# BIOMECHANICAL ANALYSIS OF SEVEN FORWARD GIANT SWINGS AT THE UNEVEN PARALLEL BARS

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## INTRODUCTION

During the downswing phase of a giant swing at the uneven bars, gymnasts are forced to either flex their hips forward ("flexed-hip clearance"), legs close together, or spread their legs wide apart ("straddle clearance") to avoid hitting the lower bar with their feet or shanks. In our sample, gymnasts who chose to clear the lower bar by flexing their hips (Fig. 1) markedly plhyperextended the spine during the second half of the upswing, while gymnasts using the straddle clearance (Fig. 2) maintained a slight flexion at the hips and shoulders during most of the upswing and eventually extended to handstand. Coaches report that gymnasts who hyperextend the spine in the last part of giant swings, when the body is close to handstand position, have a fair chance to get seriously injured at the spine. It must be pointed out that the exercise may be repeated several times a day during training sessions. Is spine hyperextension a painful but forced choice to reach the final handstand when the gymnast does not possesses enough angular momentum at the end of the downswing? Does the straddle clearance help the gymnast to gain more angular momentum during the downswing, so that the gymnast is free to utilize a less effective, but not painful technique during the upswing? The answer to both questions is clearly negative, within the limitations of this study. Data gathered in this study show that, although spine hyperextension is widely used,' it is not the most efficient way to reduce the loss of angular momentum during the upswing, as coaches believe. On the contrary, in our study the loss of angular momentum during the upswing was smaller for gymnasts who did not hyperextend the spine. The upswing with flexed shoulders and hips is not as easy to learn as the upswing with spine hyperextension, but improves performance and does not produce back pain.

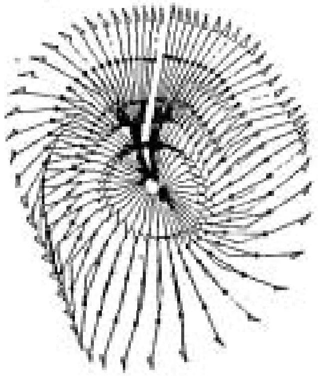

**Figure 1 - Flexed-hip lower bar clearance, and spine** hyperextension during upswing.

## METHODS

Seven performances of forward giant swing were filmed during an International competition in Rome, with a Mekel high speed Super-8 motion picture camera. The average sampling rate was 23.56 Hertz. For each analyzed frame, 11 landmarks were digitized (shoulder joint and suprasternal point were assumed to be coinciding). Quintic spline functions developed by Wood and Jennings (1979) and described in detail by Vaughan (1980) were utilized to smooth the landmark coordinates and calculate instantaneous velocity of landmarks. Inertial parameters reported by Clauser et al. (1969) and adjusted by Hinrichs (1990) were used to calculate mass and center of mass of each segment. Moment of inertia data from Whitsett (1963), personalized for each subject using a procedure described by Dapena

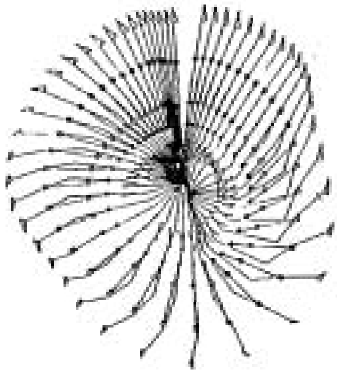

**Figure 2 - Straddle clearance, and flexed hips** and shoulders during upswing.

(1978), were used to estimate the moment of inertia of segments about axes parallel to the bar and passing through the segment center of mass. For angular kinematics, the positive direction was defined as counterclockwise, and the zero degree orientation as the positive y direction (handstand position). The moment arm of the weight force was normalized by expressing it as a proportion of the subjects' stature. Angular momentum and moment of inertia values were normalized by dividing by body mass and squared stature of the subjects.

## RESULTS AND DISCUSSION

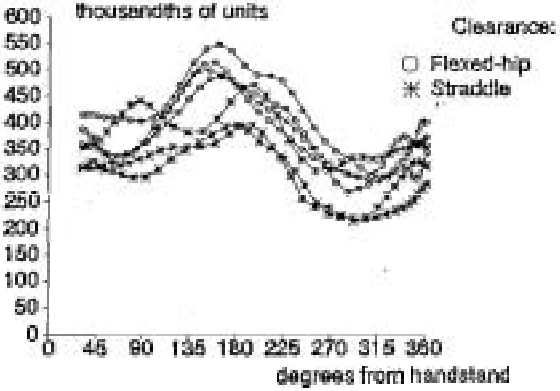

Figure 3 - Normalized moment of inertia of the body about the bar.

A giant swing is a 360 degree rotation about the bar (in this case the upper bar of the uneven bars), starting and ending at the handstand position above the bar. The gymnast's body behaves like a compound pendulum, in which friction forces produced by the air and by the bar have a non-negligible checking effect. Because of those friction forces, if the gymnast were a rigid body, the angular momentum about the bar gained during the downswing would be lost before reaching the final position. However, a gymnast is not a rigid body, and by properly changing her attitude during the exercise she manage to reach the final position with a residual positive value of angular momentum about the bar, sometimes larger than the initial value. Such changes in attitude serve to the following main purposes: gain a large amount of angular momentum about the bar during the downswing phase, and minimize the loss of angular momentum during the upswing. Gain and loss are caused respectively by positive and negative angular impulses about the bar. Both friction forces and weight force produce angular impulses. By changing her attitude, the gymnast is able to modulate the angular impulses associated with the weight force W. Changes in the angular impulses produced by friction forces will not be considered herein. Being the angular impulse by the weight equal to W·r·t, and being W constant, the gymnast can only change **r** (the average moment arm of W) or t (the duration of the considered phase). For example, the gymnast can increase the positive angular impulse (gain in angular momentum) during the downswing in two ways: 1) by increasing the distance of the CM from the bar, thus increasing the average moment arm **r** of the weight force, and 2) by increasing the duration t of the downswing. A longer downswing can be obtained by keeping high the value of the moment of inertia about the bar (Fig. 3), which in turn reduces the average angular velocity of the swing. Both the above conditions are optimally obtained with a stretched layout attitude, with all segments perfectly parallel to a radial axis passing through the bar. Unfortunately, this attitude cannot be held throughout the downswing, due to the obstacle represented by the lower bar. The opposite conditions should be met during the upswing, when a somewhat flexed or hyperextended attitude is required to reduce the negative angular impulse by the weight force. Another method to modulate the angular impulse by weight is based on trading the remote component of angular momentum for the local component and vice-versa, and was described by Hopper (1973, pp.83-85 and 104-106). This method, although used during the analyzed giant swings, did not give a major contribution to angular momentum changes, and will not be considered in detail herein.

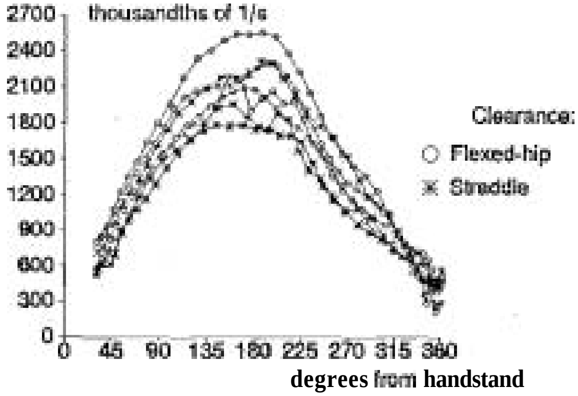

Figure 4 - Normalized angular momentum of the body about the bar.

Comparing the flexed-hip clearance with the straddle clearance, marked differences were detected in the values of the normalized moment of inertia of the body about the upper bar (Fig. 3). In particular, the moment of inertia was remarkably larger for gymnasts using the flexed-hip clearance when their center of mass passed by and beyond the lower bar (from about 90 to 180 degrees). The maximum difference between group means was $134*10^{-3}$ units (adimensional), when the center of mass was at 150 degrees to the upper bar. Beyond 180 degrees, and up to the end of the giant swing average values remained higher for gymnasts using flexed-hip clearance, which also hyperextended the spine during upswing (difference of means oscillating in the range $31*10^{-3}\div90*10^{-3}$ units). The "remote component" of the moment of inertia (Hopper, 1973) was always more that 5 times largerthan the "local component". The remote component of moment of inertia is given by the mass of the body times the square of the distance of its center of mass from the upper bar. The latter distance depends on the distances of segment centers of mass from the bar. According to data which is not reported herein, the distance of the center of mass of the legs from the bar was the main cause of the large difference in the values of moment of inertia from about 100 to 180 degrees. Values of r, the moment arm of W about the bar, were also larger for gymnasts using flexed-hip clearance, throughout the giant swing (maximum difference of means during downswing was 6% of stature at 138 degrees, and during upswing 8% at 252 degrees). The higher values of moment of inertia and weight moment arm about the bar are the reasons why the gymnasts using the flexed-hip clearance had, on the average, larger values of angular momentum at the end of the downswing (180 degrees, Tab. 1 and Fig. 4). In fact the difference at 180 degrees was almost twice the initial difference at 30 degrees. At the end of the upswing (360 degrees) the average angular momentum became slightly smaller for gymnasts using spine hyperextension. It's evident that the latter gymnasts had a larger loss of angular momentum during the upswing (2.194-.409=1.785$s^{-1}$, while the other group lost only 1.933-.466=1.467$s^{-1}$).

Table 1

Average normalized angular momentum (s") when the body center of mass position is 30, 180, and 360 degrees relative to upper bar. (Group A: flexed-hip lower bar clearance, and spine hyperextension during upswing. Group B: straddle clearance, and flexed hips and shoulders during upswing).

| | at 30 degrees | at 180 degrees | at 360 degrees |
|---|---|---|---|
| Group A | .760 | 2.194 | .409 |
| Group B | .621 | 1.933 | .466 |

## CONCLUSION

Gymnasts typically want to have some residual angular momentum at the end of a giant swing, to immediately start a new exercise keeping the same direction of rotation. Angular momentum is gained during most of the downswing and lost during the upswing. Gymnasts are free to choose any technique limiting the loss to a value equal or smaller than the gain. Contrary to the common opinion, during the downswing the "hip-flexion clearance" produces a larger gain in angular momentum than the "straddle clearance". Gymnasts using the "hip-flexion clearance" can afford a larger loss of angular momentum during the upswing. Indeed, the spine hyperextension performed during the upswing by the latter group of gymnasts is associated with a larger loss of angular momentum compared to the slight hip and shoulder flexion used by the other group. The above findings do not support the common opinion that gymnasts must needs learn the straddle clearance to free themselves from the slavery of spine hyperextension, although the opposite is not proved herein. It should be pointed out that some gymnasts cannot perform the straddle clearance due to insufficient active flexibility. Although both lower bar clearance techniques give gymnasts enough angular momentum to perform'the upswing without hyperextending the spine, in practice other factors may still force some gymnasts to hyperextend, and not only when they perform the flexed-hip clearance. For example, spine hyperextension may be used by relatively weak gymnasts, to reduce the intensity of the contraction of the shoulder extensor muscles in the second half of the upswing, by shortening the moment arm of the bar reaction force with respect to the shoulders. Dynamometry is needed to investigate this hypothesis, since torques at the shoulders may not be reliably calculated with the inverse dynamics approach when the hands are in contact with a fixed external object. Spine hyperextension might also be explained as a natural reflex induced by the intense contraction of shoulder extensor muscles during the second half of the upswing. Last but not least, spine hyperextension may be traditionally linked with the "flexed-hip clearance" for simple historical reasons. Hip and shoulder flexion during the upswing may be made easier by a stronger "leg whipping action" (Manoni, 1987, pp. 124-127). This action is slightly stronger with straddle clearance than with flexed-hip clearance. It must be pointed out, however, that both group of gymnasts flex hips and shoulders in the first half of the upswing, by about the same angles (hyperextension occurs in the second half). It is suggested that the spine hyperextension executed at the end of giant swings be indicated in the International Code of Points as an infraction, and punished with an appropriate point deduction during competitions. Such rule would undoubtedly represent an important means for preventing injuries at the spine in gymnastics.

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