BIOMECHANICAL ANALYSIS OF GYMNASTIC BACK HANDSPRING

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The purpose of this study is to compare the kinematics and kinetics of back handspring of skilled and non-skilled performers. Eight gymnasts and eight cheerleaders participted in the study. A JVC 9800 DV camera (60 Hz) was synchronized by using a LED light with a Kistler force platform (600 Hz) to collect the data. The results indicated the peak vertical GRF before take-off for gymnasts and cheerleaders are 2.3 BW and 2.19 BW; and the peak horizontal GRF before take-off are 0.67 BW and 0.53 BW respectively; the gymnasts have greater jump height, take-off center of mass (CM) velocity, horizontal CM velocity at hand push off, hip angle at take-off and longer first phase flight time than the cheerleaders. It suggests that the greater jump height and longer flight time are required for good handspring performance.

KEY WORDS: performance, take-off, kinematics, kinetics.

INTRODUCTION: The gymnastics is an official event in the first modern Olympics Games in 1896. The floor exercise is the foundation for learning the basic gymnastics movement including jumping, turning, rolling, and flipping. The athletes have to master the floor exercise before advance to other instrument events. The back handspring is one of the important skills in floor exercise and is a basic building block for many gymnastic routines (Payne and Barker, 1976). The back handspring also frequently performed in cheerleading. Until now, no detailed biomechanical analysis of back handspring has been reported. There is a need to determine the difference in the biomechanics of performance of back handspring in skilled and unskilled performers. This purpose of this study is to compare the biomechanics of back handspring between skilled gymnasts with 12 years experience and unskilled cheerleaders with one year experience.

METHODS: Eight gymnasts (height 167.9 ± 4.2 cm, age 21.9 ± 1.9 yrs, mass 65 ± 3.6 kg) and eight cheerleaders (height 174.4 ± 4.2 cm, age 19.8 ± 3.7 yrs, mass 75.3 ± 11.7 kg) participated in this study. All subjects were informed of the experimental procedures and gave their consent before participating**.** The subjects performed a 10-mimute warm-up session consisting of stretching upper and lower limb muscles before data collection. A JVC 9800 DV camera (60 Hz) was synchronized by using a LED light with a Kistler force platform (600 Hz) to collect the data of subject performing the back handspring. For each trial, the subjects were instructed to initially stand on a force platform and did a back handspring once given a verbal signal. The subject performed three successful trials and one trial was selected for analysis based on best judging score. Nine body landmarks (ear, shoulder, elbow, wrist, hip, knee, ankle, toe and heel) were digitized by the Kwon3d motion system (www.kwon3d.com). Based on a frequency content analysis of the digitized coordinate data, marker trajectories were filtered at 6 Hz using a Butterworth fourth order zero-lag filter. The second central different differentiation method was used to determine velocities. The segment COM, and body COM were calculated by using the Dempster data provided by Winter (l990). The ground reaction forces and impulses of back handspring were analyzed by Kwon GRF software. An independent t-test was used to test the variables between the gymnasts and cheerleaders on back handspring. The variables are time, body CM velocity, joint angles and velocities, force and impulse.

RESULTS AND DISCUSSION:

There are significant differences on first flight phase and push-off phase and height of CM between gymnasts and cheerleaders (Table 1). The gymnasts have a longer first flight time and a shorter push-off phase and body CM height than the cheerleaders. The gymnasts have a longer first flight phase indicated the gymnasts' using both feet forceful push-off

ground which results a longer CM height than the cheerleaders. The greater CM height after takeoff helped the gymnasts perform the turn and execute the back handspring. The gymnasts also have a shorter push-off phase suggest the hands quickly push-off floor which helps body swing and landing. Two unskilled cheerleaders performed the movement without the second flight phase. Their hands push-off the ground after their feet contact the floor. Only six cheerleaders' second flight phase was used to run the t-test. No difference was found on other time variables between two groups.

Table 1 Time of back handspring unit: s

	Gymnast (N=8)	Cheerleader (N=8)	t	p
Total time	1.98 ± 0.18	1.98 ± 0.22	.04	.968
Eccentric phase	1.05 ± 0.18	1.00 ± 0.29	.44	.669
Concentric phase	0.26 ± 0.05	0.25 ± 0.06	.38	.707
I flight phase	0.22 ± 0.02	0.17 ± 0.03	3.8	.002*
Push-off phase	0.32 ± 0.04	0.49 ± 0.08	-5.3	.000*
II flight phase	0.14 ± 0.02	0.13 ± 0.05(N=6)	.32	.759
Height of CM(cm)	89.2 ± 3.3	81.7 ± 8.8	2.25	.041*

*p<.05

The gymnasts have the greater horizontal and vertical body CM velocities than the cheerleaders at feet takeoff which also indicated the gymnasts have greater resultant body CM velocity at take-off. The greater body CM velocity at takeoff for gymnasts result the greater CM jumping height which gives a longer time for performing back handspring. The gymnasts also have greater horizontal body CM velocity at hand pushoff which help the body for the landing. The smaller values of body CM velocities at takeoff and hands push-off results the poor back handspring performance of the cheerleaders.

Table 2 Horizontal and vertical CM velocities at take-off and pushoff unit：ms^{-1}

	Gymnast (N=8)	Cheerleader (N=8)	t	p
Horizontal CM velocity take-off	1.76 ± 0.32	1.22 ± 0.47	2.65	.019*
Vertical CM velocity take-off	0.88 ± 0.23	0.39 ± 0.25	4.02	.001*
Horizontal CM velocity hand pushoff	1.58 ± 0.24	1.15 ± 0.34	2.96	.010*
Vertical CM velocity hand pushoff	-0.06 ± 0.25	-0.04 ± 0.68	-.07	.943

*p<.05

Joint angles and velocities of shoulder, hip, knee, and ankle of both groups at takeoff are listed in Table 3 and 4. The gymnasts have greater knee angle and hip and knee angular velocities than the cheerleaders at feet take-off. The greater knee extension and faster hip and knee angular velocities at take-off are the important variables for indentify good and average back handspring performance.

Table 3 Joint angle of back handspring at take-off unit：deg

	Gymnast (N=8)	Cheerleader (N=8)	t	p
Shouder	162.9 ± 7.9	165.2 ± 4.3	-.74	.474
Hip	215.9 ± 46.2	217.7 ± 8.5	-.33	.749
Knee	135.5 ± 13.2	126.2 ± 5.4	2.87	.012*
Ankle	142.1 ± 6.3	140.5 ± 2.8	.65	.528

*p<.05

Table 4 Joint angular velocity of back handspring at take-off unit：deg/s

	Gymnast (N=8)	Cheerleader (N=8)	t	p
Shouder	333.8 ± 86.1	366.1 ± 127.7	-.59	.562
Hip	767.1 ± 47.4	672.0 ± 61.3	3.47	.004*
Knee	456.5 ± 106.4	364.0 ± 59.3	2.15	.050*
Ankle	466.3 ± 103.9	379.9 ± 90.8	1.77	.098

*p<.05 *

There are significant differences on shoulder and knee angles between groups at hands touchdown. The overextension of shoulder observed on cheerleaders indicated lack of balance control during the handstand position. The cheerleaders less knee extension at hands touchdown may due to smaller knee angle at takeoff (Table 5). The control of shoulder angle and more knee extension indicated good handstand position during back handspring. The faster knee angular velocity than the cheerleaders suggest that the gymnast continue fast knee extension at hands touchdown (Table 6).

Table 5 Joint angles of back handspring at hands touchdown unit：deg

	Gymnast (N=8)	Cheerleader (N=8)	t	p
Shouder	174.8 ± 7.2	186.23 ± 3.3	-4.08	.001*
Hip	243.8 ± 6.6	247.28 ± 11.6	-.73	.476
Knee	138.0 ± 9.6	110.67 ± 17.9	3.81	.002*
Ankle	146.9 ± 7.1	147.56 ± 5.4	-.20	.846

*p<.05

Table 6 Angular velocities of back handspring at hands touchdown unit：deg/s

	Gymnast (N=8)	Cheerleader (N=8)	t	p
Shouder	-195.6 ± 121.2	-208.1 ± 72.5	.25	.807
Hip	-214.2 ± 88.0	-153.8 ± 92.9	-1.34	.202
Knee	193.3 ± 82.9	-42.8 ± 138.3	4.14	.001*
Ankle	-76.7 ± 75.0	-53.3 ± 85.3	-.58	.569

*p<.05

The gymnasts have greater hip angle and velocity than the cheerleaders at hands push off.(Table 7,8) The greater hip angle and velocity show the gymnasts fast extend the hip forceful hands push off to increase the rotation of trunk for the control landing. The less hip extension angle and slow hip angular velocity for the cheerleaders show lack of fast hip extension at hands push-off.

Table 7 Joint angles of back handspring at hands push-off unit：deg

	Gymnast (N=8)	Cheerleader (N=8)	T	p
Shouder	140.9 ± 7.5	134.1 ± 20.8	.87	.399
Hip	137.3 ± 12.1	107.0 ± 32.5	2.47	.027*
Knee	187.4 ± 9.9	164.8 ± 37.4	1.65	.121
Ankle	126.9 ± 12.4	112.6 ± 19.1	1.78	.097

*p<.05

Table 8 Joint angular velocities of back handspring at hands push-off unit：deg/s

	Gymnast (N=8)	Cheerleader (N=8)	t	p
Shouder	-17.9 ± 98.8	-58.7 ± 106.6	.79	.441
Hip	-383.1 ± 110.7	-194.6 ± 133.5	-3.08	.008*
Knee	67.6 ± 37.4	58.0 ± 95.72	.27	.794
Ankle	-39.7 ± 63.0	29.0 ± 77.8	-1.95	.072

*p<.05

The peak vertical and horizontal forces before back handspring take-off for gymnasts and cheerleaders are 2.3, 2.2 BW and 0.7, 0.5 BW respectively (Table 9). No sifnificant difference was found on peak force between two groups. Only one gymnast show all positive

horizontal force before take-off which indicated most subjects produce braking horizontal force during eccentric phase to prevent backward fall before take-off.

Table 9 Peak vertical and horizontal force at back handspring take-off unit: BW

	Gymnast (N=8)	Cheerleader (N=8)	t	p
Peak Vertical force	2.3 ± 0.3	2.2 ± 0.1	.92	.371
Peak Horizontal force	0.7 ± 0.1	0.5 ± 0.2	1.88	.082

*p<.05

No significant was found on total vertical and horizontal impulse and vertical and horizontal impulse during eccentric and concentric phase before back handspring take-off for gymnasts and cheerleaders. (Table 10)

Table 10 Eccentric, concentric and Total impulse at back handspring take-off unit: N*s

	Gymnast (N=8)	Cheerleader (N=8)	t	p
Total vertical impulse	933.2 ± 122.8	973.7 ± 168.1	-.55	.590
Total horizontal impulse	-108.4 ± 15.7	-99.6 ± 28.8	-.76	.459
Vertical impulse eccentric	665.4 ± 124.1	683.3 ± 167.0	-.24	.811
Horizontal impulse eccentric	-44.7 ± 9.4	-45.1 ± 17.3	.07	.946
Vertical impulse concentric	268.5 ± 44.4	291.1 ± 75.2	-.73	.476
Horizontal impulse concentric	-64.1 ± 12.9	-54.7 ± 13.7	-1.41	.178

*p<.05

CONCLUSION: The purpose of this study is to compare the kinematics and kinetics of back handspring of skilled and non-skilled performers. The results indicated the peak vertical GRF before take-off for gymnasts and cheerleaders are 2.3 BW and 2.19 BW; and the peak horizontal GRF before take-off are 0.67 BW and 0.53 BW respectively; The gymnasts have greater jump height, take-off center of mass (CM) velocity, horizontal CM velocity at hand push off, hip angle at take-off and longer first air time than the cheerleaders. It suggests that the greater jump height and longer flight time are required for good handspring performance.

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