DYNAMICS OF FORWARD SWINGING SKILLS ON THE PARALLEL BARS

Spiros Prassas, Colorado State University, Fort Collins, USA,
Christos Papadopoulos,
Aristoteleio Panepistimio Thessalonikis, Serres, Greece

INTRODUCTION AND PURPOSE: There is a value and a need to study individual skills for any gymnastic apparatus. Identifying skills, however, that share common elements and could therefore be grouped together may be of greater value. On the parallel bars, the back toss (BT) and the backward somersault dismount (DS) appear to share common elements, at least qualitatively. Both skills have been studied independently and their kinematics have also been presented as a group (Prassas, 1994; 1995; Prassas & Papadopoulos, 1996). The dynamics of the skills/group have not yet been investigated. Therefore, the purpose of this investigation was to study the dynamics of the upswing phase of forward swinging skills (FS) on the parallel bars which appear to share common elements.

METHODS: Thirty-four FS recorded with a NAC 400 HSV camera were analyzed utilizing an Ariel Performance Analysis System (APAS). The analyzed FS were rated by two internationally qualified judges on a scale of 1 (worst) to 10 (best). Two-dimensional position data of 4 to 6 body points (ankles, hips, shoulders and wrists, plus knees and/or elbows as needed) were digitally smoothed with a cut-off frequency of 6 Hz before being submitted to further analysis. Dempster's (1955) data as presented by Plagenhoef (1971) were utilized to predict the segmental and total body anthropometric parameters necessary to solve the mechanical equations. Variables examined were: 1) average vertical and horizontal forces during the upswing phase of FS; 2) reduction of vertical force prior to pushoff; and 3) angular momentum at pushoff. Forces were calculated utilizing the impulse-momentum relationship according to the equation $\mathbf{F}.t = \Delta\mathbf{M}$ where **F**=average force, $\Delta\mathbf{M}$ = changes in the linear momentum and t = time interval; with $F_y=(\Delta M_y+W)/t$, where W is the gymnast's weight, and $F_x =(\Delta M_x)/t$. and normalized by body weight. Angular momentum was normalized for height and mass according to the method described by Hinrichs, Cavanagh & Williams (1983).

RESULTS AND DISCUSSION: Table 1 presents pushoff angular momentum, vertical and horizontal upswing forces, and maximum height above the bars for the BT (n=16) and DS (n=18). T-tests revealed significant differences during the upswing phase in average vertical forces during the entire upswing phase (Vertical force 1; 1.083 vs. 1.116 times body weight for the BD and BT, respectively) resulting in significantly larger height of the CM above the bars (49.36 vs. 64.48 % of height for the BD and BT, respectively). No significant difference in vertical forces during the late phase of the upswing (Vertical force 2) and angular momentum at pushoff were found. Average horizontal forces during the entire upswing phase were significantly larger in the BT (0.519 vs. 0.857 times body weight for the BD and BT, respectively). The function of these forces is to reduce the forward velocity of the CM to an optimum 0 m/sec at pushoff. This reduction is more crucial to the successful execution of the BT as opposed to DS. Hence the

greater horizontal forces in the BT correspond to the gymnasts' efforts to minimize/eliminate the pushoff horizontal velocity. An additional function of both the vertical and horizontal forces is to control angular momentum.

Table 1
Maximum Height above the Bars
and Kinetic Result for DS and BT (M, SD)

Variable	Dismount (n=18)		Back Toss (n=18)		*t*-score	*p*
Maximum height above bars (% of height)	49.36	(10.1)	64.48	(5.49)	- 4.62	<.001
Angular momentum (normalized)	0.134	(0.02)	0.134	(0.04)	0.005	n/s
Horizontal force (%)	0.519	(0.13)	0.857	(0.23)	-5.347	<.001
Vertical force 1 (%)	1.083	(0.03)	1.116	(0.04)	-3.055	.005
Vertical force 2 (%)	0.511	(0.34)	0.379	(0.43)	0.999	n/s

Table 2 presents pushoff angular momentum, vertical and horizontal upswing forces, and maximum height of the CM above the parallel bars for the high (score>7.0; n=15) and low (score≤6.5; n=19) scored FS. It was found that the average vertical forces during the entire upward swing phase and the angular momentum at pushoff were not significantly different between high

Table 2
Maximum Height Above the Bars
and Kinetic Results for High and Low Scored FS (M, SD)

Variable	High Scored (n=15)		Low Scored (n=19)		*t*-score	*p*
Maximum height above bars (% of height)	61.77	(5.31)	50.62	(11.07)	3.579	<.001
Angular momentum (normalized)	0.129	(0.02)	0.137	(0.04)	- 0.84	n/s
Horizontal force (%)	0.582	(0.19)	0.754	(0.27)	-2.10	.040
Vertical force 1 (%)	1.108	(0.03)	1.091	(0.04)	1.482	n/s
Vertical force 2	0.625	(0.24)	0.309	(0.42)	2.577	.015

and low scored FS (1.108 vs. 1.09 times body weight, and 0.129 vs. 0.137 for force and angular momentum, respectively). The reduction of the average vertical forces, however, was significantly greater in the low scored FS during the latest part of the upward swing, resulting in significantly less height above the bars (Table 2).

CONCLUSIONS: The results of the study revealed that:

1. There were similarities and differences between the two types of FS examined. Specifically: a) the angular momentum and the vertical force during the late phase of the upswing were similar for the BT and the DS, and b) the two skills were different in (total) average vertical and horizontal force during the pushoff phase and maximum height above the bars.
2. The angular momentum at pushoff and the vertical forces during the entire upswing phase were similar for both high and low scored FS. Low scored FS exhibited significantly greater horizontal forces during the pushoff phase, greater reduction in vertical force during the late part of the pushoff phase, and less maximum height above the bars.

REFERENCES:

Abdel-Aziz, Y. I., Karara, H. M. (1971). Direct Linear Transformation from Comparator Coordinates into Object Space Coordinates in Close-Range Photogrammetry. In American Society of Photogrammetry (Ed.), *Proceedings of the Symposium on Close-Range Photogrammetry* (pp. 1-18). Falls Church, VA.

Dempster, W. T. (1955). Space Requirements of the Seated Operator. WADC Technical Report *(*pp. 55-159). Dayton, OH: Wright-Patterson Air Force Base

Hinrichs, R. N., Cavanagh, P. R., Williams, K. R. (1983). Upper Extremities Contributions to the Angular Momentum in Running. In *Biomechanics VIII-B* (pp. 641-647). Champaign, Ill.: Human Kinetics.

Plagenhoef, S. (1971). Patterns of Human Motion: A Cinematographic Analysis (pp. 20-21). Englewood Cliffs, N.J.: Prentice Hall.

Prassas, S. G., Papadopoulos, C. (1997). Differentiation and Prediction in Forward Swing Skills on the Parallel Bars. *Medicine and Science in Sports and Exercise* **29**, 5.

Prassas, S. (1995). Technique Analysis of the 1992 Compulsory Dismount from the Parallel Bars. In Tony Bauer (Ed.), *Proceedings-XIII International Symposium on Biomechanics in Sports* (pp. 160-163). Thunder Bay, Ontario: Lakehead University.

Prassas, S. (1994). Technique Analysis of the Back Toss on the Parallel Bars Performed by Elite Gymnasts. In A. Barabás, G. Fábián (Eds.), *Biomechanics in Sports XII* (pp. 249-251). Budapest: Hungarian University of Physical Education.