Kinematic Comparison of Dolgaechagi between Excellent and Non-excellent Male Taekwondo Athletes

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I. Introduction

Taekwondo was originally developed as a fighting art in Korea and has been distributed all over the world. Taekwondo is a competitive game in martial arts, and the kicking leg is the main weapon in competition, which is the unique feature to taekwondo (Hong, 1997). Furthermore, it has been an official Olympic sport since the 2000 Sydney Olympic Games. The WTF General Assembly, the highest decision-making body of the world’s taekwondo governing body, has voted to overwhelmingly approve the proposed amendments to the WTF Rules and Regulations and the WTF Competition Rules to be effective from June 2009. Among the newly approved WTF Competition Rules were the introduction of a differentiation of valid points (one point for a valid punch or kick to the trunk protector, two points for a valid "turning kick" to the body, and three points for a valid kick to the head). "Turning kick" refers to a kick in which athletes’ vision is momentary lost. These amended rules have directly affected Taekwondo competition strategy of athletes & coaches, which eventually brings changes in competition techniques. Earlier Round house kick use to be one of the most common techniques for scoring, but recently "turning kick", has become popular to score two points if delivered accurately and powerfully on the body. Therefore, it is necessary to analyze the kicking techniques, which has backward turning motion to understand the training implications and to improve the efficiency for getting higher scores in competitions.

Taekwondo kicking techniques could be mainly classified by two kicking patterns, swing kicking pattern and thrust kicking pattern, which are similar concepts of throwlike movement pattern and pushlike movement pattern suggested by Kreigghgau & Barthels (1990). Studies have been conducted on the biomechanical
analysis of Taekwondo kicking techniques such as front kick (Choon-Hong Lee, 2005) round house kick (Peng Liu, 2000), axe kick (Yeh-Jung Tsai, 2004), Side kick (Jung Hyun Lee, 2007) and so on. So far, there are only few studies done on the kicking techniques which has backward turning motion such as back kick, spin whip kick and tornado kick.

Kang, Sang-Hack (2006) analyzed dolgaechagi movements of elementary taekwondo players reported that the centre of gravity was a little backward from the maximum height of the kicking foot snap.

Sung, Cheol Lee (1991) studied the "biomechanical Analysis of Dolgaechagi in Taekwondo" and found that, during the cycle of the full kicking motion, two peak values of shoulder and hip rotational angular velocities, respectively, were observed.

Lee, Sung-Cheol (1991) analyzed the angular momentum during dolgaechagi in taekwondo and found that leading arm and arm of the same side of leading leg were contributed to develop the angular momentum and form the moment of touching the ground by the kicking foot as the angular momentum of leading leg and arm was decreased. Angular momentum was transferred to the kicking leg to maximize the velocity of the kicking foot.

Kang, Sung-Chul(1996) reported that the kicking timing of Dolgaechagi was 0.20 + 0.02s during second takeoff to impact. After second takeoff, COG position/height ratio was to be continuing higher till impact. Maximum velocity of thigh, shank, foot was increased sequentially and this showed whip like motion. Left–right horizontal velocity of foot was high at impact. If angular momentum of trunk and thigh properly transferred to shank and foot till impact and knee angular velocity and angular momentum of shank and foot, the Dolgaechagi can be performed effectively.

There is no study which compares the dynamics of Dolgaechagi among elite Taekwondo athletes. The purpose of this study was to conduct the kinematic comparison of Dolgaechagi between excellent and non–excellent male Taekwondo athletes.

II. Method

1. Subjects

Eight elite male Taekwondo athletes who are not suffering from any disease or injury were chosen as subjects from the Taekwondo sparring team of College of Physical Education, Kyung Hee University. All of them had been practicing Taekwondo for at least 10 years. In order to be considered an expert or elite athlete each Taekwondo players should have won, at least, a medal in a National or university level Taekwondo champion championship.
Table 1. Mean & standard deviation of age, height, weight & career of the subjects

<table>
<thead>
<tr>
<th>Age (Yrs.)</th>
<th>Height (㎝)</th>
<th>Weight (Kgs.)</th>
<th>Career (Yrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.25 ± .71</td>
<td>177.38 ± 4.3</td>
<td>68.87 ± 4.4</td>
<td>12.13 ± 2.6</td>
</tr>
</tbody>
</table>

2. Equipments

A three-dimensional motion analysis system was used to record the kicking motion, which includes Six high-speed IR cameras (60Hz), to record the motion, two AMTI force plates (1000N) were used to collect the Ground Reaction Force data. All the cameras and force plates were connected to Synch box to synchronize the signals. Synch box was connected to the 6 channel analogs to DV converter and amplifier, which was further connected to a computer.

For the purpose of this study 28 highly visible markers were placed across different landmarks of the body as per Helen Hayes marker set. The 3d motion data and GRF data were analyzed using KWON 3D software.

3. Data Collection

Subjects perform a warm-up session of approximately 10 min, which involved footwork, execution of turning motions and Dolgaechagi kicks. Subjects were informed about the procedure of experiment and execution of Dolgaechagi using both the force plates for takeoff and for landing. They were instructed to start the Dolgaechagi by placing their front foot on and rear foot off the first force plate and land on the other force plate to finish. For the final video capture of each pair, one subject stood in front of the kicking subject holding the target and other performed Dolgaechagi on the target held by the other partner. Data was collected within two days. For the purpose of this study, the support leg was defined as the leg which first leaves the ground and the kicking leg was defined as the leg which moves towards the target for impact.

All eight subjects’ total kicking timing was recorded and subjects were divided into two groups accordingly. Subjects those who had total kicking timing less than 0.8 sec. were considered to be in excellent group whereas those who had total kicking timing more than 0.8 were in non-excellent group.

For analysis, Dolgaechagi motion was broken down into four phases to make the events for analysis as follows:

Phase 1- Initial Rotation phase: The period from initial movements till the take off of the support leg.
Phase 2- Support Leg Swing phase: The period from the take off of support leg till the take off of the kicking leg.
Phase 3- Airborne phase: The period between take off of the kicking leg and landing of the support leg.
Phase 4- Kicking Phase: The period between landing of support leg and impact of the kicking leg.
4. Data Analysis

Selected data was transferred from KWON 3D to Microsoft Excel. T.test and correlation coefficient analysis were conducted using SPSS 12 for Windows.

III. Results & Discussion

For the development of effective skills, the timing effect is an important factor for competitive taekwondo. Quicker the response time, the more time available for defense or offence strategy. Therefore, an elite athlete should possess shorter response time (Chang, 1997). Timing of performing Dolgaechagi is the timing of interval between the signal of stimulus (Initial movements) and completion of performance (Impact) which is the sum of the reaction and performance timing. From the Dolgaechagi kicking parameters, we can see when the athletes attacked suspended target which was at abdomen level; its kicking timing for each phase was different.

Data determined that whether within the trials of one subject or between different subjects of same group, the kinematic curves were very similar but, there were differences between kicking timing of each phase between two groups.

Table 2. Mean & Standard Deviation for Each Phase of Kicking Timing

<table>
<thead>
<tr>
<th>GROUP</th>
<th>Total Kicking Time</th>
<th>Initial Rotation Phase : P1</th>
<th>Support Leg Swing Phase : P2</th>
<th>Airborne Phase : P3</th>
<th>Kicking Phase : P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX</td>
<td>0.71 ± 0.04</td>
<td>0.20 ± 0.03</td>
<td>0.32 ± 0.05</td>
<td>0.16 ± 0.01</td>
<td>0.03 ± 0.02</td>
</tr>
<tr>
<td>NON-EX</td>
<td>0.85 ± 0.04</td>
<td>0.31 ± 0.07</td>
<td>0.34 ± 0.03</td>
<td>0.16 ± 0.01</td>
<td>0.04 ± 0.01</td>
</tr>
</tbody>
</table>

Results showed that the total kicking timing had different distribution of timing for each phase of kick. It was observed that Phase 1 & Phase 2 time taken by the excellent group was much shorter than those of non-excellent group. The percentage of total kicking timing in excellent and non-excellent group during each phase are shown in "Table 3 & 4".

Table 3. Total Kicking Time Ratio of each phase, Excellent Group

<table>
<thead>
<tr>
<th>Phase : 1</th>
<th>Phase : 2</th>
<th>Phase : 3</th>
<th>Phase : 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.1%</td>
<td>45%</td>
<td>22.2%</td>
<td>4.7%</td>
</tr>
</tbody>
</table>

"Table 3 & 4" shows the time ratio of total kicking timing in each phase of kick among excellent and non-excellent group respectively. It is observed that the time ratio was different among both groups.
Table 4. Total Kicking Time Ratio of each phase, Non-Excellent Group.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Phase : 1</th>
<th>Phase : 2</th>
<th>Phase : 3</th>
<th>Phase : 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>36.1%</td>
<td>39.5%</td>
<td>19.3%</td>
<td>5.1%</td>
</tr>
</tbody>
</table>

Total time for phase 1 & 2 taken by excellent group was 73.1%. A higher percentage of total kicking time with a difference of 16.9% was observed in phase 2 (45%) than phase 1 (28.1%). It was observed that excellent group took much shorter time in phase 1 than those of non-excellent group.

Total time for phase 1 & 2 taken by non-excellent group was 75.6%. The difference observed between phase 1 and phase 2 was 3.4%. This was relatively higher than the excellent group.

<Table 5> shows that there was a significant positive correlation between the total kicking time and phase 1 time. It is assumed that excellent groups’ shorter total kicking timing was positively effected by the shorter initial trunk rotation time than non-excellent group.

<Table 5> shows that there was a significant positive correlation between the total kicking time and the range of support leg toe in its X & Y axis. It is assumed that the swing movement of support leg during phase 1 & 2 in excellent group was bigger than the excellent group which affected the total kicking timing. Excellent group’s support leg swing movement must have been much economic and close to the line of target whereas non-excellent athletes must have performed unwanted movements during support leg swing resulting the total kicking timing to increase more than the excellent group.

Table 6. Correlation between Total Kicking Timing and Range of Support Leg Toe X & Y Axis.

<table>
<thead>
<tr>
<th>Axis</th>
<th>X Axis</th>
<th>Y Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Kicking Time</td>
<td>.761**</td>
<td>.759**</td>
</tr>
</tbody>
</table>

Angular velocity of pelvis in excellent group is shown in <Figure 1>. The data showed great differences among two groups. The excellent groups had the peak mean angular velocity of pelvis in X axis (248.7 deg/s), which was higher compare to the non-excellent group (203.8 deg/s). From the graph pattern it could be seen that during the whole movement the peak of pelvis angular velocity in X axis was achieved before the end of 4th phase in the excellent group. The graph showed a uniform increase during 2nd and 3rd phase which includes support leg swing and airborne motion.
Angular velocity of pelvis in non-excellent group is shown in Figure 2. A highly fluctuated angular velocity of pelvis in X axis could be observed among non-excellent athletes, especially during the 2nd phase, which is the most important part of rotation in dorgaechagi. The angular velocity first increased and then again decreased during the 2nd phase of kick among the non-excellent group. Unlike the excellent group the peak was achieved at the very beginning of 4th phase among non-excellent group. It is assumed that the early and unformal angular velocity of pelvic in X axis has caused hindrance in moving the body efficiently towards the target.
Angular velocities of pelvis (Y axis) is shown in Figure 3 & 4. The data showed that, there were differences among two groups. The excellent group’s peak mean angular velocity of pelvis in Y axis (259.9 deg/s), was higher then non-excellent group (207.4 deg/s.) In excellent group the pattern showed that pelvis angular velocity in Y axis was achieved in the middle of 3rd and 4th phase, when the whole body was in air. A dramatic increase in angular velocity was observed after the end of 1st phase. There was a decreased angular velocity for a short time during the 2nd phase and then a rapid increase till the airborne phase among the excellent group athletes.
Table 7. Peak Angular Velocity of Pelvic in X & Y Axis.

<table>
<thead>
<tr>
<th></th>
<th>X Axis (Rad/s)</th>
<th>Y Axis (Rad/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>248.7</td>
<td>259.9</td>
</tr>
<tr>
<td>Non-excellent</td>
<td>203.8</td>
<td>207.4</td>
</tr>
</tbody>
</table>

IV. Conclusion

In the present study conclusion described are as follows:

There was a significant difference between Total Kicking Timing between excellent group and non-excellent group. Excellent group was found to be faster than the non-excellent group in each phase of kicking timing. Excellent group’s total kicking timing was distributed as 28.1% for Initial Trunk Rotation phase, 45% for Support Leg swing phase, 22.2% for Airborne phase and 4.7% for Kicking phase. Non-excellent group’s total kicking timing was distributed as 36.1% for Initial Trunk Rotation phase, 39.5% for Support Leg swing phase, 19.3% for Airborne phase and 5.1% for Kicking phase. This was because the Initial trunk rotation phase (Phase: 1) has significantly positive relation .869** (p<0.01), with the total kicking timing. It is suggested that an effective whole body initial trunk rotation at the longitudinal axis should be considered for training to make Dolgaechagi faster. Since the range of support leg was found to have positive correlation with total kicking timing X axis .761** (p<0.01) & Y axis .759** (p<0.01), it is suggested that the support leg swing should be considered as one of the major factor which affect Dolgaechagi motion. The excellent groups had the peak mean angular velocity of pelvis in X axis (248.7 deg/s), which was higher compare to the non-excellent group (203.8 deg/s). The excellent groups had the peak mean angular velocity of pelvis in Y axis (259.9 deg/s), which was higher compare to the non-excellent group (207.4 deg/s).

Dolgaechagi is a complex technique to be used in a Taekwondo competition because it involves backward rotation which needs high level of balance and co-ordination to synchronize the segmental interaction specially in it’s rotation. Since most of the important kinematic factors are related to rotation, it is suggested that Taekwondo athletes should be trained to make an efficient rotation for the improvement in Dolgaechagi.

국문초록

남자 엘리트 태권도 선수 중 우수집단과 비우수집단 간 태권도 돌개차기의 운동학적 비교

Virdi, G. S. · 박성진 · 구본호 · 홍건 · 문황운 · 박영진

2008년 베이징 올림픽 이후 성공적인 발차기에 대한 다득점 가능성이 태권도 경기 규칙의 변화로 반영되고 있다. 최근에는 회전하여 차는 몸통공격 발차기의 득점이 2점이 되면서 태권도 선수들 간에 회전하여 차는 방식의 발차기가 빈번히 행해지고 있다. 이 회전하여 차는 발차기는 일시적으로 선수의 시야가 상대선수에게서 벗어나며 행해지는 공격으로 뒤파거나 돌개차기가 이에 해당하는 발차기이다. 따라서 향후 태권도 겨루기 경기에서 돌개차기에 대한 비중이 높아질 것으로 예상되며 그 중요성이 더욱 강조되고 있다.

본 연구는 8명의 남자 태권도 선수를 대상으로 돌개차기의 발차기 시간을 기준으로 우수집단 4명과 비우수집단 4명으로 나누어 각 그룹 간 차이를 운동학적 변인을 통하여 비교하였다. 측정된 돌개차기 동작의 분석을 위해 사용된 시스템은 (주)비솔 사의 Kwon3D XP 동작 분석 소프트웨어와 6기의 IR camera(60 frames/s, Motion Master, Visol Inc)이며 모든 피험자는 헬렌헤이즈 마커셋(Helen Hayes marker set)에 따라 전신에 반사마커를 부착하였다.

연구결과 분석을 위해 나눈 국면별로 두 집단 간 전체 발차기 시간과 국면별 발차기 시간에 유의한 차이를 나타내었다. 특별히 두 집단 간 제 1국면(Initial Trunk Rotation)의 수행시간과 전체 발차기 시간이 유의한 (p<0.01) 차이를 나타내었고 이는 우수집단과 비우수집단을 나누는 기준에 영향을 미친 것으로 사료된다.

주요어: 태권도, 돌개차기, 운동학, 겨루기

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