MECHANICAL ANALYSIS OF THE INVERTED GIANT SWING

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Strength, balance, flexibility, speed, proper timing, and stamina have long been considered a necessity for the sport of gymnastics. However, the explosive worldwide development of the sport the last decade established another factor --the mastering of swinging --to be of paramount importance for gymnasts desiring to succeed in competition.

Among the different kinds of swings, the giant swing refers to those gymnastic skills which require a full 360 degree rotation of the gymnast's suspended body about a relatively fixed point. Depending on the direction of the rotation, the gymnast's body configuration and the type of handgrasp, the degree of difficulty for the various types of the existing giant swings ranges from low to high. With reference to the horizontal bar, the forward and backward giant swings are considered, for example, fundamental but of low difficulty, whereas the so called "inverted" and "German" giant swings are given high marks for difficulty.

The forward and backward giant swings have been studied quantitatively by a number of investigators. Among them Cureton (1939) utilized cinematographic techniques to analyze the forward giant swing. He determined the maximum centrifugal force to be about 4.9 times the subject's weight occurring at 135 degrees from the starting point (Quadrant II). Kopp and Reid (1980) conducted a force and torque analysis of both forward and backward giant swings, obtaining (by means of strain gauges bonded to the high bar) mean maximum values for the forces acting on the bar of 3.5 and 3.7 times body weight for the above giant swings, respectively. In validating a N-link analysis program capable of calculating the torques producing an observed motion, Dainis (1974) calculated the shoulder and hip joint torques of backward giants executed with good and poor technique.

Although similarities between the mechanics of different types of swings should be expected and extrapolation of the results and conclusions from one type to another seems logical, it would be valuable to investigate the mechanics of advanced giant swings especially in light of the danger that is always present in advanced skills. It was the purpose of this study to investigate the mechanics of the IGS, a skill of higher difficulty, and one which ordinarily is a part of any gymnast's optional high bar routine.

METHODS

Subjects

Three highly skilled gymnasts served as subjects. They were: (1) Peter Korman (subject A), bronze medalist in the 1976 summer Olympics, (2) Don Dembrow (subject B), who represented the United States in international competitions, and (3) Dale Dembrow (subject C), who competed in college. Their age, height and weight at the time of data collection were as follows:

	A	B	C
Age (yrs)	26	25	26
Height (m)	1.68	1.68	1.71
Weight (kg)	59	59	68

Data Collection and Analysis

The filming took place at the University of Maryland, College Park Campus. A Photosonics 16mm-1PL camera, fitted with a 25mm Kern-Paillard lens, was placed 19.42m from the center of the high bar with the optical axis perpendicular to the plane of motion. The transport speed was set at 80 frames/sec, and was verified by utilizing a 10Hz pulsed signal applied to an internal LED timing light.

Standard computer programs on file at the University of Maryland Physical Education Department, were utilized for kinematic and kinetic analysis. A Numonics, Inc. 1224 digitizer interfaced with the University's computer system was utilized to digitize three reference points (used to align the frames and as a scaling factor), the center of the high bar, and the centers of the shoulder, hip, and ankle joints. The segmental parameters used in this study were those derived by Demster (1955) as presented by Plagenhoef (1971). A digital filtering frequency of 3Hz was employed in smoothing the raw displacement data. For each subject, a full rotation, beginning and ending at the point where the center of mass (CM) was above the high bar (90 degrees from the right X axis), was submitted to analysis.

RESULTS AND DISCUSSION

Figure 1 presents two dimensional representations of the analyzed performances taken directly from the filmstrip, as well as trajectory paths of the subjects' centers of mass (CM). The velocity vector of each gymnast's CM is shown in each kinegram. Notice that the trajectory of the CM of subject B is the most circular, whereas the path of subject C is the flattest on the top part of the swing.

Temporal results are presented in Table I: it is apparent that including total (absolute) time, which was 1.68, 1.84 and 1.92 sec for subjects A, B, and C, respectively, no substantial differences can be detected. Proportionally, all subjects required one third of their total time in Quadrant I

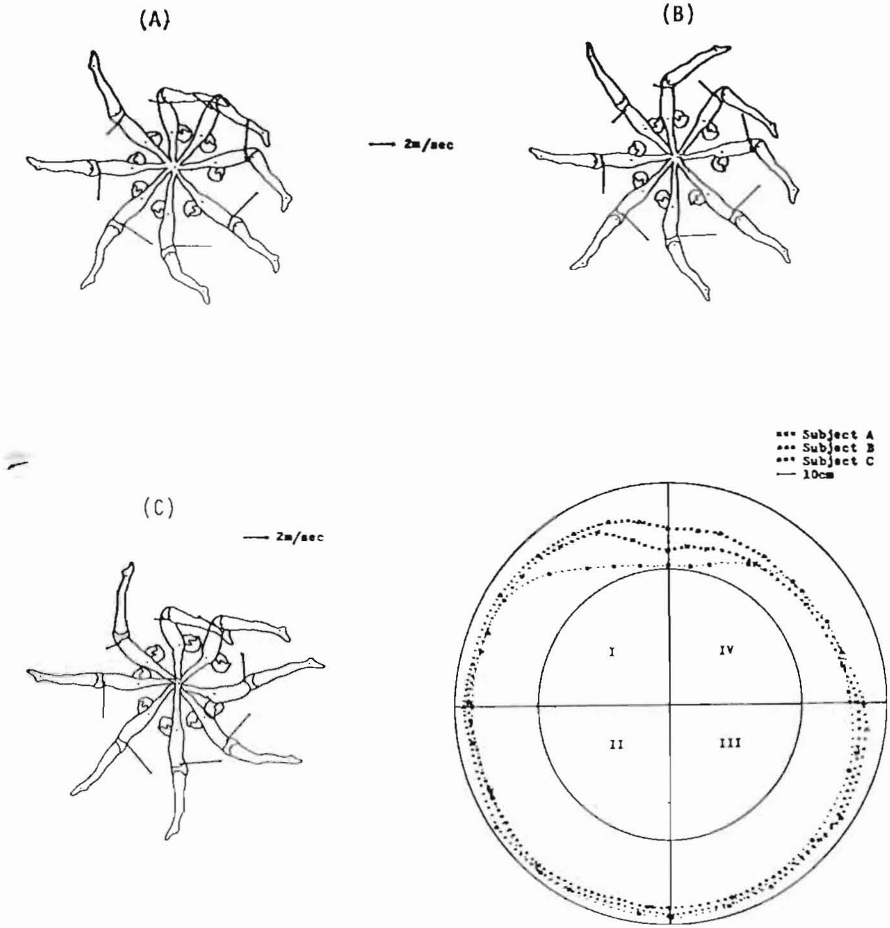

FIGURE 1: Kinegrams of the 3 analyzed IGSs, and CM paths

and less than one fifth in Quadrant III. Figure 2 presents hip vs shoulder joint angle for each subject. Alth^ugh differences between all subjects can be detected, it is apparent that the movement pattern of subjects A and B was similar during the largest portion of the movement. This similarity was consistent for the aforementioned subjects for most of the kinematic and kinetic parameters considered in this study. Consequently, Figures 3 and 4 consider subjects B and C only with the understanding that with minimal exceptions, close resemblances in the performances of subjects A and B were found.

TABLE I

Absolute and % of Total Time in Each Quadrant
(N=3)

	Subject					
	A	B	C	A	B	C
Quadrant	Absolute Time (sec)			% of Total Time		
I	.6049	.6711	.6790	35.96	36.45	35.36
II	.3399	.3289	.3650	20.20	17.86	19.05
III	.3102	.3281	.3360	18.44	17.82	17.57
IV	.4270	.5130	.5398	25.40	27.87	28.02
Total	1.6820	1.8411	1.9198	100.00	100.00	100.00

Figure 3 presents total force directed away from the bar, CM linear velocity, and radius of gyration for subjects B and C. Hip and shoulder joint torques, angular velocities and intersegmental angles are shown in Figure 4.

Examination of those Figures reveals that:

I. For subject B:

1) An initial non-linear decline in the force on the bar with a consequent steep increase until approximately two thirds into Quadrant II. The initial decline was a net result of vigorous hip joint extension, shoulder joint flexion, and gravitational force. After the force reached a maximum value of 4.02 times body weight near the end of Quadrant II, "plateauing" was maintained until approximately two thirds into Quadrant III. At that point it sharply declined up to the midpoint of Quadrant IV, when it increased once again. Comparison of Figures 3 and 4 reveals that the changes in direction of the force curve slope in the last Quadrant nearly coincided with the reverse of the hip joint motion from flexion to extension.

2) Lengthening or shortening of the radius of gyration that was related to the movement occurring at the shoulder and hip joints as well as the degree of the high bar flexion resulting from the

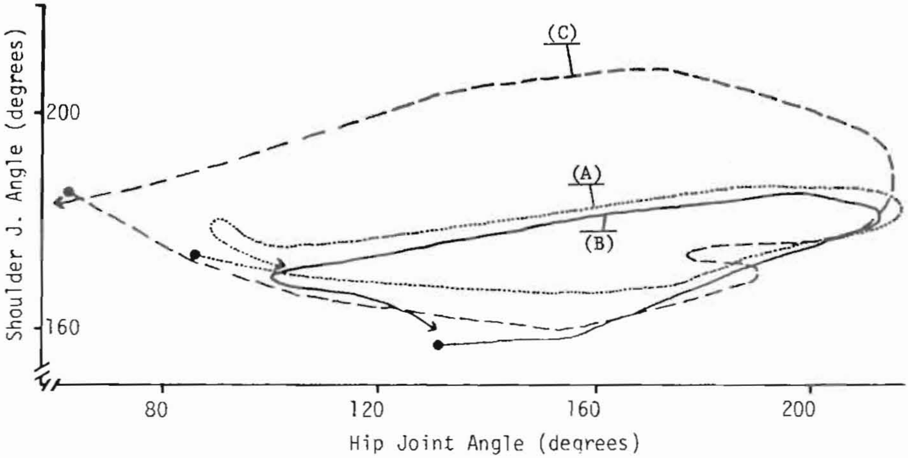

FIGURE 2: Hip vs shoulder joint angle

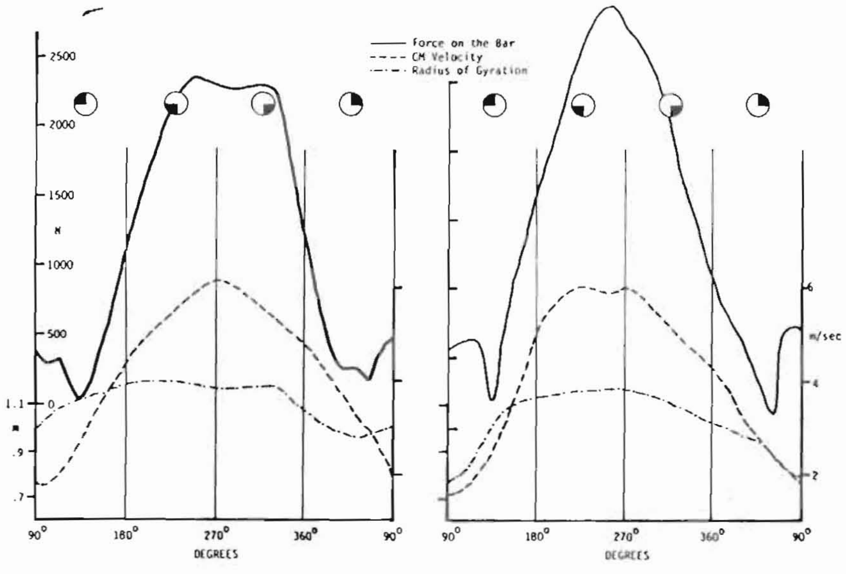

FIGURE 3: Force on the bar (total), CM velocity, and radius of gyration (subject B, left; subject C, right)

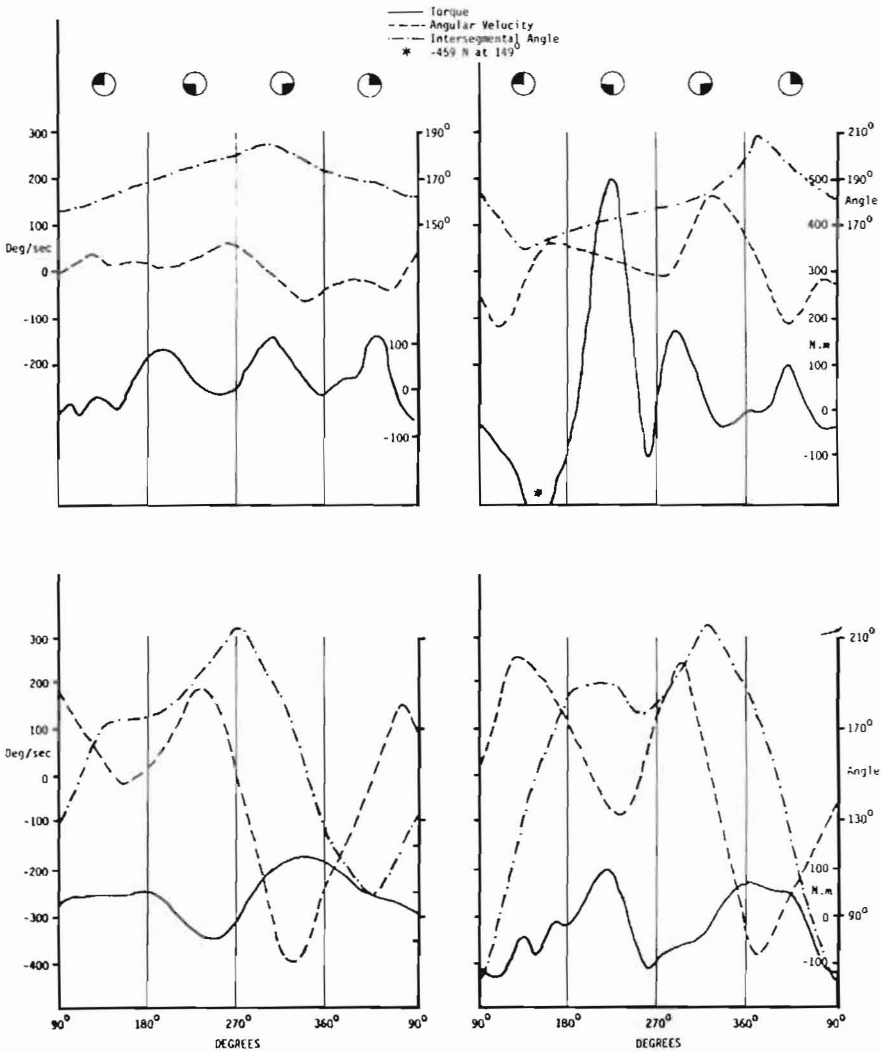

FIGURE 4: Shoulder (top) and hip (bottom) joints: Torque, angular velocity, and intersegmental angle (subject B, left; subject C, right)

force acting upon it. Recall that the origin of the system was the center of the bar and not the wrist joint center. Consequently, it may well be assumed that there was an interrelationship between the "plateau" of the force on the bar and the mild increase in the subject's radius of gyration occurring in Quadrant II, but the exact nature of that relationship needs further investigation for clarification.

3) Continuous shoulder joint flexion from the beginning to just past the bottom of the swing. Thereafter shoulder joint extension occurred until the end of the swing.

4) A steep initial increase in hip joint angle followed by a plateau and an additional steep increase until the bottom of the swing. The purpose of the second steep increase in hip angle--referred to as "beating" or "whipping of the hips" among gymnasts--is to generate additional angular velocity necessary for the ascending portion of the swing. It may also serve the purpose of placing the hip flexors in a more favorable physiological position to carry out the subsequent sharp hip joint flexion.

II. For subject C:

1) An initial mild increase in the force on the bar, followed by a decrease, and a subsequent steep increase to reach a maximum value of 4.63 times body weight just prior to the bottom of the swing, where the force curve sharply reversed its direction. In the latter portion of the rotation--except the very end--the shape of the force curve was similar to that of subject B. The initial mild increase in force on the bar indicates that the net result of the combined action of the subject's hip and shoulder joints (see Figure 4) was not yet vigorous enough to counteract the gravitational force.

2) Lengthening of the radius of gyration until the bottom of the swing, which was more pronounced midway into Quadrant I, followed by continuous shortening until the end of the rotation.

3) Initial extension of the (hyperflexed) shoulder joint followed by continuous flexion until the beginning of Quadrant IV when extension occurred again.

4) Vigorous hip joint extension from the beginning to midway into Quadrant III, interrupted momentarily by a small but distinct flexion. The short hip joint flexion provided a physiological advantage to the hip extensors for the subsequent "whipping" of the hips by lengthening the muscle fibers before contraction. From midway into Quadrant III until the end of the swing, the hip joint angle sharply decreased.

III. Both subjects exhibited:

1) Non-linear patterns in the slope of the shoulder and hip torque curves. Those torques should be interpreted as either initiators

or inhibitors to flexions or extensions at the respective joints, or as indicators of joint stabilization function.. Of particular interest is the magnitude and sharp change in direction of the slope of subject C's shoulder joint torque curve in Quadrant I necessary to stabilize the joint in its extension-flexion motion. This stabilization, however, should not necessarily be attributed only to active muscular contraction; it is likely that passive ligament reaction contributed substantially as well. Notice, also, that for subject C, a hip joint extensor torque necessary to inhibit the short hip flexion was present in Quadrant II.

2) An oscillating shoulder and hip joint angular velocity, much larger (in absolute values) in the second joint.

Table II presents, radius of gyration and CM velocity at selected positions. By comparing the velocity of the subjects' CM at the initial position and at the end of Quadrants I and II it appears that subject C showed a larger velocity increment in Quadrant I. The increments were 1.74, 2.71, and 4.63 m/sec, for subjects A, B, and C, respectively. The opposite had occurred in Quadrant II, where subject C achieved an increment of .78 m/sec with subjects A and B demonstrating increments of 1.96 and 1.63 m/sec, respectively. The larger and more rapid increment in the radius of gyration of subject C in Quadrant I accounts for the first phenomenon, whereas the second phenomenon can be attributed to the whipping action of the hip joints of subjects A and B.

TABLE II

Radius of Gyration (m) and CM Velocity (m/sec)
at the Initial Position (IP) and at the End of
Each Quadrant
(N=3)

		Subject A	Subject B	Subject C
Radius of Gyration	IP	0.854	0.995	0.776
	I	1.163	1.178	1.135
	II	1.123	1.163	1.168
	III	1.036	1.077	1.030
	IV	0.915	1.020	0.759
CM Velocity	IP	2.290	1.820	1.660
	I	4.440	4.530	5.290
	II	6.400	6.160	6.070
	III	1.036	1.077	1.030
	IV	0.915	1.020	0.759

All subjects exhibited a decline in center of mass velocity throughout the ascending phase of the swing, as a result of moving against gravity. By comparing the subjects' radii of gyration from the bottom of the swing until the end of Quadrant III (see Table II) decrements of 0.087, 0.086, and 0.138m can be found for subjects A, B, and C, respectively. The corresponding decrements of the subjects' CM velocities were, 1.56, 1.44, and 1.83 m/sec. Thus, although subject B was the one with the smallest decrement in his radius of gyration, he was able to maintain a relatively higher velocity. In contrast, subject C, with an opposite pattern demonstrated the largest loss of velocity. The same pattern was found in the last Quadrant, which indicates that there may be a superiority in the performance of subject B: an immediate initiation of hip flexion after the CM passes beneath the bar while the forces exerted on the bar are maintained in high levels (with a net result of a slight increment in the subject's radius of gyration), seems to indicate superior performance. A reduction of that force after approximately two thirds into Quadrant III (while the hip joint is still flexing) with a concomitant decrease in the subject's radius of gyration, appears to indicate superiority. Lastly, a gradual extension of the (hyper-flexed) shoulder joint initiated a few degrees after the CM passes beneath the bar and continues up to the completion of the rotation, appears to be advantageous.

SUMMARY AND CONCLUSIONS

The performance of three highly skilled gymnasts executing the IGS was filmed and analyzed kinematically and kinetically. The analysis revealed that two of the subjects utilized similar mechanical patterns, but the third, at times, deviated substantially. It was found that, in general, execution of the IGS involves large changes in body configuration as a result of large hip and shoulder movement ranges. However, the timing factor, relative to when these joint movements occurred, was not consistent among the three gymnasts, which resulted in differing techniques. Although the velocity of the CM generally increased during the descending portion of the movement and decreased in the ascending portion, the increments/decrements were not consistent among subjects. Surprisingly, these increments/decrements were not always directly and proportionally related to respective increments/decrements in the subjects' radii of gyration.

Although a case can be made that all the recorded performances were aesthetically pleasing, the technique of subject B resulted in a smaller loss in CM velocity in the ascending phase of the swing, and generated the smallest forces on the bar (4.39, 4.02, and 4.63 times body weight for subjects A, B, and C, respectively). Consequently, the technique of subject B is the recommended model to follow.

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