MECHANICS OF THE STOOP-IN-PIKE THROUGH TO INVERTED GIANTS

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Gymnastics is a versatile sport that encourages and rewards individuality and creativity. As a result, a great number of skills have been developed on each piece of apparatus over the years; more are expected in the future. Although most of these skills are unique to each apparatus, some broad classifications can be made. Generally, gymnastic skills are of the "swinging", "balance", "strength", or "tumbling" type. Or they can be classified as "primary" and "secondary". Primary skills are skills that constitute the "core" of each individual routine such as giant swings, somersaults, handstands, etc. Secondary are skills connecting the primary ones within a routine, such as the round-off, handsprings, various leaps and the "stoop-in pike through to inverted giants".

Although a substantial amount of research has been conducted in the area of gymnastics, especially in the region regarding "primary" skills, the versatility, diversity, and accelerated development of the sport requires even more study. This need is accentuated by the high level of difficulty found in today's competition, drastically increasing the possibility of serious injuries, or even death.

Rules set by the International Federation of Gymnastics (FIG) require that the optional high bar routine of any gymnast aspiring the highest marks should include a giant swing with an "eagle" grip. The mechanics of this giant swing (inverted giant swing) have been investigated previously (Prassas and Kelley, 1985). However, the leading or transitional skill, the "stoop-in pike through to inverted giants" has not been studied. It was, thus, the purpose of this project to investigate the mechanics of this transitional skill, believing that such an investigation will be valuable in instruction, improving performance, and preventing injury. It can be argued that biomechanical analysis of "secondary" skills is of equal, and at times greater, importance to the study of "primary" skills since the former constitute the foundations upon which the latter are built. In this case, the validity of the argument seems indisputable since the "stoop-in.." is considered, in the gymnastic world, to be a serious source of injury, mainly of the shoulder joint.

Methods

Subjects:

Four gymnasts served as subjects. Subject one had competed internationally, Subject two competed in college, and Subjects three and four were, at the time of data collection, members of the Naval Academy's gymnastic team. The subjects' age, height, and mass are presented in Table 1.

TABLE 1
Subjects' Characteristics

	Subject			
	1	2	3	4
Age (yrs)	25	26	26	21
Height (m)	1.68	1.71	1.72	1.69
Mass (Kg)	59	68	69	68.5

Data collection and analysis:

Filming was conducted at two sites: Naval Academy, Annapolis Maryland, and University of Maryland, College Park Campus. A Photosonics 16mm-1PL camera, fitted with a 25mm Kern-Pailard lens and loaded with Kodac RAR 2498 black/white reversal film was utilized to record 2-3 trials for each subject. The camera's transport speed was set at 80 fps and was verified with a 10Hz pulsed signal applied to an internal LED timing light.

For each subject one trial was chosen for analysis. A Numonics 1224 digitizer interfaced with a Univac 1140 computer was used to extract sequential two dimensional coordinates of the wrist, shoulder, hip, knee, and ankle joints. The knee joint of Subject one was not digitized since the gymnast did not break the joint's alignment throughout the movement. The segmental parameters used in this study were those derived by Demster (1955) as presented by Plagenhoef (1971). The digitized data were filtered at a cut-off frequency of 2Hz before being submitted to further analysis.

Results and Discussion

Figure 1 shows 2-dimensional representations of the two performances judged to be the most (Subject one) and least (Subject four) skilled among the four analyzed trials. In addition to skill level, the two trials differ in technique.

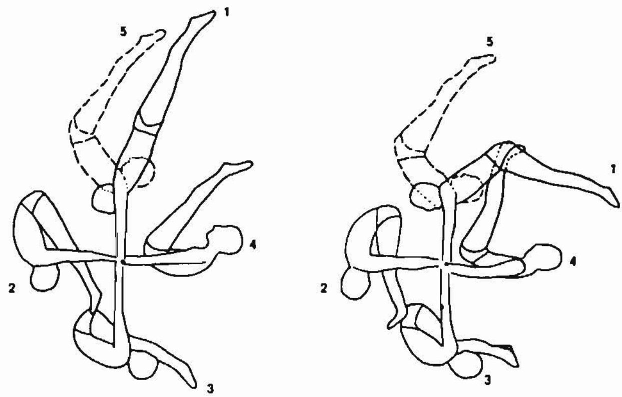

Figure 1. Kinegrams of two "stoop-ins pike trough to inverted giants" for subject one (left) and four (right). Motion occurs in a counter clockwise direction.

The performance of the first subject represents the "late drop" technique, whereas the performance of Subject four is representative of the "early drop." Among the two techniques, the former is rewarded more by the judges, thus it is the one most recommended. Beginner gymnasts, however, inherently prefer to start the piking motion long before they reach the handstand position at the top of the (preliminary to the stoop-in) forward giant swing, i.e., they prefer the second technique. This preference is based on the feeling and belief that the "late drop" generates higher forces at the bar, resulting frequently in "loosing" the grip and "flying-off" the bar. It is believed that additional muscular forces are required if the "early drop" is to be adapted. Subject two performed the "early drop," whereas the third subject executed the late drop.

Table 2 presents the time (sec) each subject needed to complete each quadrant of the rotation and percent of total time for a complete revolution of the subjects' center of mass (CM) beginning and ending above the bar, 90 degrees from the right horizontal.

TABLE 2
Temporal Results

Quadrant	Subject			
	1	2	3	4
I	0.525 (42%)	0.475 (38%)	0.662 (52%)	0.325 (32%)
II	0.750 (60%)	0.704 (57%)	0.875 (68%)	0.550 (53%)
III	0.950 (76%)	0.913 (74%)	1.085 (85%)	0.750 (73%)
IV	1.250 (100%)	1.235 (100%)	1.275 (100%)	1.030 (100%)

Although no substantial differences among subjects and techniques can be found regarding total times, other differences can be detected. For example, in the late drop technique the gymnast is required to "brake" the drop in the first quadrant in order to facilitate hip joint flexion, by maintaining a relatively wide shoulder joint angle and inhibiting consciously the forward rotation. It is shown in the table that Subjects one and three (the "late droppers") consumed proportionally more time in the first quadrant than the "early droppers" did.

Selected kinematic and kinetic data for two subjects is presented in Figures 2, 3, and 4. The relationship between the shoulder (sja), hip (hja), and knee (kja) joint angles and the shoulder (sjav) and hip (hjav) joint(s) angular velocities is found in Figure 2.

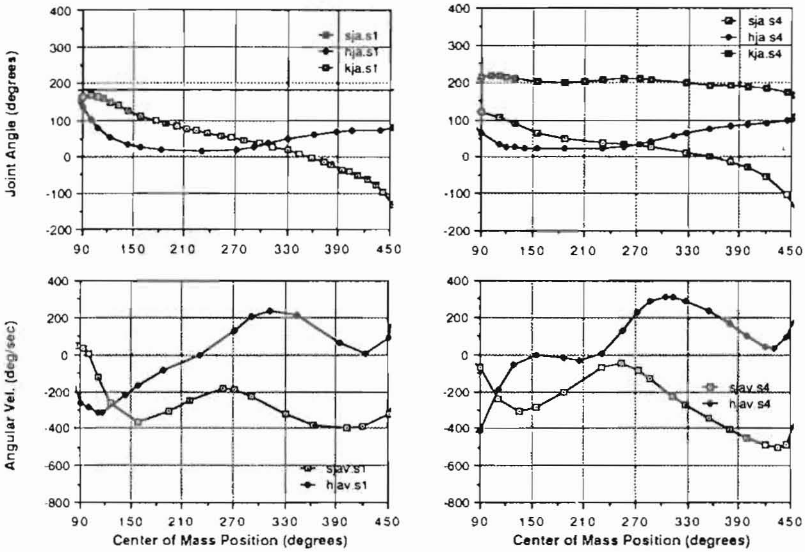

Figure 2. Shoulder (sja), hip (hja), and knee (kja) joint angles, and shoulder (sav) and hip (hav) joint angular velocities for two subjects.

Besides the obvious and most pronounced difference regarding the knee joint angle which however is subject and not technique related, there are no profound or surprising differences in this set of kinematics. Notice, however, the steeper decrease in the hip joint angle of Subject one and the "braking" action at this shoulder joint, which is manifested through a relatively steeper decrease in the joint's angular velocity.

Figure 3 presents the subjects' CM paths and linear velocities. In agreement with the previous figure where body configuration in the form of each joint's angle history was assessed, Figure 3 reveals that the amplitude of the trajectory of the CM of subject one was larger throughout the complete revolution.

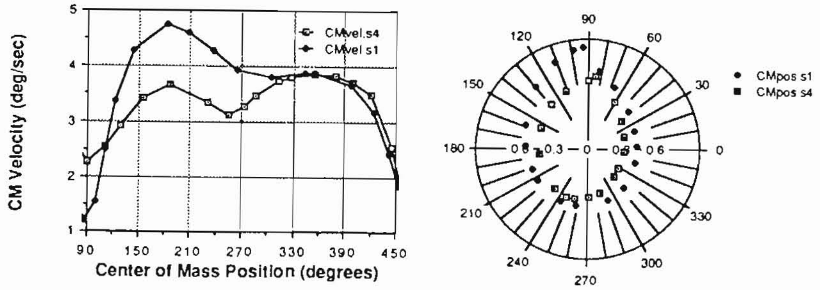

Figure 3. Center of mass velocity (CMvel) and position (CMpos) for two subjects.

Regarding the subjects' CM velocity, Subject four showed two almost symmetrical peaks in each of the descending and ascending portions of the movement, whereas the peak for Subject one was more pronounced midway into the descending phase. An explanation for the "slowing down" when passing through the bottom of the swing (which was found in all subjects) could be that the continuous reduction in shoulder joint angle cannot be achieved at ever increasing speeds. After all, the trunk and upper extremities are "rubbing" each other as the trunk passes "through" the upper extremities in preparation for shoulder joint dislocation. Since the "early drop" technique results in a more pronounced "slowing down," it is suggested that compared to the "late drop," larger hip and/or shoulder joint muscular forces might be needed at selected positions of the ascending phase to complete the movement.

Contrary to some gymnasts' feelings that a "late drop" would require larger forces to keep contact with the bar, it is revealed in Figure 4 that both techniques generate almost identical (total) bar force curves. Maximum values between four and five times body weight were reached near the bottom of the swing, which is in agreement with peak force values reported previously for various giant swings (Prassas and Kelley, 1985; Kopp and Reid, 1980).

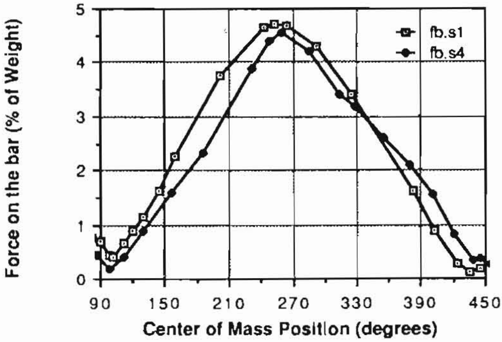

Figure 4. Force on the bar for two subjects.

Table 3 presents summarized data for all subjects. Examination of this data reveals similarities and differences between subjects and techniques. Note, for example, that the timing of the maximum force on the bar was almost identical for all subjects. Or, comparison of the shoulder and hip joints' angular data shows (as expected) larger shoulder and hip joint angles at the initial position and for the shoulder joint at the end of the first quadrant for subjects one and three ("early drop" technique).

TABLE 3
Selected Parameters for the Four "Stoops"

	Subject			
	1	2	3	4
	Shoulder/Hip/Knee Joint Angle (degrees)			
IP	162/134/180	156/106/178	163/155/106	121/65/147
I	96/19.5/180	68/20/83	83/20/157	53/25/160
II	51/20/180	56/56/31	46/25/170	31/33/150
III	-5/61/180	-5/93/180	17/48/174	-1/77/168
IV	-121/75/180	-100/76/180	-55/102/175	-115/100/184
MHJA	13° at 232°	20° at 170°	20° at 181°	22° at 231°
MFB	4.7 at 253°	4.3 at 271°	5 at 268°	4.54 at 259°
SJA of 0° at	355°	353°	388°	353°

IP: initial position; I-IV: (end) of quadrant; MHJA: minimum hip joint angle; MFB: maximum force on the bar (% of weight); SJA: shoulder joint angle; the negative sign denotes joint hyperextention.

In theory, a perfectly executed (and maximally rewarded) "stoop-in" would be one in which the gymnast's body is vertically aligned above the bar, i.e., shoulder and hip joint angle of 180 degrees, at the top of the previous giant swing before the piking motion begins, and again at the top when he "comes out" of the pike after shoulder joint "dislocation" occurs. A movement such as this one would, probably, require that the gymnast passes through zero degrees of shoulder joint angle considerably sooner than any of the present subjects, possibly passing through "zero" degrees at the beginning of the upswing. It would, also require application and utilization of shoulder and hip joint muscular forces (mainly of the extensors) at different positions during the movement and at different joint angles.

Since none of the analyzed "stoop-ins" were similar to the ideal (with the performance of subject one being the most skillful) and since no kinetic data for the shoulder and other joints is yet available, no conclusive and specific recommendations regarding the proper timing for the muscular actions of the shoulder and hip joints can be offered. From a mechanical viewpoint, generation of higher velocities in the downswing (by increasing as much as possible the amplitude of the swing which will require fine coordination of shoulder and hip joint motion) will decrease the additional muscular demands required in the upswing. Higher downswing velocities, however, will generate greater peak bar forces, which have to be accounted for by the gymnast.

Summary and Conclusions

The performance of four gymnasts representing two techniques of the "stoop-in..." was filmed and analyzed. The analysis revealed that, contrary to what it is believed, both techniques generate almost identical total forces on the bar. From a practical standpoint this can be useful in teaching the skill, since it might eliminate some of the fear experienced by beginner gymnasts when first experimenting with the movement.

None of the analyzed performances were ideal. The performance of Subject one was, overall, the most skillful. It was characterized by a "braking"action in the beginning of the descending phase to facilitate the (quick and "tight") hip joint flexion and a relatively large shoulder joint angle at the highest point of the upswing. Additional analysis, including more skilled performances, is needed in order to identify the variables that contribute most to successful execution of the skill.

References

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Acknowledgements

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