BIOMECHANICS OF THE OI-TSUKI IN ZENKUTSU-DACHI

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INTRODUCTION

The punch studied herein is the oi-tsuki (lunge punch) in zenkutsu-dachi (front stance). A common description found for this skill is as follows. In the zenkutsu-dachi position the knee and hip of the front leg are flexed. The rear leg is extended at the knee with the hip joint in outward rotation. The rear foot is dorsiflexed at the ankle and directed forward and outward. The outward rotation of the ankle is between 20 and 45 degrees. Weight distribution on front and rear feet is 60 and 40 percent. The length of the stance is twice the width of the karateka's shoulders. The fist with which the punch is delivered is placed at the waist, forearm supinated. During the forward motion in zenkutsu-dachi the rear leg slides forward and at the same time the fist is accelerated as the forearm extends at the elbow and the arm flexes at the shoulder. The fist starts at the waist with the closed palm upward and as the fist is moved forward, the forearm pronates until the closed palm is downward when the arm is fully extended.

Authors of karate books disagree about certain aspects of an oi-tsuki in zenkutsu-dachi. They disagree about the turn-out angle of the rear foot, the weight distribution on front and rear feet, and the length and width of stance.

Nakayama said the front foot should bear 60 percent of the body's weight and the rear foot 40 percent (Nakayama, 1981). Song claimed that 70 percent of the body's weight is supported by the front foot and 30 percent by the rear. The turn-out angle of the rear foot should be between 20 and 30 degrees (Song, 1968). Ventrusca suggested a turn-out angle of 45 degrees of the rear foot (Ventrusca, 1970).

Need for the Study. An objective analysis of the oi-tsuki in zenkutsu-dachi would reveal how highly experienced karatekas actually execute the oi-tsuki in a zenkutsu-dachi and such information could be reflected in teaching cues.

Purpose of the Study. The purpose of this study was to perform a kinematic analysis of the oi-tsuki (lunge punch) in a zenkutsu-dachi (front stance) as performed by highly skilled karate athletes using three different foot positions of the rear leg to investigate the relationship between foot position and execution time. The subjects performed the oi-tsuki in a natural foot position (condition 1), in a zero-degree foot position with specified stance (condition 2), and a zero-degree foot position with no specified stance (condition 3). Research questions about velocities of body parts (trunk, fist, ankle), length and width of stance, weight distribution on front and rear feet, and the turn-out angle of the rear foot were posed.

Hypothesis. The execution time for delivering the oi-tsuki in zenkutsu-dachi is less in a zero-degree foot position with no specified stance or a zero-degree foot position with a specified stance than it is in the natural foot position of the rear foot.

REVIEW OF LITERATURE

The review of literature showed that little research has been done which deals with the oi-tsuki performed in a zenkutsu-dachi. In the forward punch (oi-tsuki) the fist reached speeds between 5.7 and 9.8 meters per second (Feld, 1979, Nakayama, 1966). Plagenhoef investigated a boxer's punch and a karate chop and presented tracings in two planes. He concluded that the energy which can be transferred from a human body to an object depends on the striking mass, the velocity of the striking mass, and the rigidity of the human body (Plagenhoef, 1971).

Theoretically, positioning the rear foot parallel (zero-degree foot position) to the desired direction of body motion (forward) would be more effective than turning the foot outward. In the zero-degree foot position the whole length of the foot (heel to toe) can be used as a lever. This would give the foot more time to apply force against the ground (Dyson, 1973).

In the zero-degree foot position the gastrocnemius and soleus muscles are more prestretched due to the dorsiflexion of the foot than in the toe out position (plantarflexion and eversion). This greater prestretch in the zero-degree foot position increases the possible tension developed upon contraction (Barthels, 1981). Track and field coaches who were interviewed favored the turn-out angle of zero-degrees. Supporting this position, literature indicated that the zero-degree foot position, in theory, maximizes the amount of force applied in the direction of the desired movement.

METHODS

The subjects were four karatekas with either a black or a brown belt. No long term training in the changed foot positions was given. The subjects each performed ten trials in a natural foot position, in a zero-degree foot position with specified stance, and in a zero-degree foot position with no specified stance. Five of these trials in each condition were filmed with a high speed S-8 camera at 200 frames per second. The film was used to calculate velocities of body, fist, and ankle. The raw displacement values were smoothed by using a smoothing routine computer program by Miller (Miller, 1984). Measurements were taken of shoulder width, length and width of stance in the natural and zero-degree foot positions with no specified stance, the turn-out angle, and the weight distribution on front and rear feet.

Sheets of transparent graph paper with one hundred 0.1 inch squares per square inch were placed over white sheets of paper that had outlines of the subjects' foot prints. The length of stance was measured by counting the squares from the middle of the rear heel to the front heel. The width of the stance was measured by counting the squares between the middle of the right heel and the middle of the left heel. A line connecting the middle of the second toe and the middle of the heel was drawn on the footprint of the rear foot. The angle between this line and the foot's forward line of progression was measured with a protractor and called the turn-out angle.

Two Detecto physician's scales were used to measure the weight distribution between front and rear feet. The biacromial shoulder width was measured with a sliding caliper.

A complete block design was used to test the hypothesis that the execution time was less in a zero-degree foot position with no specified stance or a zero-degree foot position with specified stance than it was in a natural foot position.

RESULTS

The findings revealed that there is no significant difference in the execution times and the research hypothesis was therefore rejected (Table 1).

Table 1. Mean Execution Time for Each Subject in Each Condition (sec ± s.d.)

	Execution Times		
Subject	Condition 1[a]	Condition 2[b]	Condition 3[c]
1	.769 ±.052	.889 ±.066	.838 ±.055
2	.862 ±.020	.797 ±.040	.823 ±.021
3	.747 ±.026	.748 ±.022	.777 ±.032
4	.592 ±.016	.602 ±.044	.587 ±.036

F-value obtained 0.20 (n.s)
required F-value to be significant* 5.17
df = 2,3,6

*α = 0.05

[a]natural foot position

[b]zero-degree foot position with specified stance

[c]zero-degree foot position

Other findings include the following:

1. Body parts (trunk, fist, and ankle) did not reach their respective highest velocities at the same time. Two subjects with more training experience had a shorter time range within which their body parts reached their respective highest velocities. The shapes of the velocity graphs for all subjects in the three conditions were similar. The shapes of the velocity graphs compared from subject to subject were also similar (Figure 1).

2. The mean length of the stance in the natural foot position was less than suggested by authors of karate books. Subject three decreased his length of stance in the zero-degree foot position as compared to the natural foot position, whereas all other subjects increased their length of stance.

3. The mean weight distribution between front and rear leg in the natural foot position was 53.8 and 46.2 percent. For the zero-degree foot position it was 50.5 and 49.5 percent.

4. The mean turn-out angle of the rear foot was 27.3 degrees and ranged from 11 to 47 degrees.

<u>Qualitative Observations.</u> All subjects were observed to have the shoulder joint hyperexteded in the sagital plane and moved the punching arm backward (decrease of velocity) during the forward movement of the body.

The front legs of subjects 3 and 4 slid back a few inches at the beginning of the forward movement of the trunk in the oi-tsuki in zenkutsu-dachi in each trial.

DISCUSSION

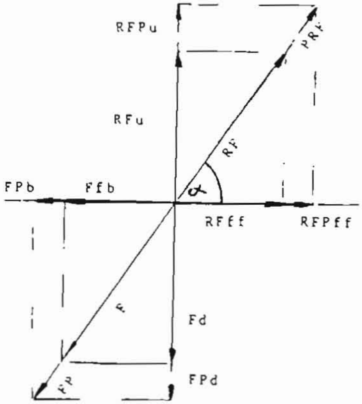
The mean execution times did not differ enough to be statistically significant when the natural foot position was changed to a zero-degree foot position with specified stance or to a zero-degree foot position with no specified stance.

When the natural foot position was changed to a zero-degree foot position other variables such as weight distribution and length and width of stance also changed. These changes indicate that when one variable is changed other variables are also affected.

When the turn-out angle of the rear foot was zero-degrees, more weight was shifted onto the rear foot. This increase of weight on the rear foot with the shift of the center of gravity towards the rear might have been one reason why the zero-degree foot position was not more effective than the natural foot position in executing a lunge punch, despite the mechanical advantage of a zero-degree turn-out angle.

The following model demonstrates a possible explanation for why the execution time in the zero-degree foot position was not shorter than it was in the natural foot position. Figure 2 shows the forces applied by the rear foot to the ground and the equal and oppositely directed ground reaction forces applied to the foot.

During push-off the rear foot exerts additional push forces downward (FPd) and backwards (FPb). F will increase by the amount of the push-off force (FP). If the maximum Ffb is insufficient during push-off to allow the fast extension of the push-off leg without the foot slipping, the rear foot slips backward during this extension and less of the ground reaction force is used to accelerate the body. This can happen when   becomes very small (when the stance is very long). More weight is on the front foot and Fd of the rear foot decreases. This decreases Ffb. Consequently, during push-off RFff required to hold back the foot cannot be obtained and the rear foot slips backward. This may be the reason why Subject 3 decreased the length of his stance in the zero-degree foot position with no specified stance as compared to the natural foot position. If more weight were shifted onto the rear foot Fd would increase and so would Ffb. This would increase   and RF would point further upward. When pushing off, greater force would be directed upward than forward and less force would be available to accelerate the body in the forward direction.



F force
Fd force downwards
Ffb friction force backwards
FP push-off force
FPd push-off force downwards
FPb push-off force backwards
RF reaction force
RFff friction force forwards
RFu reaction force upward
PRF push-off reaction force
RFPff push-off friction force forwards
RFPu push-off reaction force upwards

Figure 2. Action Forces and Ground Reaction Forces against the Rear Foot of a Karateka

This author concluded that there must be an optimum range for stance length where all factors (α and forces) are in an optimum ratio to accelerate the body forward as fast as possible. If the stance is too short or too long, execution time might increase.

Another possible explanation of why the execution time did not change in the zero-degree foot position as compared to the natural foot position could be that the push-off with the rear foot is not an important factor in reaching a fast execution time. The subjects were more experienced in the natural foot position and had received no long term training in the zero-degree foot position. They were not significantly faster or slower in execution time between the different foot positions, so one may conclude that karatekas who are well-trained in a zero-degree foot position may significantly decrease their execution times.

The most kinetic energy could theoretically be transferred when body velocity and fist velocity are highest at instant of impact. By this author's assumption, Subjects 3 and 4 should be able to transfer more energy to a target than Subjects 1 and 2 because their highest trunk and fist velocities occurred closer together.

Another factor determining the amount of kinetic energy which can be transferred is the rigidity of the body at instant of impact (Plagenhoef,1971). The rigidity of the body could not be determined in this study and further investigation with respect to this aspect of the punch is necessary.

CONCLUSIONS

Based on the findings in this study this author concluded that there was no advantage with regard to execution time when the oi-tsuki in zenkutsu-dachi was performed with a zero-degree foot position compared to a natural foot position.

The turn-out angle of the rear foot is dependent on the subject's range of motion of the hip, knee and subtalar joints.

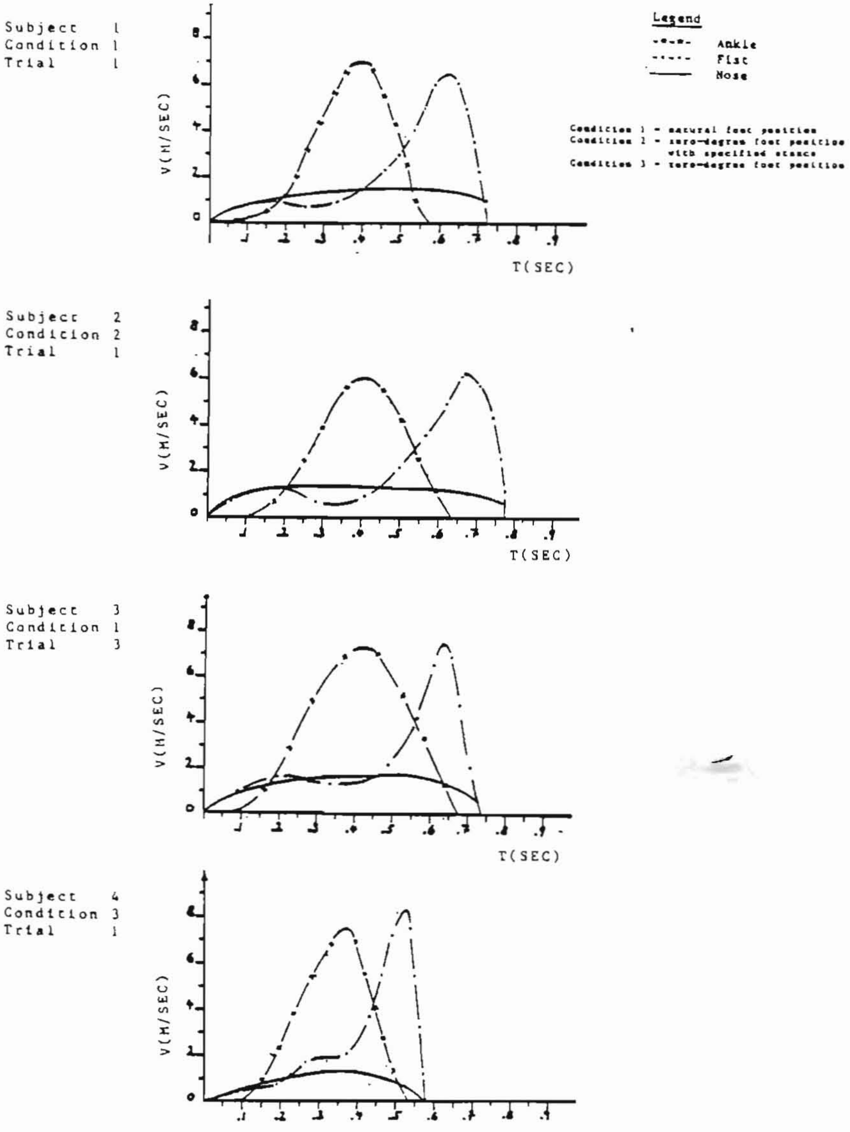


Figure 1. Fastest Trials of All Subjects

More experienced karatekas had a smaller time range within which body parts reached their respective highest velocities and therefore could generate more kinetic energy for impact than did less experienced karatekas.

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