
BIOMECHANICS OF COMBATIVES AND MARTIAL ARTS

AN ANALYSIS OF WORK AND POWER PRODUCED BY DIFFERENT KARATE STYLES IN THE KARATE REVERSE PUNCH IN FRONT STANCE

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Introduction

The purpose of this study was to obtain baseline kinematic data on the work and power produced by different karate styles in the karate reverse punch in front stance. It is the second part of a two part study on the kinematics of the reverse punch in front stance. The first part, which dealt with an analysis of movement patterns is presented elsewhere in these proceedings. (Stull and Barham, 1988) Four black belt performers were selected as subjects for these two studies. One subject was selected to represent each of the four karate styles studied, which were Shotokan, Tae Kwon Do, Kung-fu, and Kempo. Each of these styles placed emphasis on the reverse punch in front stance, and each subject was highly skilled in the execution of this technique. The subjects were allowed to use their dominant punching hand and were filmed at 100 frames per second with the camera located perpendicular to the sagittal plane of the movement. It was hypothesized that the work and power involved in the execution of the karate reverse punch in front stance would be approximately the same for all styles.

The Concepts of Work, Energy and Power

The concepts of work, energy, and power are concepts that are not well understood by many professionals in the sports world. A powerful punch, for example, is not one that necessarily impacts with the greatest force and/or that does the greatest damage to an opponent or object struck. These effects are produced by the kinetic energy of the punch and not its power. Because of this wide spread misunderstanding it is important that we take time now to review these concepts.

The Concepts of Work and Energy

The concepts of mechanical work and energy are interrelated in that work produces energy and energy is anything capable of doing work. This interrelationship is given by the following equation:

$$FD = mgh + 1/2 mV^2 \quad (\text{equation A})$$

The left side of equation A, (Fd), is identified as the work done during a movement situation, while the two quantities on the right side are identified as the gravitational potential energy, (mgh), and the kinetic energy, ($1/2mV^2$), produced by the work.

The significance of equation A is that it shows that the speed (V) of the fist in a karate punch, for example, and its energy ($1/2 mV^2$) at the time of contact with an opponent or object struck are produced by the work (Fd) done by the karateka during the delivery of the punch. The limiting factors here are (1) the amount of net force produced by the karateka and (2) the distance over which the punch and therefore the force is delivered. In the karate reverse punch, where the fist follows a horizontal straight line path, the work done by the karateka produces no gravitational potential energy. Only kinetic energy is produced in this punch, and it is this energy that does work upon the opponent or object struck. The right side of equation A shows that kinetic energy and therefore the amount of work done is dependent upon the amount of body mass (m) brought into the motion and the speed (V) of the fist at the moment of contact.

Equation A can be rearranged to obtain the equation below, which gives the force delivered by a punch at the moment of impact.

$$F = \frac{1/2 mV^2}{d} \quad (\text{equation B})$$

This equation shows that the force of impact of a punch is directly proportional to the kinetic energy of the fist and inversely proportional to the distance over which the kinetic energy is absorbed. The force of the impact and therefore the potential damage done to an opponent or object struck can be increased by reducing the amount of "give" during the impact by either the karateka or the opponent or object struck.

The Concept of Power

The concept of power is illustrated by dividing both sides of equation A by the time (t) during which the work is done to obtain

$$\text{Power} = \frac{Fd}{t} = \frac{mgh}{t} + \frac{1/2 mV^2}{t} \quad (\text{equation C})$$

The right side of equation C is especially interesting because it gives the rate of energy production. In many human performance situations, especially in karate, it is the rate of kinetic energy production that is the most important. A given amount of kinetic energy, for example, can be produced rapidly or it can be produced slowly. The key concept here is that power is given by the speed of the energy production, i.e., the greater the speed the greater the power.

Equation A shows that a given amount of kinetic energy can be produced by either a large force acting through a short distance or a smaller force acting through a longer distance. Applying the force, however, through the longer distance will usually require more time so that the rate at which the kinetic energy is produced is less and by definition there is less power (equation C).

The Roles Played by Work and Power in Karate

Analysis of the power of the karate reverse punch, since no gravitational potential energy is produced, requires an analysis of the speed of kinetic energy production. The power of a punch, i.e., the rate at which kinetic energy is produced, is important in some karate situations, while in other situations it is only the amount of work done in the production of peak kinetic energy of the fist at the time of contact

that is important. These two types of situations produce two different priorities for the karateka.

The two priorities are represented as end points on a continuum with the priority for work at one end and the priority for speed at the other. The priority for work exists when there are no time constraints and the performance goal is the production of maximum kinetic energy. The priority for speed exists when there is a rigid time constraint and the performance goal is to produce a quick response.

The two extreme examples of these priorities are light-contact sparring and board breaking. In light contact sparring, the goal is to score points to selected target areas on an opponent. To be effective one must maximize the speed of response since the goal is not to deliver a blow to the opponent, but only to score a "touch" or point. Board or object breaking, on the other hand, is a situation in which response time is not important and the priority is upon the production of maximum (peak) kinetic energy at the moment of impact so that the greatest amount of work is done on the board or object struck. In many self-defense and full contact sparring situations, however, there is a mixing of the two priorities. In these situations there is a need to strike quickly so that the blow can be landed without being slipped or blocked, yet have enough kinetic energy to make the blow effective.

Analysis of Work and Power in the Present Study

The Results

The velocity-time curves for the fist obtained for the four karate styles are shown in Figure 1. It is evident from these curves that the quickest of the four performers was the one using the Shotokan technique with similar curves being shown for the Kempo and Kung-fu performers. The Tae Kwon Do (TKD) performer, however, developed the greatest peak velocity and, therefore, the greatest kinetic energy (assuming that the mass utilized by the four performers in their movements was a constant).

Discussion

The obvious conclusion that must be drawn from this study is that the research hypothesis of similar work and power being produced during the performance of the reverse punch in front stance by the four karate styles must be rejected. This conclusion is supported by the

results of this study, which indicate the different karate styles must be analyzed in terms of their different priorities. To repeat, breaking a concrete slab as opposed to countering a frontal attack in the street would entail different priorities. In the first example, short movement time and high rate of kinetic energy production (power) are not as important as maximum kinetic energy at the moment of contact. This was illustrated in the TKD subject data. The particular punching style of this subject incorporated a small but perceptible “wind-up”-type action. Data gathered in the TKD pattern revealed the highest peak velocity on one hand, but also the highest total movement time, and lowest average velocity on the other. This TKD subjects particular style puts a strong emphasis on “breaking” skills as in breaking wood, or cement slabs. Breaking requires high peak velocities for maximum kinetic energy without the combat prerequisite of having a short movement time. In street fighting, however, the development of peak kinetic energy at the expense of a short movement time, high average velocity, and power could mean the difference between life and death.

In summary, the results of this analysis indicate that the movement pattern emphasized in the TKD style are designed for the performance of work and the production of maximum kinetic energy which is required for the breaking of objects. The movement patterns reflected in the other styles may be more applicable to combative purposes in which power, i.e., the quickness of energy production, is the primary goal.

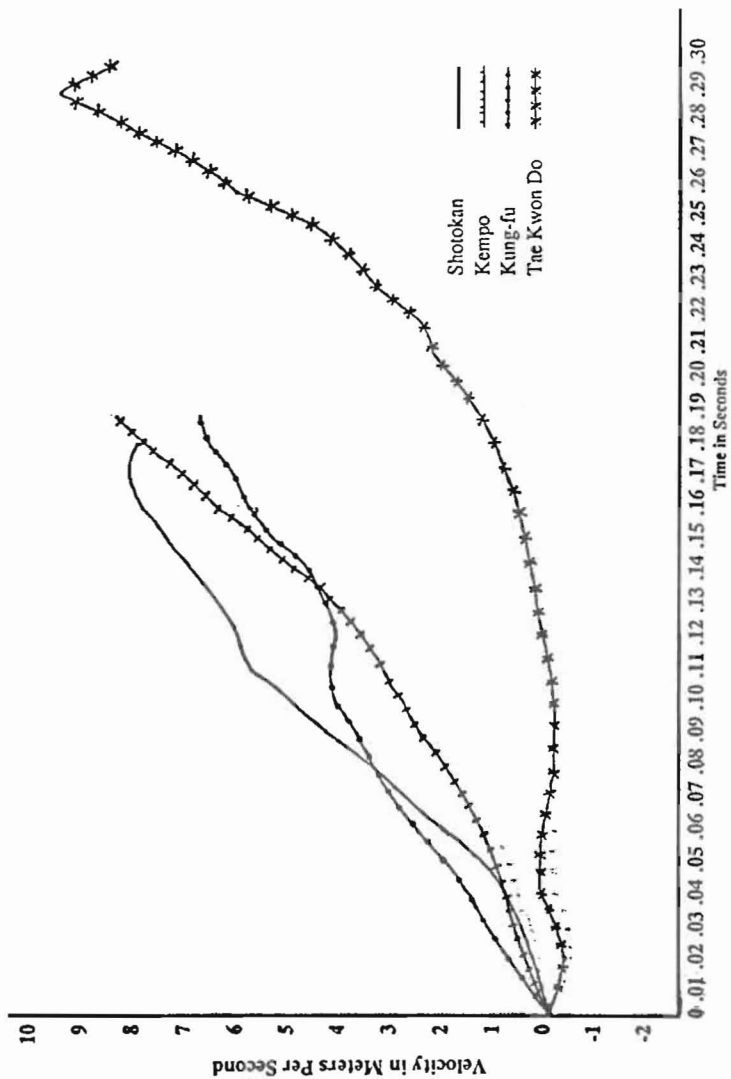


Figure 1. A comparison of wrist velocity versus time elapsed in the reverse punch trial.

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