INTRODUCTION

There have been various studies on the release parameters of a javelin, such as the release angle, attitude angle, attack angle and initial velocity (Bartlett et al, 1996; Best et al, 1993; Best et al, 1995). These studies suggested that initial velocity was the most important factor for obtaining the throw distance. However, the rational throwing movements needed to obtain a higher initial velocity were not clarified.

The purpose of the present study was to investigate the kinematic characteristics of javelin throwing movement in order to clarify the most effective technique and its mechanism.

METHODS

The subjects were 49 male javelin throwers, whose throwing movement was filmed at 200 fps using two high-speed video cameras at three official athletic competitions in Japan. The range of the throwing trials investigated was 45.25 m to 77.22 m. Twenty-four body landmarks and three points (tip, grip and tail) on the javelin were digitized and their three-dimensional coordinates were calculated using the DLT method. The optimum cut-off frequency (4.5–20.5 Hz) was determined using the residual analysis method, and the coordinates were smoothed by the 4th Butterworth digital filter. The items calculated were the body’s segments and the force applied to the javelin. The force applied to the javelin was the product of the acceleration of the javelin’s center of mass and the mass of javelin (800 g).

RESULTS AND DISCUSSION

Segment angle of the throwing arm at javelin release

Figure 1 shows the relationships between the initial velocity and the elbow joint angle (upper figure) and adduction-abduction shoulder joint angle (lower figure) at the moment of javelin release. Elite throwers had a tendency to keep the elbow joint angle and adduction-abduction shoulder joint angle smaller at the moment of release ($r=-0.437$, $p<0.001$; $r=-0.454$, $p<0.01$, respectively). These results indicate that elite throwers released the javelin at a smaller elbow joint angle and a smaller adduction-abduction shoulder joint angle, suggesting that elite throwers accelerated the javelin with a more flexed position of the elbow joint and a more adducted position of the shoulder joint.

That is, elite throwers utilized more internal rotations of the shoulder joint than novice throwers to obtain a high initial javelin velocity. Although it has been generally instructed by coaches to keep the elbow high (abducted position of the shoulder joint) and to extend the elbow joint at the moment of release, the present results suggest that these instructions should be reconsidered.

Front knee angle at the moment of foot contact and javelin release

Figure 2 shows the relationships between the initial velocity and the front knee angle at the moment of foot contact (upper) and javelin release (lower). Both of the knee angles showed significant negative correlations with the initial javelin velocity.

These results suggested that elite throwers had a tendency to keep the front knee angle at a more extended position during the phase just prior to release. Whitting et al (1991) have reported that the front knee angle was greater during the same phase in throwers who demonstrated better performance. The present results agreed with their findings, and support the general coaching instructions to keep the knee extended position to change the approach.
running velocity into the forward rotation of the trunk effectively.

Force applied to the javelin

The force required to accelerate the javelin was calculated as the product of the acceleration of the center of mass of the javelin and the javelin mass. Figure 3 shows the average changes in the force applied to the javelin in novice, middle and elite groups whose throwing distances were 45 m to 60 m, 60 m to 70 m, and 70 m and over, respectively. The elite group developed a remarkably high rate of force development followed by a higher peak force, and the force remained higher until javelin release. The peak force and the force at the moment of javelin release showed a significant positive correlation with the initial javelin velocity (r=0.727, p<0.001; r=0.586, p<0.001, respectively: fig.4). These findings support the characteristics of changes in force development observed in Figure 3.

Although the peak force showed a significant positive correlation with the acceleration of the forward arm swing (the acceleration of the grip minus that of the shoulder; r=0.688, p<0.001: fig.5), the angular acceleration of forward rotation of the trunk showed no significant correlation.

These results suggested that the arm swing played an important role in development of the force applied to the javelin.

Figure 2: Relationships between the initial javelin velocity and the front knee angle at the moment of front foot contact (upper) and javelin release (lower). **: p<0.01

**SUMMARY**

Elite throwers generate a higher peak force and apply it until the moment of javelin release. The force is generated mainly by the arm swing, and elite throwers demonstrated an arm movement with a more flexed position of the elbow joint and a more adducted position of the shoulder joint. Thus, these arm movements play an important role in
development of the force applied to the javelin to achieve a higher initial velocity. The present study has clarified that elite throwers accomplish an effective movement in order to obtain a longer throw distance.

**REFERENCES**


**Figure 5:** Relationship between the initial velocity and the acceleration by arm ***; p<0.001