# CHARACTERISTICS OF KINEMATICS AND KINETICS OF STROKES IN KARATE – BIOMECHANICAL APPROACH

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The purpose of the paper is to discuss the matter of results of stroke velocity measurements and kinetic parameters (maximum force of stroke and angle of impact) of hand strokes (gyaku tsuki) and leg strokes (mae geri, yoko geri) in karate shotokan. A group of competitors, consisting of 21 persons, took part in the laboratory experiment. Measurements of kinetic parameters were realised on Kistler three-component force plate with synchronous measurement of hand (foot) velocity which was executed on MRC self-constructed equipment.

**KEY WORDS:** fighting sports, karate, force of stroke, velocity of stroke

**INTRODUCTION:** Kinematic parameters of stroke are elements (quantities) related to velocity of chosen body point before contact with the target of the stroke. Kinetic elements are the ones that result from the run of reaction force between striking body part and the target.

The technique of stroke in karate shotokan is based on speed and involvement of equivalent body mass in stroke. Effectiveness of stroke is determined by quantity of transferred momentum or energy. Analysis of the process proves the existence of correlation between speed and force and other parameters of stroke kinetics (Pieter and Pieter, 1995, Dziewiecki, 2002). High speed determines not only mechanic results of stroke but also, being related to the time of exercising particular technique, to a large extent it influences the success of competitor by means of surpring the opponent and preventing him from effective defence. Hand velocity in the moment of stroke is the final effect of movement and is indispensable, in relation to kinetic parameters, for further analysis of stroke technique.

**MATERIALS AND METHODS:** Experimental research was conducted over a group of 21 competitors of karate shotokan, whose characteristics are presented in Table 1. Two thirds of the examined karate fighters possessed mastery level.

**Table 1 Characteristics of the examined competitors.**

| Number of athletes | Age (years) | Body mass (kg) | Body height (cm) | Training period (years) | Sport degree |
|---|---|---|---|---|---|
| 21 | 26.4 ± 6.8 | 78.5 ± 6.5 | 179.0 ± 5.2 | 9.7 ± 5.8 | 5 kyu - 4 dan |

With regard to the limitation imposed by the used measurement equipment, especially MRC (shadow registration method) device for measuring velocity (Dziewiecki 2002), the examined techniques were restricted to those which are characterised by approximately rectilinear motion of the striking hand or foot. As for the hand strokes gyaku tsuki was chosen, among the leg strokes – mae geri and yoko geri. These techniques are relatively simple thus effective in fight and widely used. Each of the mentioned techniques was recorded in 3 strokes inflicted by a competitor with his left or right limb (Dziewiecki, 2002).

The measurement stand is represented in general outline on Figure 1. It consisted of vertically mounted Kistler force plate of the 9261A type, equipped with appropriate shock absorption layer and MRC device for measuring velocity (Dziewiecki 2002). The plate recorded the time course function of three stroke force components: in perpendicular direction $F_z(t)$ and along the plate's plane $F_x$, $F_y(t)$.

It has been stated that within the examined techniques the perpendicular component $F_z(t)$ only slightly departs from resultant force. For this reason analysis of kinetics was executed on the basis of the run of that component: from the moment $t_0$ (the beginning of the competitor's hand contact with the shock absorption layer) till the moment $t_{max}$ (acquisition of

$F_{max}$ maximum quantity) – Figure 2. Tangential components ($F_x$, $F_y$) were used only to calculate stroke angles.

Maximum stroke force $F_{max}$ was marked as well as its impulse $I = \int_{t_0}^{t_{max}} F_z(t)dt$ and average value of stroke force $< F > = \frac{I}{t_{max} - t_0}$.

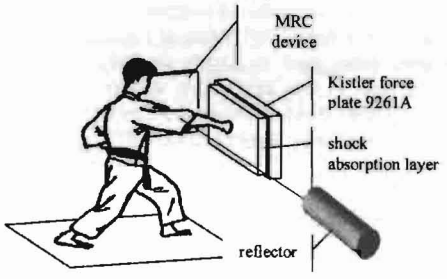



**Figure 1 Stand for measuring kinematics and kinetics of stroke.**

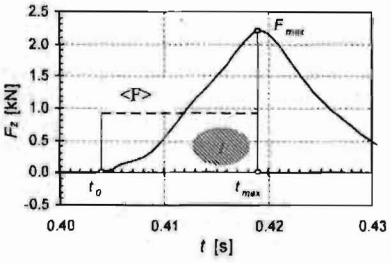
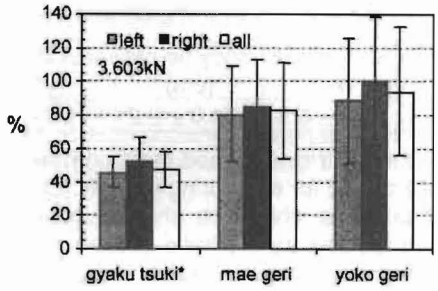



**Figure 2 Exemplary run of perpendicular force stroke component (gyaku tsuki).**

**RESULTS AND DISCUSSION:** Results of maximum stroke force measurements are represented on Figure 3.

Examined hand strokes appear to be approximately two times weaker than foot strokes. The time of hand contact with stroke target - till acquisition of $F_{max}$ - is, as well, two times weaker than the time of foot contact. The strongest strokes appeared to be yoko geri. The right foot stroke force $F_{max}$ was calculated, on the average, at the level of about 3.6 kN. The greatest stroke force of about 7 kN was recorded. Usually right limb strokes produced higher results, however the differences appeared to be statistically significant ($\alpha < 0.05$) only with hand strokes. With foot strokes relatively large scatter of results was observed, even within the measurements of the same competitor. Stroke forces of the same techniques, presented in literature, are characterised by repeated differentiation of values. It is definitely caused by the researchers' use of measurement equipment of different rigidity level.




* Differences between left and right limb are statistically significant ($\alpha$<0.05)

**Figure 3 Results of maximum stroke force measurements (average values ± SD).**

Even though the examined strokes were supposed to be directed perpendicularly onto the plate, a tendency of deviation of resultant force was strongly marked (Figure 4). It is especially visible on the example of gyaku tsuki stroke. The stroke was aimed at the centre of plate - right hand strokes are directed to left, left hand - to the right. Deviation of resultant stroke force in both cases was calculated at the level of about 10°. Explanation of observed regularities lies in the technique of hand stroke production: steady support of spread feet, permitting rotation of hip and shoulder girdle towards the 'inside' while preparing to strike,

causes that striking hand does not move directly along a straight line but along a slight angle along the horizontal plane (lateral component of stroke force).

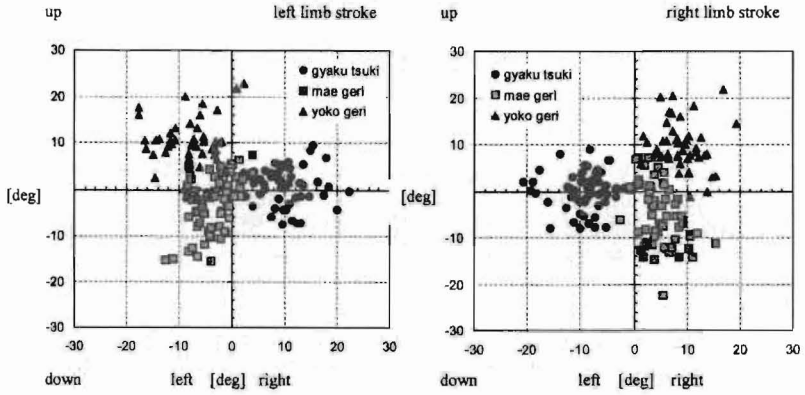
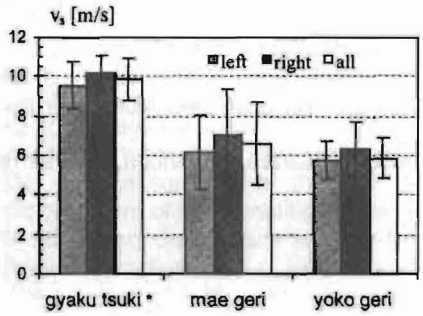



**Figure 4 Deviation of resultant stroke forces in the examined strokes.**

In the case of examined foot strokes, stroke force was directed slightly 'outside'. This direction of resultant force seems to be obvious: singular point of support of competitor during execution of stroke prevented him from expanding significant torque momentum of surface reactive forces around vertical axis in order to give striking foot higher speed, as it was in the cases of hand strokes. Furthermore with such angles stroke force vector was lying approximately on the vertical plane, passing through the points of contact of the competitor's body with surrounding environment (point of support, point of contact with target) without unbalancing him in side - direction. Approximate values of stroke angles were calculated by Dworak et al, (2001).

Figure 5 presents the average stroke velocities. With gyaku tsuki stroke velocity was calculated at the level of about 10 m/s. The highest recorded stroke velocity was 12.4 m/s. Velocity of foot strokes appeared to be much lower and equalled 6-7 m/s. Very significant differences were marked in the run of hand and foot velocity at the measuring length of 30 cm before the stroke target. Hand velocity does not change significantly (Figure 6) whereas in the run of foot velocity, rapid decrease is observed: distinct minimum and little increase just before the contact with target.




* Differences between left and right limb are statistically significant ($\alpha < 0.05$).

**Figure 5 Average stroke velocities.**

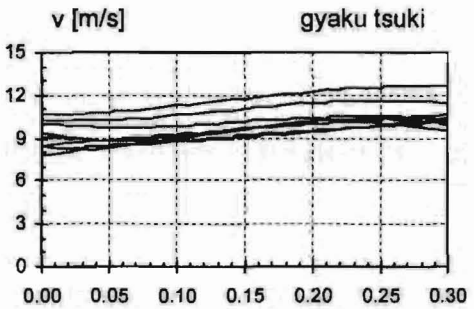



**Figure 6 Exemplary runs of hand stroke velocity.**

The velocity levels developed by competitors while striking, which are quoted in literature, rarely project beyond 15 m/s. Naturally, they are different for hand and leg strokes and at the same time they depend on the examined technique of stroke. Smaller scatter of values is

observed in hand techniques. The majority of data concerns the seiken tsuki stroke. Wilk et al, (1983) valued the velocity of striking at 5.7-9.8 m/s, Kato – at most at 7.1 m/s and 8.1 m/s, Zbinowsky – 10.1 m/s, Paper – 7.5 m/s, Smith and Hammill – 10.5-12.3 m/s (after Sterkowicz, 1992). Exemplary levels of velocity recorded with leg strokes ( it was restricted to strokes that were technically approximate to the one examined) look as follows: mae geri i yoko geri – 9.9-14.4 m/s (Wilk), yoko geri - 4.7 m/s (max 9.7 m/s) (Kato), yop chagi – 6.6 m/s (Pieter, 1995) and 8.8 m/s (Serina and Lieu, 1991).

**CONCLUSIONS:** Contrary to the other measurements in sport (time of covering certain distance, height of jump, upraised weight) results of measurement of stroke kinetics cannot be treated as absolutely calculated, comparable quantities. Stroke forces in all conditions can differ significantly even when the stroke is executed by the same competitor, using the same technique. It is only possible to compare the results if the measurements are executed on the same kind of equipment. Levels of stroke force of gyaku tsuki appeared to be more or less two times smaller than mae geri and yoko geri and probably approximate relation is to be calculated when executing measurements in different conditions.
Stroke force of gyaku tsuki and yoko geri is acquisited differently, in the first case owing to high speed, in the second - thanks to engaging adequately larger body mass. This conclusion is confirmed by the several-times-larger substitute mass of leg strokes.

**REFERENCES:**

Dziewiecki K. (2002). Zależność między kinematycznymi i dynamicznymi parametrami uderzeń w sportach walki.(Dependency between kinematic and kinetic parameters of strokes in fighting sports.) *Ph.D thesis. University School of Phys. Ed. Poznań*. In Polish.
Dworak L., Dziewiecki K., Kmiecik K., Mączyński J. (2001). Związek siły uderzenia z ruchem środka masy zawodnika. Materiały XVII Konferencji Naukowej „Biomechanika' 2001" (Relation of the stroke force to the competitor's center of mass. *Materials of the Scientific Conference "Biomechanics 2001"), Acta of Bioengineering and Biomechanics*, vol. 3, suppl.2, 123-130. In Polish.
Fidelus K., Dziewiecki K., Jaszczuk J., Czaplicki A., Bujak Z. (1998). Zależność między prędkością i parametrami dynamicznymi przy uderzeniach w taekwondo. (Dependency between velocity and kinetic parameters in tekwondo strokes.) *Materiały XV Szkoły Biomechaniki, Biology of Sport*, vol.15 suppl.8, 87-90. In Polish.
Pieter F., Pieter W. (1995). Speed and force in selected taekwondo techniques. *Biology of Sport*, 4, 257-266.
Serina E.R., Lieu D.K. (1991). Thoracic injury potential of basic competition taekwondo kicks. *Journal of Biomechanics*, 10, 951-960.
Sterkowicz S. (1992). Charakterystyka wybranych wskaźników określających stan przygotowania zawodników karate. (The characteristics of select indicators describing the level of preparation of karate competitors.) AWF w Krakowie, Wydawnictwo Monograficzne nr 47. In Polish.
Wilk S.R., McNair R.E., Feld M.S. (1983): The Physics of Karate. *American Journal of Physics*, 51, 783-790.