MOMENT OF FORCE AND MECHANICAL POWER IN GIANT SWING ON THE HORIZONTAL BAR

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Introduction

In the giant swing backwards, frictional force acts upon the grip and air resistance acts upon the whole body (Hay, 1978; and Kreighbaum and Barthels, 1981). These resistive forces affect the rotation of the body and cause a loss of mechanical energy. Therefore in order to complete the rotation, the gymnast has to offset these energy losses using muscular work (Hay, 1978). It has been reported that changes in mechanical energy occur during the backward giant swing. The total energy of the body is decreased during the second half of the downswing and almost recovered in the first half of the upswing. These results suggest that muscular work is done in the first half of the upswing to offset the loss of mechanical energy in the last half of the downswing (Okamoto, Sakurai, Ikegami and Yabe).

The purpose of this study is to examine both the role of each joint of the body in generating mechanical energy by measuring the moment of force and the mechanical power at each joint in forward and backward giant swings, and to compare the forward and backward swings from the viewpoint of mechanical power generation.

Methods

The subjects in this study were five male university gymnasts. Their physical characteristics are shown in Table 1.

Table 1 Physical characteritics of the subjects.

Subject	Age (yrs)	Weight (kg)	Height (m)
1	20	57. 0	1. 62
2	21	58. 2	1. 63
3	19	60. 3	1. 62
4	21	62. 3	1. 67
5	19	66. 1	1. 67
mean	20. 0	60. 8	1. 64
SD	0. 9	3. 2	0. 02

Table 1: Physical characteristics of the subjects.

The subjects performed the giant swing backward and forward on the horizontal bar. These performances were filmed from the side with a high-speed camera (Photo Sonics 16-1PL) at a speed of 33 frames per second. The optical axis of the camera was perpendicular to the plane of motion. Prior to the filming, body landmarks were identified on the gymnasts.. Each rotation, starting from the handstand position, was divided into four phases. Each phase consisted of 90 degrees of angular displacement. (Figure 1)

An eight-segment mathematical model of the body was used for mechanical analysis. This model consisted of the head, trunk, upper arm, forearm, hand, thigh, shank, and foot segments. The body landmarks were digitized from the films to obtain the required coordinates. The segment masses and center of mass were calculated from the data of Dempster and the segment moments of inertia were obtained from the data of Widule.

The segment endpoint data were smoothed using a digital filter with a cutoff frequency of 3.1 Hz. The moment of force at each joint was obtained by solving the equation of motion about the eight-segment mathematical model, and then mechanical power at each joint was calculated as the product of the moment of force and the angular velocity of each joint (Winter, 1979). However, power at the wrist joint could not be calculated because the dactylion is hardly seen in the films. Therefore, total power was calculated by summing the power at six joints of an eight-segment mathematical model (without the wrist joint).

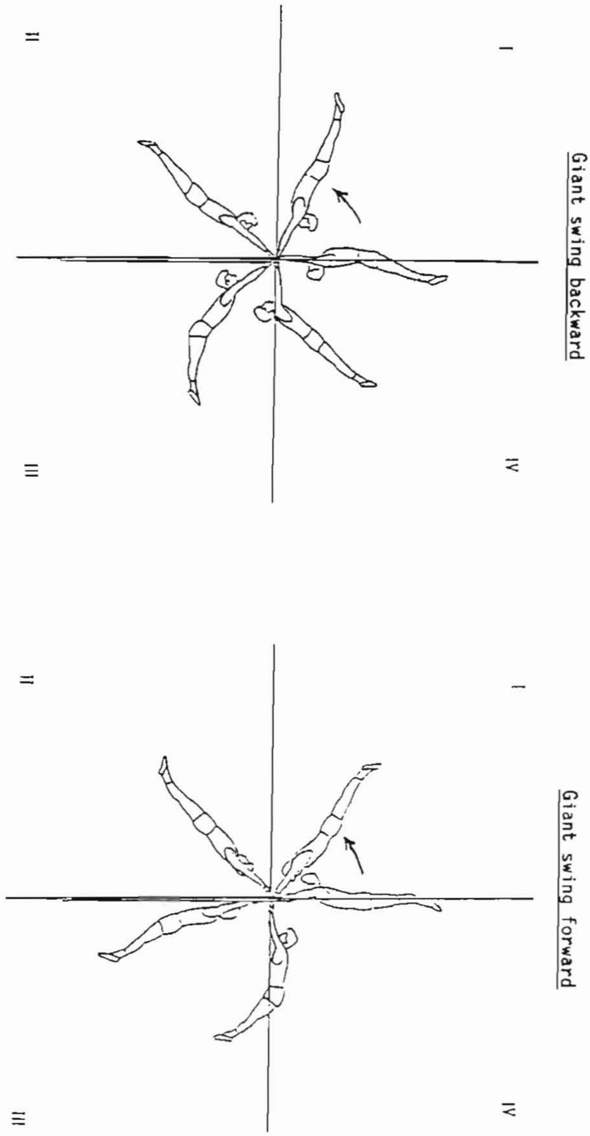

Figure 1: Analytical phases in the giant swing backward (left) and forward (right) on the horizontal bar.

The period for one rotation was normalized to 100%. The moment of force and mechanical power of each subject was divided by his body mass for standardization. After normalization, average curves of joint angle, moment of force and mechanical power were calculated at each 0.25% interval of the one normalized rotation period to coincide with the four phases described above. The standard deviation at each of these intervals was also calculated.

Results

In the giant swings backward and forward, most of the total power was generated by the hip and shoulder joints. The other joints hardly generated any mechanical energy. Consequently, only data from analyses of the hip and shoulder joints are presented.

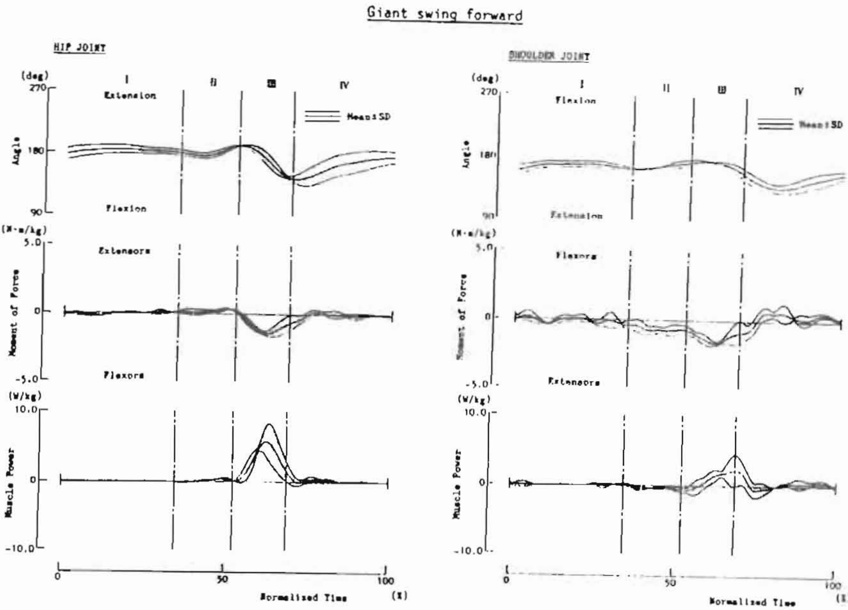

Figure 2: Changes in angle (upper), moment of force (middle) and muscle power (lower) at hip (left) and shoulder (right) joints in the giant swing backward on the horizontal bar.

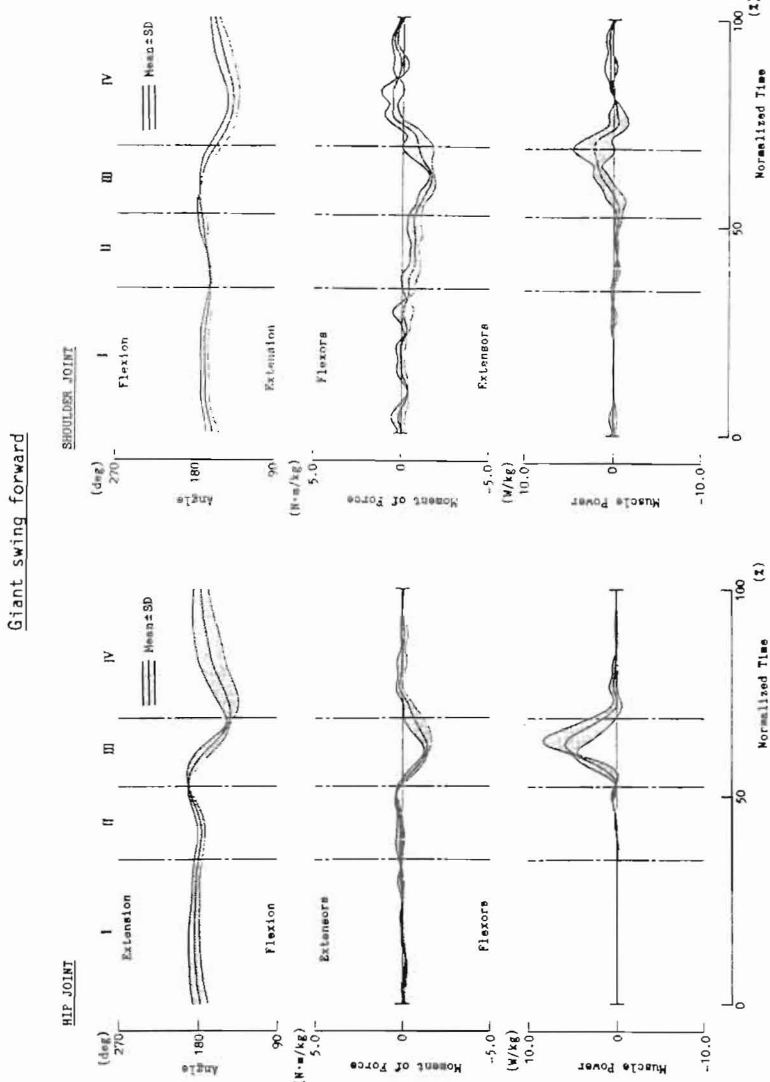

Figure 3: Changes in angle (upper), moment of force (middle) and muscle power (lower) at hip (left) and shoulder (right) joints in the giant swing forward on the horizontal bar.

Figure 2 and 3 show the changes in angle, moment of force and muscle power at hip and shoulder joints in both swings. During the third phase of both swings movement was observed at the hip joint. Flexion of the hip joint was observed during forward giant swing, and in the same phase extension of the shoulder joint was also observed for the giant swing backward. In the giant swing forward, extension of the shoulder joint was observed from the end half of the third phase to the early fourth phase. Most of the muscle power at the hip and shoulder joints showed positive values in the third phase of both swings.

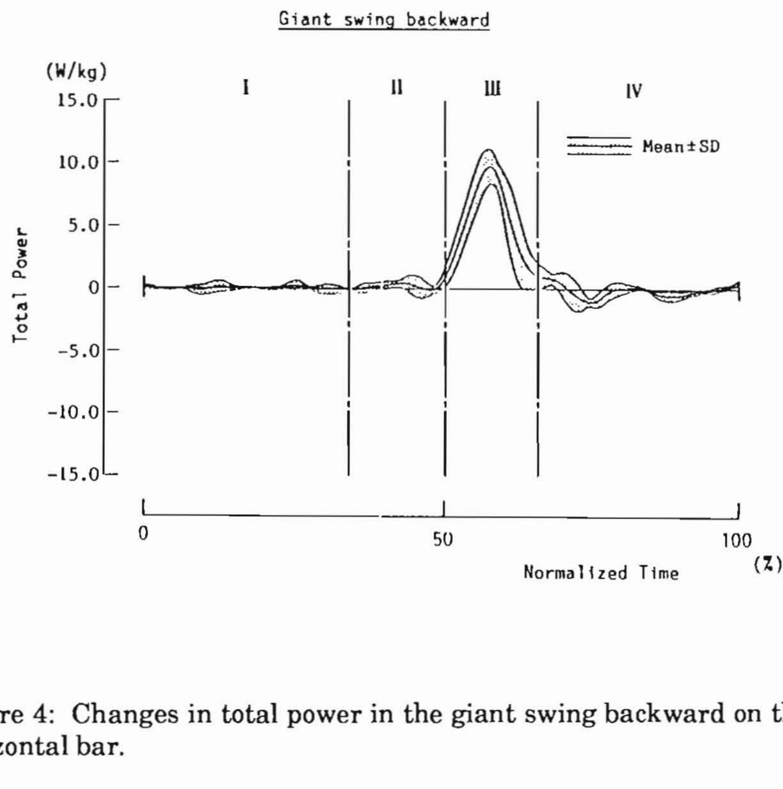

Figure 4: Changes in total power in the giant swing backward on the horizontal bar.

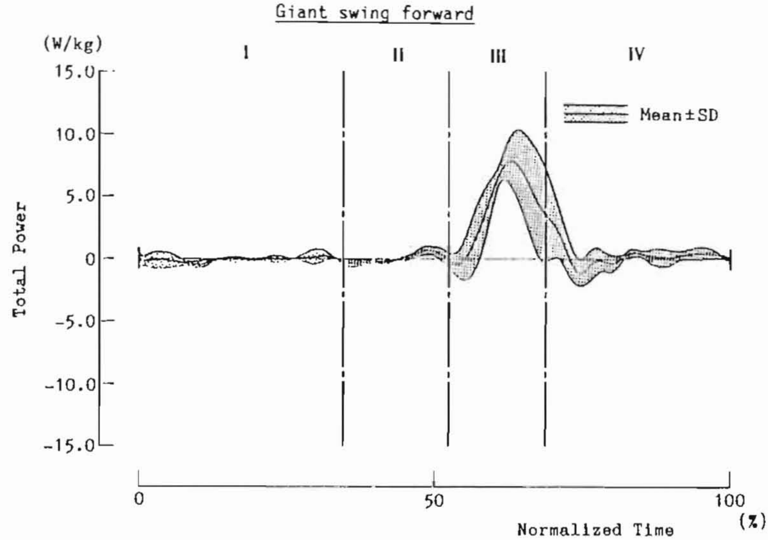

Figure 5: Changes in total power in the giant swing forward on the horizontal bar.

Figure 4 and 5 show changes in the total power of both swings. The majority of the total mechanical power was generated in the third phase.

Figure 6 and 7 show the maximal power at the hip and shoulder joints in both swings. In the backward giant swings, the maximal power at the hip and shoulder joints was 5.55 ± 0.78 (W/kg) (mean ± SD) and 6.34 ± 2.11 (W/kg), respectively. This difference in maximal power between the hip and shoulder joints was not statistically significant. On the other hand, the maximal power at the hip and shoulder joints in the forward giant swing was 6.75 ± 1.04 (W/kg) and 3.32 ± 1.11 (W/kg), respectively. Overall the maximal power at the hip joint was significantly larger than that of shoulder joint.

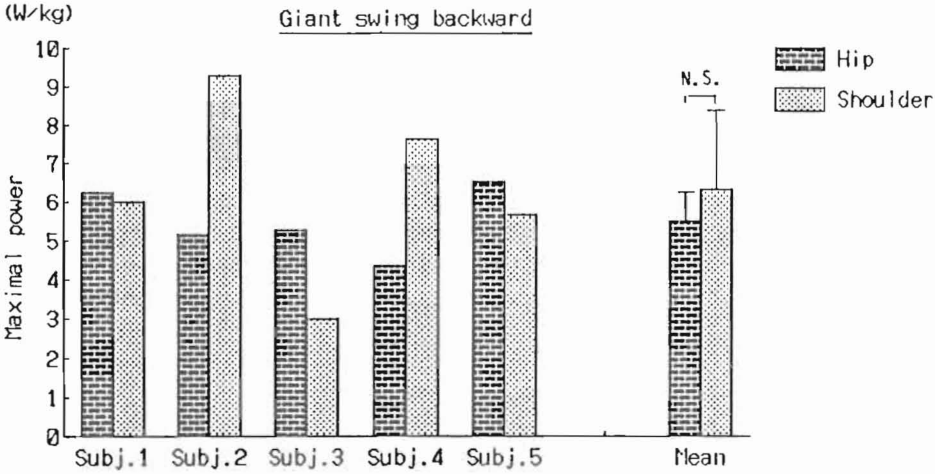

Figure 6: Maximal power of hip and shoulder joints in the giant swing backward on the horizontal bar. N.S. indicates that the difference is not statistically significant.

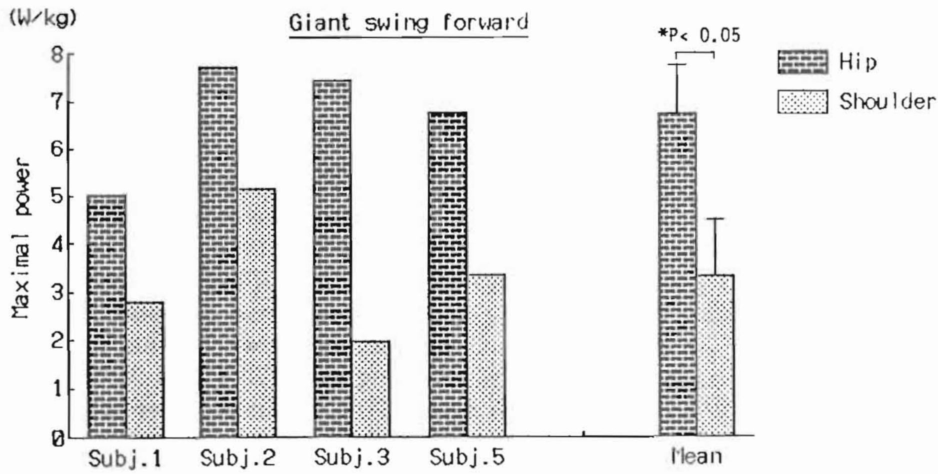

Figure 7: Maximal power of hip and shoulder joints in the giant swing forward on the horizontal bar. Asterisk indicates that the difference is significantly different.

Discussion

When giant swings are performed on the horizontal bar, a frictional force and air resistance act on the rotating body of the gymnast. These resistive forces decrease the mechanical energy of the gymnast's body. To make the rotation successful muscular work must be done to compensate for the loss in mechanical energy during the downswing. This work should be sufficient to raise the energy to the level established in the handstand position,

In the present study, changes in the moment of force and mechanical power at each joint could be measured continuously be utilizing cinematography and a mathematical model for analysis of giant swings. Mechanical power was generated by flexion of the hip joint and extension of the shoulder joint in the third phase of both swings. Thus, muscular work was done in the third phase of both swings to offset the losses in mechanical energy due to friction and air resistance.

In the backward giant swing, flexion of the hip joint and extension of the shoulder joint accelerate the rotation of the body. On the other hand, these movements in the forard giant swing decelerate the rotation of the body. Extension of the shoulder joint is more effective than flexion of the hip joint in decelerating the rotation of the body in the forward giant swing. Therefore, maximal power of shoulder joint was smaller than that of hip joint in this swing.

Conclusion

It was concluded that muscular work was mainly done by the hip and the shoulder joints to offset the energy losses due to friction and air resistance in the forward and backward giant swings on the horizontal bar. Most of the positive work was done by flexion of the hip joint and extension of the shoulder joint in the first half of the upswing during both swings. The difference in maximal power between the hip and shoulder joints was not statistically significant in the backward giant swing. However, maximal power at the hip joint was significantly larger than that of shoulder joint in the forward giant swing.

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