MEASUREMENT AND COMPARISON OF TAEKWONDO AND YONGMUDO TURNING KICK IMPACT FORCE FOR TWO TARGET HEIGHTS

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The main purpose of this research was to compare the impact characteristics of Taekwondo (TKD) and Yongmudo (YMD) player's turning kick according to the height. In this study, 5 highly skilled YMD and TKD players participated. To measure the impact force, two accelerometers were fixed to a PVC pipe in a sandbag. Each subject performed 10 turning kicks trunk and face height in random order. Only the trial with the most accurate (most central impact) measurement was used in the statistical analysis ($\alpha<0.05$). For impact force, there was a significant difference according to the height approximately 6400±898N, 6393±1382N for the mid section and 5419±659N, 5475±1293N for the high section of TKD and YMD groups, but not between groups. The swing phase for the TKD group was significantly shorter than the YMD group's. The TKD groups' recovery phase of the trunk height turning kick was significantly shorter. There was a difference in the players' COM movement as the TKD players' moved significantly more forward. In conclusion, as the turning kick was performed quicker by the TKD players with a similar impact force and more forward motion, it is evaluated to be a better technique of turning kicking.

KEY WORDS: Turning kick, Impact force, Taekwondo, Yongmudo

INTRODUCTION:

Taekwondo is a Korean martial art form that was originally taught for warfare, self-defense and physical fitness. In competition Taekwondo, points are scored when contact to the torso or head produces a 'trembling shock' (WTF rule book). Needless to say that with the opponent required to produce a 'trembling shock' for the acknowledgement of points, there have been many injuries caused (Zemper & Pieter, 1989). As a direct result of these high number of injuries chest protection and head protection are now required for participation in kyorugi. With this in mind the evaluation of chest gear and head protection must be considered.

Yongmudo is a martial art that has been developed by Yong-In University professors and it was created by combining and modifying the techniques of Taekwondo, Hapkido, Judo, fencing and ssireum (Yongin website, 2007 Oct. 12th). It is considered a third generation martial art; first generation being one of action, second generation of mental endurance and the third generation a combination of the two generations. With the purpose of YMD as being an overall self defense system the turning kick was slightly modified so that as to be able to use proceeding techniques.

According to Sidthilaw (1996), the impact forces recorded for a beginner Muai Thai Kickboxer's roundhouse kick was estimated to be 6702±3514N, 7240±3477N and 5618±3253N for low, medium and head height respectively. For the estimation of force, three one dimensional *50g* accelerometers perpendicular were fixed inside a bowling ball. This bowling ball was then placed in a sand bag. In other related research, Chiu, Wang and Chen (2007), the kicking force of the roundhouse and back kick and the speed of the kicking foot were measured. Chiu et al. (2007) used a different method to measure the kicking force, an air bag was fixed to a wall and the difference in air pressure caused by the force of the kick was measured. The roundhouse kick and back kick force measured at 8252±720N and 8023±836N. The kicking forces of various kicks were measured by a force transducer and they ranged from 2759 to 9711.9 N (Gray, 1979). Even with these other studies (Chiu, Wang and Chen 2007, Gray 1979, Sidthilaw 1996) related to the forces created by martial artists it is believed that the results in these studies could be improved by reviewing other researchers' designs and modify them.

With the purpose of the Yongmudo and Taekwondo turning kick being slightly different, the YMD technique has been modified for this. Taekwondo players tend to use a more snapping motion so as to be able to prepare them for another attack using their legs whereas the Yongmudo players follow many of the turning kicks with other attacks using various methods i.e. punch, grappling etc. It was therefore deemed that a comparison between the impact forces of these two styles could be used as a comparison between the technique of kicking with a snap (TKD) and a swing (YMD).

METHODS:

Subjects: Five Yongmudo and Taekwondo players were recruited through Yongin University. Each of these subjects has over 10 years experience in various martial arts and were asked to complete a medical history form and a consent form (TKD: mass 66.94±6.1kg, height 1.74±0.03m, leg length 0.92±0.03m YMD: mass 71.52±6.5kg, height 1.75±0.02m, leg length 0.91±0.02m). Any subjects that are or have been suffering from serious musculoskeletal injury within the last two years were excluded.

Data collection: The experimental equipment used were 7 vicon cameras, two 3D accelerometers and two AMTI force platforms. The 7 Vicon cameras (MX 13) were used to record the kinematical data at a 150Hz and all data was processed and filtered by the Woltring filter (Woltring, 1986) at 15 Hz. Two PCB 356A15 tri-axial 50*g* limit accelerometers measured the acceleration of the sandbag. These accelerometers were fixed onto a PVC pipe by the wedging and gluing the accelerometers to a wooden panel which was screwed into position at both ends of the PVC (Fig.1). To calibrate the accelerometers, punching bag was dropped from several varying heights onto the AMTI force platform. The acceleration outputs from the accelerometer and the force platform was recorded at 1500 Hz and compared. There were many trials performed however due to the sensitivity of the accelerometers only the reliable data was used to calibrate the system for estimation of the kicking force (Fig.2).

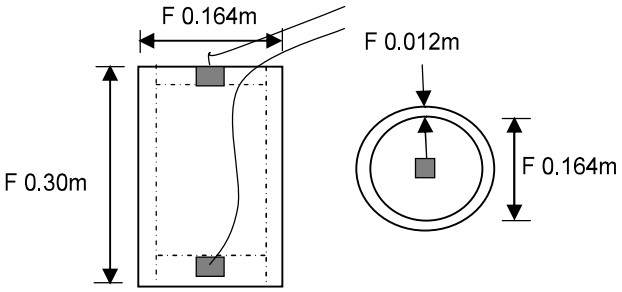

Figure 1: Side and plan view of PVC pipe

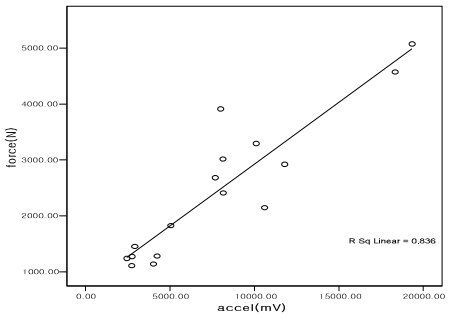

Figure 2: Plot of calibration data

A high value of Pearson's correlation coefficient r= 0.914 was recorded. In relevant research r=0.978 was obtained (Sidthilaw, 1996). For the estimation of the kicking force measured by the accelerometers the acceleration value is entered into the Equation 1.

$$\text{Estimated Force (N)} = 0.221(\text{accelerometer's value}) + 716.734 \quad (1)$$

Experimental procedure: After signature of the consent forms the subject was instructed to warm up. After a sufficient warm up, the subject was instructed to perform the roundhouse kick twenty times in total. Ten kicks were done at trunk height and ten kicks were done at approximately head height. This was randomly rearranged. Each kick had to be done efficiently according to the following conditions; correct height, appropriate direction and balance, etc.

The kinetic and kinematic data was exported from Workstation© and Polygon© and exported into Microsoft Excel to produce the necessary graphs and results. The ground reaction forces

(GRFs), acceleration of the pipe in the punching bag, the motion of the center of mass (COM) of the subject, the range of motion (ROM) and angular velocity for each of the involved joints, hip and knee, kicking foot speed and phase times were all analyzed.

Variables:
1) Estimated Kicking Force was calculated from the calibration equation.
2) Normalized GRFs of the kicking foot at push off were calculated by dividing the maximum force of the kicking foot pushing off to initiate the kick by subject's body weight.
3) Knee chamber defines the body's position where the knee extension angle is minimum.
4) Swing phase is defined as the period from the foot off to the impact.
5) Recovery phase is defined as the period from the impact to the foot down.

Statistical analysis: To perform the statistical analysis all the needed data was exported into SPSS 12.0. For each of the groups the kick height, the mean and standard deviations were calculated. Two way ANOVA with repeated measures were used to check if there was a significant statistical difference. A significance level of $p<0.05$ was used for all statistical analysis.

Table 2. Summary of all recorded variables.

Variables	Turning Kick (TKD)	Turning Kick (YMD)	High Turning Kick (TKD)	High Turning Kick (YMD)
Estimated Kicking Force*	6400±898 N	6393±1382 N	5419±659 N	5475±1293 N
Normalized Ground Force Reaction of Kicking foot	17.80±2.2 N/kg	17.83±4.82 N/kg	19.2±2.9 N/kg	17.79±2.2 N/kg
Max. Kicking Foot Velocity*	17.66±1.67 m/s	18.27±1.11 m/s	16.45±0.63 m/s	17.18±0.49 m/s
Hip's Range of Motion	155.44±8.6°	141±13°	162.7±13.05°	136±8°
Hip's Angular Velocity	693.4±114.9°/s	580±121°/s	708.4±29.6°/s	625±124°/s
Knee's Flexion/ extension Angle	63.4±8.5°	65.9±4.59°	62.1±10.2°	66.4±4.08°
Knee's Angular Velocity	1585.8±181.2 °/s	1625±140 °/s	1639.6±218.6 °/ s	1607±188 °/s
Swing Phase*/**	0.33±0.03 s	0.4±0.05 s	0.36±0.02 s	0.44±0.06 s
Recovery Phase*/**	0.39±0.06 s	0.46±0.05 s	0.48±0.04 s	0.52±0.07 s
COM lateral	24.8±10.8 cm	0.3±0.15 cm	21.4±4.2 cm	0.34±0.15 cm
COM forward*	90.1±7.0 cm	0.67±0.08 cm	87.6±20.8 cm	0.72±0.14 cm
COM vertical	23.8±2.7 cm	0.21±0.02 cm	26.3±4.6 cm	0.25±0.02 cm

*Represents that there was a significant difference between the two heights, $\alpha<0.05$.
**Represents that there was a significant difference between the two styles, $\alpha<0.05$

RESULTS & DISCUSSION:

To determine the differences in the impact force and turning kick motion according to the kick height, peak impact force, maximum velocity of kicking foot, GRF of the kicking foot, hip's rotating ROM and angular velocity, knee's flexion/extension ROM and angular velocity and the subject's center of mass movement were calculated by Vicon's program workstation.
It is clear that from these results, there is a huge amount of force created by both Taekwondo and Yongmudo player's turning kick. As expected there is a significant difference between peak impact forces according to the height of the target. There is a slight difference between some of the preceding research related with the measurement of kicking forces. Each of these other researchers used different methods but many of them give results corresponding to our results. In the case of Chui (2007), his method gives higher impact force because the air pressure bag is fixed against the wall and thus absorbs all the force. In Sidthilaw's study (1996) as there was only one accelerometer used, there was high probability of the subject kicking the sandbag off-center and thus measuring inaccurately. As a direct result of this the within subjects trials for the same height the standard deviation was approximately 50%. In

this study the standard deviation was reduced to 14% as two 3D accelerometers were fixed to the ends of a PVC pipe which likewise was place in a sandbag. This reduction could be interpreted as an improvement in the measurement of impact forces. Also with such large forces, approx. 5500~7500N, it was recommended to participants that safety equipment should definitely be used during kyorugi. As for the difference of motion of the turning kick there was a larger rotation of the pelvis for the TKD group. The speed swing and recovery phases were shorter for the TKD group.

CONCLUSION

In conclusion, the turning kick's impact force was approx. 6400N and 5447N for midsection and high section turning kick. The turning kick was performed quicker by the TKD players with a similar impact force with more forward motion.

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