STUDY ON GYMNASTICS RING MOVEMENTS USING FORCE MEASURING SYSTEM

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The purpose of this paper was to analyze five giant-swing phases performed on the rings using force-measuring system, which was synchronized with EMG and film. The results showed similar patterns in pulling force, shoulder angle, hip angle, hip velocity and ankle velocity when performing the movements of backward swing phase, dropped shoulder, giant-swing, and upward swing phase. The pulling-force changed from smaller than the body weight to greater than the body weight in the process of the backward swing. The first peak of pulling force occurred as shoulder drop phase ends. The second peak of pulling force occurred in the backward swing phase. The pulling force decreased gradually in the process of the upward swing.

KEY WORDS: force sensor, pulling-force, f rings, EMG

INTRODUCTION: Based on a paucity of research, it would appear that less attention has been placed on studying the movements performed on the rings in gymnastics. Reports on synchronized measurements on ring movements are lacking. The use of biomechanical analysis to determine the characteristics of this specialized routine will address the apparent deficiency. In this study, the force sensors, high speed cine-camera, and telemetry electromyography (EMG) were simultaneously operated by means of a synchronous signal generator in order to provide data on the specific series of movements performed on the rings. In this study, a different technique, namely internal synchronization was developed. This differed from the previous study where the external synchronization method was used. Therefor the purpose of this study was to explore the biomechanical characteristics of ring movements in order to provide additional knowledge of high performance gymnastics for both coaches and gymnasts.

METHODS: Five male junior elite gymnasts at national level were selected as subjects to participate in this study. The age, body weight and body height of the subjects were 15.4 years, 43,9 kg and 154.8 cm respectively. A high-speed cine-camera (LBS-16A, China) operating at 100 Hz frequency was positioned at distance of 22.5m to the motion plane. A pulling force sensor (HLY-I/1000KG, China), was mounted between the strap of the rings and the steel rigging and was connected to the multi-function recorder through WHEATSTION-BRIDGE. This was used to record the force that the gymnasts exerted on the rings during movement. Telemetry surface EMG (Multi-Telemeter 551, Japan) was used to measure the EMG signals of muscles of gluteus maximus, biceps femoris and triceps during movements. The synchronization of filming, force measurement and EMG record was realized by triggering a synchronous signal generator. EMG and force signals were recorded by a microcomputer (Apple II) for further processing. The film materials were then analyzed on film motion analysis system (NAC MOVIES 100, Japan). Backward swing phase consisted of (1) Forward giant circle, (2) Backward swing to handstand, (3) Forward rotation of the shoulder, (4) Back up-rise, and (5) Backward swing in hang position. These movements were selected for analysis. This routine provides a basis for development of high degree of difficulty moves performed on the rings.

RESULTS AND DISCUSSION: Some kinematics and kinetics measures associated with the phases in that the pulling forces were reduced to the minimum and are presented in Table 1. The forward giant circle begins with handstand, thus the pulling force is the same as the body weight. As the forward swing phase begins, the center of gravity of the body moves away gradually from the point of support, the body swings forward to an angle of between

20°and 30° and the pulling force curve begins to decrease. As the body swings forward near to the angle of 38°, the center of gravity moves off the point of support, the pulling force curve decreases noticeably until it reaches a minimal value of 12.99kg, with an associated slow feeling of weightlessness. By observing the change in the hip angles, it is not difficult to determine that the hip angle is maintained at about 173°, approximately the maximum of 180°. At this point, all the measured force curve is below the body weight line until the body swings backward to the horizontal plane. With displacement at rest, the hip and ankle velocity reaches 1.19 and 1.96m/s respectively.

Table 1 Kinematics and Dynamics Measures when the Pulling Force is Reduced to the Minimum

	1 (kg)	2 (°)	3 (°)	4 (°)	5 (m/s)	6 (m/s)	7 (m/s)	8 (times)
A	12.99± 0.59	38± 3	163± 2	173± 2	1.19± 0.32	1.96± 0.37	1.08± 0.44	0.28± 0.03
B	23.33± 2.88	—	—	—	—	—	—	—
C	31.00± 1.73	—	—	—	—	—	—	—
D	34.58± 3.40	—	—	—	—	—	—	—
E	29.32± 4.30	—	—	—	—	—	—	—

Note: A: Forward giant circle. B: Backward swing to handstand. C: Forward shoulder rotation. D: Back up-rise. E: Backward swing in hang position. 1: Pulling force; 2: Down swing angle; 3: Shoulder angle; 4: Hip angle; 5:Hip velocity; 6: Ankle velocity; 7: The velocity of the center of gravity of body; 8: Times as heavy as the body weight.

Table 2 Kinematics and Dynamics Measures when the Pulling Force was Larger than the Body Weight

	1 (kg)	2 (°)	3 (°)	4 (°)	5 (m/s)	6 (m/s)	7 (m/s)	8 (times)
A	40— 45	153± 7	142± 5	145± 10	4.34± 0.24	10.17± 0.88	3.93± 0.21	1
B	40— 45	150± 5	137± 8	44± 10	3.36± 0.16	7.24± 0.35	3.13± 0.1 5	1
C	40— 45	146± 6	140± 8	140± 2	3.65± 0.38	9.07± 0.57	3.52± 0.29	1
D	40— 45	159± 7	135± 10	146± 4	3.23± 0.38	9.01± 0.74	3.08± 0.10	1
E	40— 45	159± 2	142± 9	151± 2	3.64± 0.40	8.08± 0.58	3.56± 0.48	1

Note: A: Forward giant circle; B: Backward swing to handstand; C: Forward shoulder rotation; D: Back up-rise; E: Backward swing in hang position. 1: Pulling force; 2: Down swing angle; 3: Shoulder angle; 4: Hip angle; 5:Hip velocity; 6: Ankle velocity; 7: Velocity of the center of gravity of body; 8: Times as heavy as the body weight.

Calculations for the kinematics and dynamics parameters on the pulling force being heavier than the body weight are shown in table 2. It was only for an instant that the pulling force was heavier than the body weight. The angular displacement of the forward swing usually ranged from 150° to 160°. During the moves where the pulling force equaled the body weight, the

gluteus maximus and biceps femoris contracted and the velocity of both the hip and the center of gravity of the body reached their maximum value. Of the 5 movements studied, the mean value of the maximum velocity of the hip varied from 3.23m/s to 3.34m/s, and the mean value of the maximum velocity of the center of gravity of the body varied from 3.08m/s to 3.91m/s. However, the velocity of ankle increased considerably. This may be due to the fact that as one part of the body accelerated, the corresponding part of the body accelerated. The first peak of the force curve appears as the body swings forward and downward to the position of an angle between 162° to 176° and when the hip angle reaches its minimum at the same time. The dynamics and kinetics parameters at this phase are shown in table 3. Among 5 movements, the average hip angle ranged from131° to145°. At the first peak, the increase of the hip angle indicated the beginning of the giant-swing. The ratio of the force to the body weight for each movement ranged from 4.27 to 4.66 body weight, showing a slight change. This may due to the fact that the movement was finished with dropped shoulder with a natural swing movement.

Table 3 Kinematics and Dynamics Measures when the First Peak of the Force Curve Occurred

	1 (kg)	2 (°)	3 (°)	4 (°)	5 (m/s)	6 (m/s)	7 (m/s)	8 (times)
A	207.83± 26.07	162± 11	152± 2	135± 3	3.84± 0.84	11.82± 0.41	3.27± 0.50	4.66± 0.04
B	200.60± 21.21	167± 4	149± 9	131± 5	2.79± 0.15	11.20± 0.28	2.80± 0.28	4.55± 0.19
C	200.25± 21.56	176± 3	160± 2	134± 3	1.62± 0.45	11.16± 0.52	2.17± 0.65	4.55± 0.17
D	187.40± 21.77	174± 2	154± 7	143± 2	1.97± 0.32	10.80± 0.28	2.53± 0.42	4.40± 0.04
E	182.10± 20.15	172± 2	155± 7	145± 4	2.15± 0.21	11.20± 0.59	2.64± 0.36	4.27± 0.27

Note: A: Forward giant circle; B: Backward swing to handstand; C: Forward shoulder rotation; D: Back up-rise; E: Backward swing in hang position; 1: Pulling force; 2: Down swing angle; 3: Shoulder angle; 4: Hip angle; 5:Hip velocity; 6: Ankle velocity; 7: Velocity of the center of gravity of body; 8: Times as heavy as the body weight.

Table 4 Kinematics and Dynamics Measures when the Second Peak of the Force Curve Occurred

	1 (kg)	2 (ms)	3 (°)	4 (°)	5 (m/s)	6 (m/s)	7 (m/s)	8 (times)
A	349.75± 45.12	8.00± 3.24*	179± 1	188± 1	1.55± 0.13	13.45± 0.38	0.90± 0.30	7.50± 0.65
B	336.98± 46.10	11.33± 3.04*	177± 1	187± 2	1.58± 0.22	12.87± 0.61	0.78± 0.19	6.94± 0.36
C	327.26± 50.87	4.50± 0.70*	177± 1	188± 4	1.77± 0.14	12.29± 0.14	1.32± 0.58	6.73± 0.41
D	312.70± 53.16	13.00± 3.46*	178± 3	188± 5	1.92± 0.16	11.68± 0.50	1.03± 0.31	6.59± 0.48
E	300.78± 50.71	11.00± 4.65*	176± 2	190± 2	1.50± 0.27	11.60± 0.35	0.85± 0.13	6.30± 0.33

Note: A: Forward giant circle; B: Backward swing to handstand; C: Forward shoulder rotation; D: Back up-rise; E: Backward swing in hang position; 1: pulling force; 2: The instant passing vertical plane. 3: shoulder angle; 4: hip angle; 5:hip velocity; 6: ankle velocity; 7: the velocity of the center of gravity of body; 8: times as heavy as the body weight.

The data of dynamics and kinetics parameters indicating when the second peak of the force curve occurs are shown in table 4. The results show that after giant-swing, the force increased continuously. Among the 5 movements studied, the pulling force varied from 300kg to 349kg or 6.30 to 7.50 body weight. That means that the more difficult the movement, the greater the ratio of pulling force to the body weight.

CONCLUSION:

1. With completion of the move as the body swings forward, the backward swing begins and the pulling force varies from 12.99 kg to 34.58kg, lower than the body weight. This is the period when the gymnast will utilize potential energy
2. When the pulling force is greater than the body weight, both the center of gravity of the body and the hip reach their maximum velocity. The former was between 3.08m/s and 3.93m/s and the latter 3.23m/s and 4.34m/s. The lower back muscles such as gluteus maximus, the biceps femoris are fully contracted at this time.
3. The first peak value of the pulling force varies slightly between 182 kg and 207kg, while the hip angle reduces to its minimum value of between 131° and 145°. The major muscles are fully stretched and the giant-swing begins.
4. At the second peak, the value of the pulling force was between 300 kg and 349kg, the greatest among all phases. The time when the maximum components of the force are generated is between 4.50ms and 13.00ms after the vertical plane. This period presents a challenge for the performer to utilize potential kinetic energy.

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