THE BIOMECHANICAL ANALYSIS OF ROUNDHOUSE KICK IN TAEKWONDO

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The purpose of this research was to compare 360° turning roundhouse kick performed by dominant leg and non-dominant leg on kinetic and kinematic variables, and then to find the variables that correlate to the impact velocity. Nine elite taekwondo athletes were recruited. The data were collected with two Redlake cameras (125 Hz) and two Kistler force plates (1250 Hz). The difference between maximal height and beginning of body CM, max velocity of toe/ankle, impact velocity of toe, maximal vertical force of front leg, vertical/horizontal impulse of front leg, were found to be significantly different between dominant and non-dominant leg; and the difference between maximal height and impact of body CM, max velocity of toe/ankle, maximal vertical force of back leg were found to be significantly correlated with the impact velocity.

KEY WORDS: dominant, non-dominant, impact velocity.

INTRODUCTION: In taekwondo, the 360° turning kicks have become essential skills for two reasons: (1) they are the aspects practitioners must be proficient at *dan* (senior) promotion tests; (2) they have become important skill in competition due to the new rules of taekwondo, the athletes may earn more score by using this skill. Research in taekwondo so far have focused much on basic movements (Hwang, 1986; Sung, 1987), but movements of higher difficulty are less studied. Therefore, the purpose of this study was to identify difference between left and right legs, and to find out the factors contributing to the impact velocity, on the 360° turning roundhouse kick. We analyzed the kinetic and kinematic variables of the dominant leg (DL) and non-dominant leg (NDL) on the 360° turning roundhouse kick.

METHODS: Elite taekwondo athletes (n=9) were recruited as participants, with age of 22.3±2.6 years, height of 173.6±3.9 cm, weight of 67.3±6.8 kg. Two digital video cameras (Redlake CAMARA, 125HZ) and two force plate (Kistler, Type 9287, 1250 Hz) were synchronized to record the subjects' performance of the 360° turning roundhouse kick. Twenty-five control points were used for direct linear transformation (DLT) calibration. Twenty-one body landmarks were digitized with the Kwon 3D software. The Butterworth function with the fourth-order zero lag digital filtering option was used to filter the kinematic data. The force plate data were processed with Kwon3D GRF software.
The movement performed was 360° turning roundhouse kick, with DL and NDL; each leg performed 3 times by each participant, and the best one (judged through the participant's balance during action, the velocity of the kick, the position on the sand bag being hit, and the landing of both legs) was analyzed. The variables measured are as follows: kinetic variables are (1) CM difference between peak height and ready height, (2) peak toe velocity, (3) impact toe velocity, (4) peak ankle linear velocity; kinematic variables are (1) peak back leg vertical force, (2) peak front leg vertical force, (3) front leg vertical impulse, (4) front leg horizontal impulse.
Statistical analysis used SPSS 13.0 software. The means of the variables were compared between dominant and non-dominant legs by using paired *t*-test; correlation between the resultant velocity of toe at impact (IVt) and other variables were analyzed via Pearson's product-moment correlation (α=.05).

RESULTS AND DISCUSSION: Table 1 gives the result of *t*-test comparison between DL and NDL, and correlation between resultant velocity of toe at impact and other variables. For all variables significant in t test comparison, the mean values of the DL are better (faster/larger) than the NDL.

Table 1
Results of *t*-test and correlation analysis of 360° turning roundhouse kick.

No.	Variable	Mean±SD DL	Mean±SD NDL	Significant difference	Significant correlation DL	Significant correlation NDL
Kinetic variables						
1	CM difference between peak height and ready height	28.3±5.5 (cm)	24.1±5.4 (cm)	✻		
2	Peak toe velocity	14.4±1.4 (m/s)	13.2±1.4 (m/s)	✻	.711	.735
3	Impact toe velocity	9.5±1.1 (m/s)	8.5±1.1 (m/s)	✻		
4	Peak ankle linear velocity	10.0±1.2 (m/s)	9.5±.9 (m/s)	✻	.754	.703
Kinematic variables						
1	Peak back leg vertical force	1245.2±208.0 (N)	1257.8±314.4 (N)		.716	.681
2	Peak front leg vertical force	1600.5±302.8 (N)	1497.5±289.6 (N)	✻	.717	
3	Front leg vertical impulse	319.6±43.4 (N*s)	255.9±81.1 (N*s)	✻		.691
4	Front leg horizontal impulse	40.8±15.8 (N*s)	30.5±14.6 (N*s)	✻		- .696

✻: $p<.05$

Kinetics: The peak toe velocity of DL is significantly larger than that of NDL. Though in training it's usually demanded that both legs have the same quality and quantity of practice, "dominant" can essentially mean an advantage in performance. One point worth mentioning is that, we discovered that the peak toe velocity always occurred before impact toe velocity, and for DL it occurred 0.04 sec (Figure 1) before impact, for the NDL it occurred 0.048 sec before impact, for all 9 participants. Since the time lag between peak toe velocity and velocity was shorter for DL, we presumed that the shorter the time lag, the better the performance.

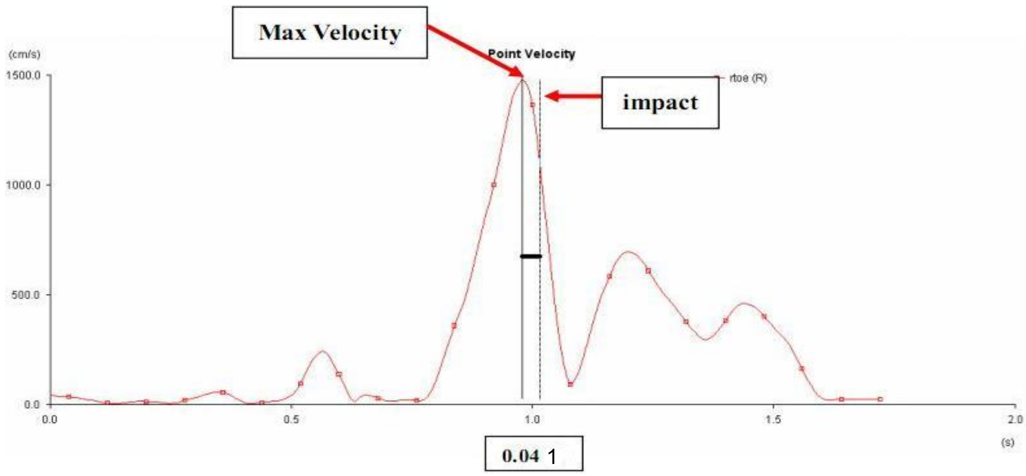

Figure 1: The time lag between maximal velocity and impact velocity of the dominant leg.

Peak ankle linear velocity of DL was significantly greater than that of NDL ($p<.05$). The maximal velocities of the joints occurred in the order of hip, knee, ankle, which was in the pattern of the kinetic chain showed in Figure 2 (Steindler, 1955), and that the velocity reached significance level for the distal joint is corresponsive to the result that peak toe velocity was significantly different between DL and NDL.

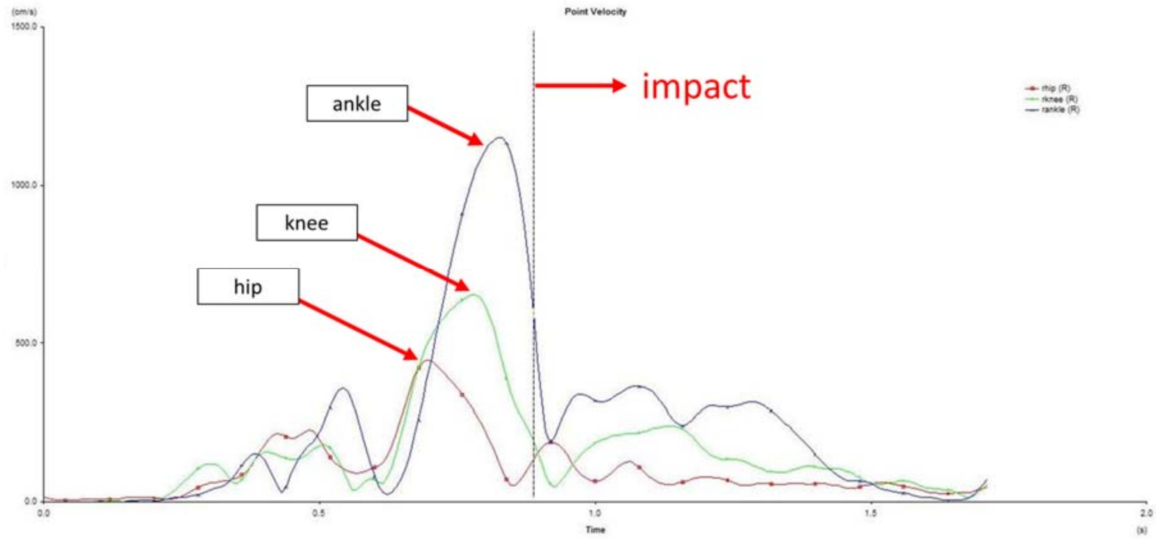

Figure 2: The kinetic chain pattern of the resultant linear velocities of hip, knee and ankle joints.

Kinematics: For force, only peak front leg vertical force reached significance level ($p<.05$), and this represents that this is an important kinematic variable for the 360° turning roundhouse kick. The results also show that CM difference between peak height and ready height of DL's performance is significantly greater than that of NDL's performance ($p<.01$). This indicates that the propelling force of the DL as front leg is greater than that of the NDL.
For impulse, front leg vertical impulse and horizontal impulse reached significance level ($p<.05$). The duration of front leg applying force on the ground was no difference between DL and NDL, so it was the force that contribute to the impulse. If we apply the impulse-momentum method, the impulse (J) = $F*\Delta t = \Delta P = m*\Delta v$. Assume the mass of the body to be constant, with greater impulse, the body acquire greater momentum, thus greater velocity can be performed. The results corresponded to the advantage of DL.
Correlation analysis: We analyzed the correlation between the impact toe velocity and other variables. The variables reaching significance level are showed in Table 1.
For kinetic variables, two were significant correlation with impact toe velocity for both DL and NDL: peak toe velocity ($p<.05$) and peak ankle linear velocity ($p<.05$). Peak toe velocity, occurred before impact, if trained to become greater, the velocity at impact is supposed to be greater as well. Peak ankle linear velocity reaching significance level shows that the greater the linear velocity of ankle, the greater the impact velocity.
For kinematic variables, only one was in significant correlation with impact toe velocity for both DL and NDL: peak back leg vertical force ($p<.05$). This means if the peak vertical force of back leg is greater, the impact velocity will be greater.
Due to the limitation of experimental setting, the participants had to stand still on the force plates, and the positions of force plates and sand bag are fixed, which was different from practicing or in competition, where athletes may be used to jumping stance, and attack with distance of their own choice. Nevertheless, the results give coaches and practitioners important information in training, and the efficiency of focusing on the key biomechanical variables, thus providing further improvement for both training and academic research.

CONCLUSION: For the t test comparison, DL is significantly better (faster/larger) than NDL in the following 7 variables: CM difference between peak height and ready height, peak toe velocity, impact toe velocity, peak ankle linear velocity, peak front leg vertical force, front leg vertical impulse and front leg horizontal impulse. We established biomechanical variables for 360° turning roundhouse kick, providing reference for training and further research. The difference between legs shows that although DL and NDL are demanded to have same quality and quantity of training, DL's advantage still exists in many aspects.
For the correlation analysis, our result shows that peak toe velocity, peak ankle linear velocity and peak back leg vertical force contribute significantly to the impact velocity. So in

training, we can focus on these variables, and see if improving them makes better performance.

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