males and females. The touch-down and take-off angles of the CM to ground contact and the horizontal were 64 ± 6, and 88 ± 3.0' for males, and 69 ± 4 and 87 ± 5" for females.

Introduction

The most difficult acrobatic movements on floor depend upon the efficient execution of the transition skills, the round-off and flic-flac, acting as accelerators prior to take-off. The backward take-off initiates the linear and rotational impulses for multiple somersaults with various body positions. The aim of the take-off for double somersaults in the backward direction on floor is the optimization of take-off velocities by attaining a large amount of kinetic energy necessary to achieve a large magnitude of angular momentum. By far the most comprehensive studies on backward take-offs on Floor have been provided by (Brueggemann 1983, 1987 and 1994), (Knoll and Krug 1989), and (Hwang et al. 1990). One of the purposes of Brueggemann's investigations was to determine the contributions of the arms, the trunk and the legs to total angular and linear momentum of the body. Brueggemann also employed force platforms to record ground reaction forces (GRF) during the support phase (touch-down to take-off). The legs and trunk were responsible for the majority of the impulse exerted against the ground during take-off. The contribution of the legs, which is approximately twice that of the trunk, is almost entirely due to their large mass. Therefore the accurate positioning of the legs at touch-down is of considerable importance in order to control the angular velocity of the body.
(Knoll and Krug 1989) reported results from selected acrobatic series performed by male and female gymnasts during the gymnastics world championships in Stuttgart 1989. They concluded, that the most important factors at take-off for a successful somersault were jumping height and angular momentum. In all cases the legs played the dominant role in contributing to the total angular momentum during take-off.
(Newton et al. 1993) reported on selected biomechanical data of the triple back somersault on a single acrobat, gathered as part of an on going study in automated 3-D analysis. Their findings showed a 29% increase in vertical velocity at take-off over that reported for double

back somersaults, giving a 57% increase in height reached by the centre of gravity. The vertical take-off velocity of 5.8 mls was due to the conversion of the horizontal touch-down velocity of 5.81 mls and the take-off angle of 89".

Subjects

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

Equipment and Data Capture

Take-offs on floor were filmed during competitions with 2 PAL video cameras with 11500th second shutter speed from the catwalks above the floor of the Brisbane Entertainment Centre. The competition area was lit by high power television lighting. Performances were filmed in 3-D, requiring two cameras genlocked for time synchronization. The camera set was genlocked independently using AV-36 genlock, and all signals were cabled to a central control room, where the PAL VCR was located, and EBU time-coding and recording was done. During subsequent digitization, time synchronization of paired camera views was based primarily on the on-screen time code (field-accurate). However, a back-up system (notebook computer) was also used: a digital-to-analog convertor was triggered in software to send a pulse to an Event Synchronisation Unit - ESU (Peak Performance Technologies), which simultaneously displayed a white block on all video signals (approximately every second).
To obtain the three-dimensional data from two-dimensional views a PEAK calibration frame was recorded at various intervals during each filming day. This usually occurred before and after each session. This yields a calibrated object space of 2.05m x 2.05m x 1.3m. The size of each cameras field of view, necessitated the placement of the calibration frame in three positions on the floor area: central floor position, between centre of floor and corner, and corner of floor.

Data Analysis

Analysis of the tapes was performed using a Peak-5, 3-D video data acquisition system. The 2-D 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. Linear and angular kinematics were calculated from the 3-D coordinates by finite differences (Miller & Nelson, 1973).

Results and Discussion

The "take-off phase" is defined as the elapsed time from touch-down (from round-off or flic-flac, first frame foot contact) to take-off (first frame none ground contact).

Take-off Angles

The angle formed by the CM to ground contact (toes) and the horizontal was measured at touch-down and take-off and referred to as touchdown and takeoff angle.

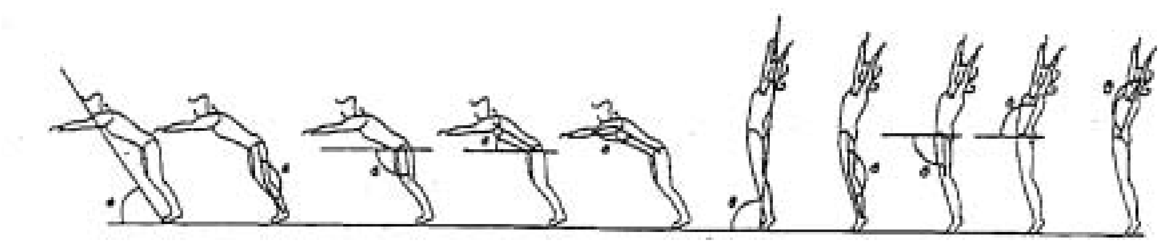

Fig 1. Touch-down and take-off angles for CM to ground contact and the horizontal, knee, thigh to horizontal, trunk to horizontal, and shoulder, for both male and female gymnasts.

Analysis of the data revealed, that the most important performance factor determining somersault height was the vertical velocity of the CM which at take-off was 4.2 ± 0.46 m/s for males, and 3.54 ± 0.85 m/s for females. This difference was apparent in the maximum CM height during the somersault and was measured at 2.16 ± 0.15 m for males compared with 1.95 ± 0.22 m for females, a difference of 0.21 m in somersault height. The higher values of mean maximum CM height during the somersault for males was due to a combination of several performance factors such as angle of CM to ground contact and horizontal, and faster leg extension. The vertical velocity value for the male gymnasts (4.2 a 0.46 m/s) was lower, compared to those of previously reported studies by (Brueggemann, 1983) of 4.57 m/s, (Hwang et al., 1990) 4.46 m/s, and (Newton et al., 1993) 5.8 m/s. This was most likely due to localized leg muscle fatigue as 70% of the analysed take-offs in this study were performed as the finishing acrobatic series. (Brueggemann, 1983, 1987) and (Hwang et al., 1990) reported, that the leg muscles played the dominant role in take-offs. The horizontal velocity at touch-down was 4.32 ± 0.47 and 4.05 ± 0.47 m/s and decreased to 3.21 ± 0.49 and 2.30 ± 2.27 m/s at take-off for males and females respectively. The mean duration of the take-off phase was 130 ms for males and 120 ms for females. The touch-down and take-off angles of the CM to ground contact and the horizontal were 64 + 6.0 and 88 + 3.0' for males, and 69 ± 6.0 and 87 ± 5.0" for female gymnasts.

A summary of the mean kinematic floor take-off data for both male and female gymnasts is presented in Table 1.

	Males n= 10 Mean	SD	Females n= 8 Mean	SD
Take-off duration (sec)	**0.130**	0.08	0.120	0.06
CM height (m)				
Touch-down	**0.88**	0.13	0.77	0.22
Take-off	**1.30**	0.11	1.14	0.09
Max. CM height during jump (m)	**2.16**	0.15	1.95	0.22
Right knee angle (deg)				
Take-off	**160**	8	165	7
Trunk to horizontal (deg)				
Take-off	**96**	11	103	23
Thigh to horizontal (deg)				
Take-off	**93**	9	102	7
CM to ground contact angle (deg)				
Touch-down	**64**	6	69	4
Take-off	**88**	3	87	5
Shoulder angle (deg)				
Touch-down	**131**	7	122	7
Take-off	**130**	13	136	9
Max. CM vert. velocity (m/s)				
Touch-down	**1.17**	0.46	2.35	0.60
Take-off	**4.20**	0.46	3.54	0.85
Max. CM horiz. velocity (m/s)				
Touch-down	**4.32**	0.47	4.05	0.47
Take-off	**3.21**	0.49	2.30	2.27
Ang. vel. at take-off (deg/sec)				
R. shoulder	**-260**	178	-169	241
R. hip	**303**	166	196	81
R. knee	**-244**	340	104	150
R. ankle	**352**	400	647	260

Table 1. Summary of Means and Standard Deviations for the Kinematic Data of Take-Offs for Male and Female Gymnasts

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