

MAXIMUM VELOCITY OF THE STRIKING LEG DURING THE MARTIAL ARTS FRONT, SIDE AND TURNING KICKS AND THE RELATIONSHIP TO TECHNIQUE DURATION

Corinne Abraham, Joanna Kingman, and Rosemary Dyson
University College Chichester, Chichester, West Sussex, PO19 4PE, UK.

Eight male martial artists performed five repetitions of the front, side and turning kicks at a target. 3-D movement was recorded and automatically digitised at 200 Hz using Peak Motus. The mean maximum velocity (\pm SE) of the striking leg was $11.77 \pm 0.18 \text{ m}\cdot\text{s}^{-1}$ for the front kick, $10.44 \pm 0.16 \text{ m}\cdot\text{s}^{-1}$ for the side kick and $13.06 \pm 0.33 \text{ m}\cdot\text{s}^{-1}$ for the turning kick. Differences between the front and the side kick, and the front and turning kick were significant ($p = 0.001$), with the greatest difference between the turning and the side kick ($p < 0.0001$). The mean duration of the front, side and turning kicks was 0.23 s, 0.25 s and 0.24 s. The side kick was significantly longer than the front kick ($p = 0.03$). For the front kick, the faster the maximum velocity then the shorter the duration ($r = -0.751$, $p < 0.0001$).

KEY WORDS: correlation, kung-fu, roundhouse, speed, strike

INTRODUCTION: The velocity of the striking foot in martial arts has been reported in the course of studies of kicking techniques by Wilk et al. (1983), Hwang (1987), Joon et al. (1987), Pieter and Pieter (1995). However, direct comparison of these studies was difficult as the recorded velocities were likely to be specific to the details of kicking technique employed within each study, and also upon the experience of the participants. There were also differences in methodology, which are likely to have influenced the measurements e.g. camera recording criteria and procedures for digitisation of kinematic data. In 1987, Hwang reported on the importance of the use of a target to achieve a realistic and motivating testing procedure for determination of the velocity of the kicking leg in martial arts. The length of time it takes to perform a technique is important in martial arts, as it often dictates success. A technique is deemed to have failed should the timing of the movement be incorrect, or it is blocked or avoided. The choice of an appropriate kick technique for a purpose is therefore critical. The aims of the study were to determine firstly, the maximum velocity of the foot during three different types of kick and, secondly, the duration of each type of kick. A further aim was to establish the relationship between the maximum velocity and duration of each technique. The three kick techniques investigated in this study are summarised in Figures 1, 2, and 3.



Figure 1 - Front kick.



Figure 2 - Side Kick.

The front kick is initiated by the toes extending, the ankle plantar flexing and then the knee and hip flexing, bringing the shank closer to the thigh and the knee up towards the chest. The knee is then extended, the hips push forward and the ankle dorsi-flexes to contact the target with the ball of the foot.

The side kick is initiated by the toes extending and the ankle plantar flexing. The knee and hip are flexed as the grounded leg rotates 90° and the hip of the attacking leg abducts. The knee and hip are then extended, maintaining the hip in the abducted position, to contact the target with the heel or knife-edge (lateral side) of the foot.

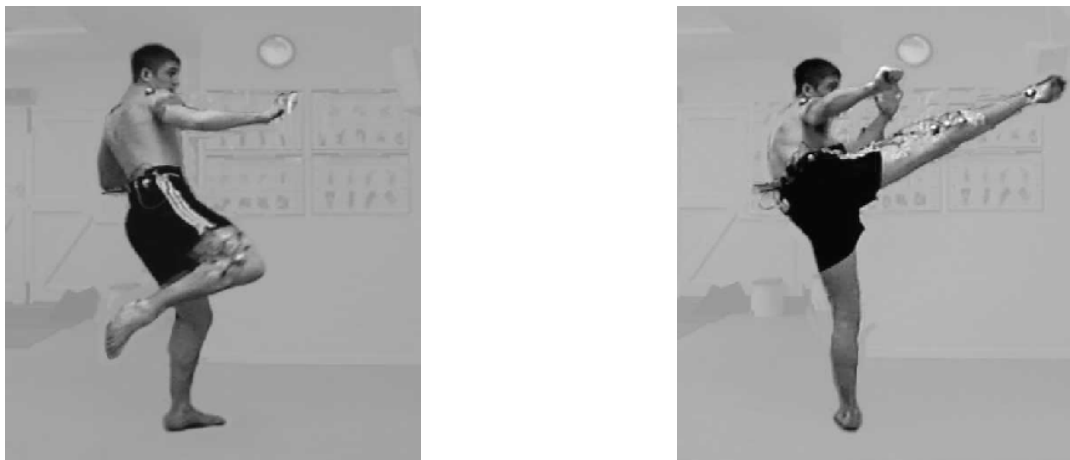


Figure 3 - Turning Kick (also called roundhouse kick).

The turning kick is initiated with plantar flexion of the ankle and extension of the toes. The knee is then flexed and the hip is abducted and flexed, so that the knee moves in an arc around the body (using the hip as a pivot point). The knee is extended as the hip medially rotates and the ankle remains plantar flexed so that contact is with the arch of the foot on the target.

METHODS: Execution of all kick techniques was from the left fighting stance, with both feet on the floor, using the rear (right) leg for the strike. The target (50 cm × 75 cm) was hand held at a pre-determined comfortable distance from the participant. All participants were instructed to contact the target at a height corresponding to their own chest height, with their maximum

velocity and force. A target pad was used in order to simulate technique performance that would be similar to that carried out when fighting with an opponent, as significantly different velocity patterns for the foot of participants kicking with and without a target pad have been demonstrated by Hwang (1987). Eight male participants gave informed consent and performed a warm-up including stretching exercises prior to testing. A 15 mm, retro-reflective, 3D ball-marker was positioned immediately below the lateral malleolus of the right fibula. The kicking movement of the right striking leg was recorded using a Peak Motus system (Peak Performance Technologies, USA), which included two stationary genlocked, high-speed 200 Hz cameras mounted on tripods and with an inter-camera angle of 72°. Camera shutter speed was set at 1/1000 s, depth of focus approximately 4 m, and $f = 2.8$ for optimum picture quality. A digital event and video control unit was used to synchronise the camera views (Peak Performance Technologies, USA). Images were recorded onto SVHS videotape using Panasonic high-speed AG-5700-E video recorders. Floodlights were positioned at a similar height to, and in line with, each camera in order to illuminate the participant. A plain matt black backdrop was used to simplify the field of view. Prior to participant activity, a 17-point three-dimensional calibration frame and anterior/posterior – medio-lateral orientation axis were filmed in the position of the participant. Participants were allowed five practice kicks each for the front, side and turning kick techniques to allow familiarisation with the testing surroundings, procedure, their position in relation to the cameras, and the distance to the target. Following the familiarisation kicks, and 60 s rest, the participants were reminded that each kick was to be as fast and with as much force as possible for the remainder of the testing procedure. Ten repetitions of each of the three kick techniques were performed with a 60 s interval between the different types of kick. Participants were counted into each kick (i.e. 3-2-1-kick). Verbal encouragement was given throughout in order to help maximise performance. Of the ten trial repetitions for each technique, the first and last were excluded from the analysis in order to reduce variation within participant performance. From the remainder, five were selected according to visual assessment of accurate technique. Five trials of each technique for each participant were digitised using a Panasonic AG-MD-830-E replay unit and Peak Motus 5-3-1 software for Windows 98. Position co-ordinates of the optical centre of the reflective marker were automatically digitised (Peak Performance Technologies) at 200 Hz. By performing eight repeat digitisations of the same trial, user reliability was confirmed. Data were filtered using a quintic spline. Displacement and velocity data for the motion were calculated and peak velocity was determined, as well as the exact times of the toe of the kicking leg leaving the ground and contacting with the target for determination of duration. After checking the assumptions required, velocity and technique duration data were compared between techniques, using a one-way analysis of variance and a Tukey post-hoc test.

RESULTS AND DISCUSSION: The maximum velocity achieved during the turning kick was faster than the front kick, and the front kick was faster than the side kick (Table 1). The differences in maximum velocity between the front kick and both the side kick and the turning kick were significant ($p = 0.001$). However, the greatest difference was between the turning kick and the side kick ($p < 0.0001$).

Table 1 - Maximum Velocity ($m \cdot s^{-1}$) of the Striking Leg During Martial Arts Kicking

Technique	Mean	SD	SE
Front kick	11.77	1.14	0.18
Side kick	10.44	1.02	0.16
Turning kick	13.06	2.11	0.33

Table 2 - Duration (s) of the Three Techniques of Martial Arts Kicking

Technique	Mean	SD	SE
Front kick	0.23	0.028	0.004
Side kick	0.25	0.020	0.003
Turning kick	0.24	0.034	0.005

The duration of the side kick was significantly longer by 0.02 s than the duration of the front kick as shown in Table 2 ($p = 0.03$), but there were no other significant differences between the kicks. Figure 4 shows that for the front kick, as the velocity increased then the duration was reduced. The correlation between velocity of the front kick and the duration of the kick was reasonably strong (-0.75). However for the side and turning kick, the relationship between maximum kick velocity and kick duration failed to reach a probability of 0.05.

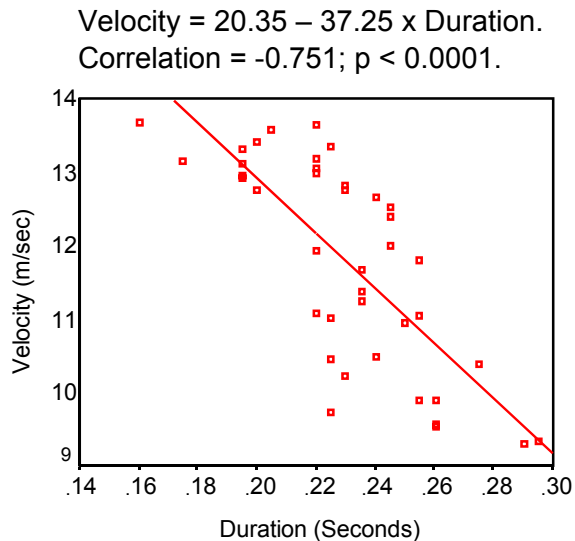


Figure 4 - Linear fit of kick velocity and duration for the front kick.

This study indicated that the turning kick was the fastest of the three kicks, and yet the duration was not significantly longer than the side kick or shorter than the front kick. The maximum velocity of the turning kick was 25% more than in the side kick, which would suggest that this would be the more powerful kick. The rotatory body movements included in the side and turning kicks may act to modify the velocity-duration relationship.

CONCLUSION: The mean maximum velocity (\pm SE) of the striking leg was $11.77 \pm 0.18 \text{ m}\cdot\text{s}^{-1}$ for the front kick, $10.44 \pm 0.16 \text{ m}\cdot\text{s}^{-1}$ for the side kick, and $13.06 \pm 0.33 \text{ m}\cdot\text{s}^{-1}$ for the turning kick, and these were significantly different. For the front kick, the maximum velocity and duration of the kick were inversely related (correlation = -0.751 , $p < 0.0001$).

REFERENCES:

- Hwang, I. (1987). Analysis of the kicking leg in taekwondo. *Biomechanics in Sports III Proceedings of ISBS*. Edited by Terauds, J. et al. DelMar, California: Academic Publishers, 39-47
- Joon, S.N. Guk, L.S., Jong, P.H., and Kyu, J.S (1987). An analysis of the dynamics of the basic taekwondo kicks. *United States Taekwondo Journal*, **6**, 10-15.
- Pieter F., and Pieter W. (1995). Speed and force in selected taekwondo techniques. *Biology of Sport*, **12**, 257-265.
- Wilk, S.R., McNair, R.E. and Feld, M.S. (1983). The physics of karate. *American Journal of Physics*, **9**, 783-790.