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Research Article

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Study and application on the factors of attacking effect by TKD downward kick based on the influence of dynamic model

Chao Liu

Wushu Department, Shandong Sports University, Rizhao, China

ABSTRACT

As time goes by, the pursuit of self-defending increases in a high quality which prompts KTD to be more and more popular in China. Besides, KTD is the official event in Olympic Games. To improve and optimize the skill of Chinese KTD players, the essay sums up the static energy of the players' downward kick by analyzing the mechanic and dynamic relationship caused by downward kick. On analyzing the data collected from the players' training, some defects were found out when the players were downward kicking: it takes so long time to start and draw back the leg during which the crack might be caught by the opponents. When the players swig up the right legs, they will become more stable which reduces the angle of hip joint whose change will influence the power and attacking effect of downward kick.

Key words: Mechanics analysis, dynamics analysis, Lagrange dynamic function, data analysis

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INTRODUCTION

KTD originated from Korea in 1950s, it was shaped by combining and normalizing various combat genres. It was found by General Cuihongxi around 1955 that combined KTD and the folk elements after his retirement. Since the Second World War, the people came back to Korea all over the world had integrated the martial art they learned outside with KTD. KTD was a demonstration event of Hancheng Olympics in 1988, only in the Sydney Olympics in 2000 had it become the official one. In 1989, KTD was brought into China and then the first KTD training class began in Beijing while the preparatory group was set in October 1992. By May 1995, KTD had made its fast development and spread among China as a competitive sport since the first KTD national championship race in Beijing [1-5].

KTD is a martial with both fists and feet of which feet take 70% in the moves. Due to it, the players in modern KTD matches mainly use leg fighting and fist as minor [6-8]. There will be more attack range and power for using leg than fist, so most of the moves of fists are mainly defending or parrying. Breathing is very important in KTD training, normally the loud roaring with deterrent force is needed to overwhelm the opponent in vigor. Research shows that 10% of the muscle free of a burden will fasten 9% of its contracting speed when human makes a sound which shall be more previous with up to 14% speed under burden. This is the reason why the players roar in the match. The players seek for more power and speed in moves, all of which are mainly fighting with power, fast speed and obvious attacking effect. So far, KTD can be classified by power, skill, free sparring, attacking and counter attack and the basic moves are: front snap kick, side kick, back kick, downward kick, hook kick, pushing kick, reverse kick, turning kick, jump kick, single and double serial kicks. And the essay is focus on the downward kick with fast foot lifting and explosive force.

ESTABLISHING AND SOLVING OF THE MODEL

Basic steps of downward kick

First thrust against the ground by right leg, transferring the Centre of gravity to the left leg. Clinch your hands in front of your chest, lift your right leg with hip joint as the axis, put the knee joint onto the chest, stretch your right calf over your head around the knee joint and then make a downward kick straight to the ground with the right heels being the pivot, forming a posture of actual combat. Figure 1 and 2 are the drawings of downward kick.

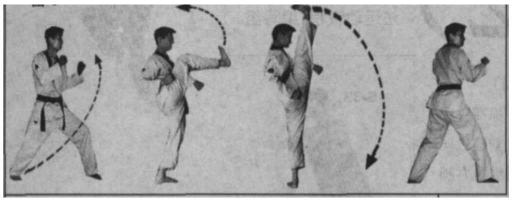

Figure 1: side drawing of downward kick

Figure 2: front drawing of downward kick

Mechanic analysis of downward kick

When downward kick happens, one needs to stretch his right leg up over the head, with the right heel being the pivot and then straight down to the ground. The player's right leg can be a rigid body during the whole process. So the downward kick of the right leg can be seen as a rigid body's rotation around the fixed-axis. Pls refer to Figure 3:

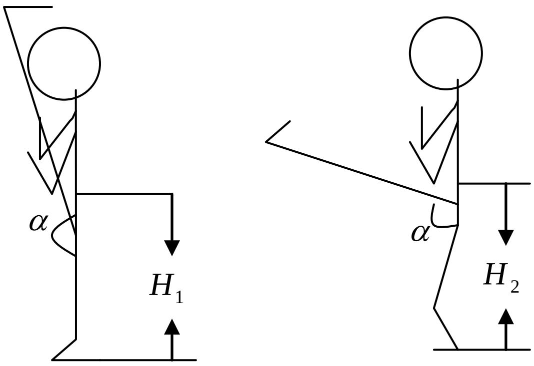

Figure 3: drawing of the right leg's rotation

A resultant moment will be formed during the process of the right leg's rotation, the formula is as follows: $M_z = I_B \bullet \beta$.

I_B is the rotation inertia of the right leg, β is the angular acceleration. Suppose the right leg is a cylindrical rigid body, so its rotation inertia $I_B = \frac{m_1 r_1^2}{2} + \frac{m_2 r_2^2}{2}$.

m_1 Shows the mass of right thigh, m_2: the mass of the right leg, r_1: the radius of the right thigh, r_2; the radius of the right leg. Angular acceleration $\beta = \frac{dw}{dt} = \frac{d^2\theta}{dt^2}$.

The player's Centre of gravity will keep low when he makes a downward kick of the right leg, and then make the gravity work $W = mg(H_1 - H_2)$.

Dynamic analysis of the downward kick

Actually, there is a certain intersection angle between the thigh and the leg when a player makes a downward kick. So the right leg can be made to be a model of two degrees of freedom. See Figure 4:

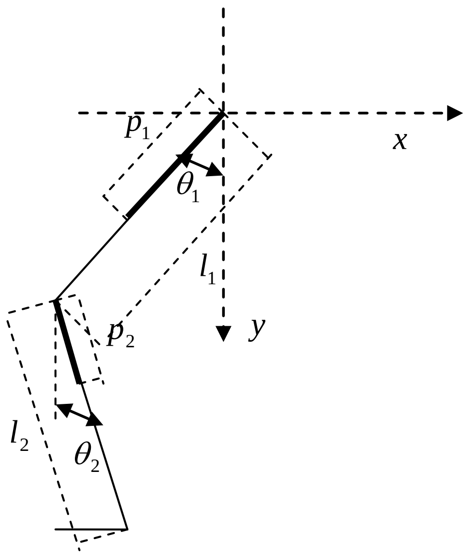

Figure 4: Rigid body degree of freedom for right leg

So the essay set a limited formula of particle dynamics by Lagrange equation. With Lagrange function L to be the D-value of system energy K and potential energy P: $L = K - P$.

The formula for system dynamics is:

$$F_i = \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i} - \frac{\partial L}{\partial q_i}\right) \qquad i = 1,2,\ldots,n$$

$\dot{q}_i$ in above formula is corresponding speed, q_i is the coordinate of potential energy. F_i Is the force in the i coordinate, θ_1, θ_2 are the intersection angles of the thigh, leg and the axes, with l_1, l_2 being the length. The distance between the Centre of hip joint/knee joint and gravity location for thigh and leg is p_1, p_2, so we can calculate the gravity coordinate for thigh (X_1, Y_1):

$$\begin{cases} X_1 = p_1 \sin\theta_1 \qquad Y_1 = p_1 \cos\theta_1 \\ X_2 = l_1 \sin\theta_1 + p_2 \sin(\theta_1 + \theta_2) \qquad Y_2 = -l_1 \cos\theta_1 - p_2 \cos(\theta_1 + \theta_2) \end{cases}$$

Likewise, the gravity coordinate (X_2, Y_2) of the leg can be calculated too. The expression of E_k (system kinetic energy) and E_p (system potential energy) is as follows:

$$\begin{cases} E_k = E_{k1} + E_{k2}, E_{k1} = \frac{1}{2} m_1 p_1^2 \dot{\theta}_1^2 \\ E_{k2} = \frac{1}{2} m_2 l_1^2 \dot{\theta}_1^2 + \frac{1}{2} m_2 p_2^2 \left(\dot{\theta}_1 + \dot{\theta}_2 \right)^2 + m_2 l_2 p_2 \left(\dot{\theta}_{01}^2 + \dot{\theta}_1 \dot{\theta}_2 \right) \cos\theta_2 \\ E_p = E_{p1} + E_{p2}, E_{p1} = \frac{1}{2} m_1 g p_1 (1 - \cos\theta_1) \\ E_{p2} = m_2 g p_2 [1 - \cos(\theta_1 + \theta_2)] + m_2 g l_1 (1 - \cos\theta_1) \end{cases}$$

Write the above formula into the expression of Lagrange function, then by the formula of Lagrange system dynamics, we can get the torques on the hip joint and knee joint M_h and M_k:

$$\begin{bmatrix} M_h \\ M_k \end{bmatrix} = \begin{bmatrix} D_{11} & D_{12} \\ D_{21} & D_{22} \end{bmatrix} \begin{bmatrix} \ddot{\theta}_1 \\ \ddot{\theta}_2 \end{bmatrix} + \begin{bmatrix} D_{111} & D_{122} \\ D_{211} & D_{222} \end{bmatrix} \begin{bmatrix} \dot{\theta}_1^2 \\ \dot{\theta}_2^2 \end{bmatrix} + \begin{bmatrix} D_{112} & D_{121} \\ D_{212} & D_{221} \end{bmatrix} \begin{bmatrix} \dot{\theta}_1 \dot{\theta}_2 \\ \dot{\theta}_2 \dot{\theta}_1 \end{bmatrix} + \begin{bmatrix} D_1 \\ D_2 \end{bmatrix}$$

D_{ijk} in above formula is :

$$\begin{bmatrix} D_{111} = 0 \quad D_{222} = 0 \quad D_{121} = 0 \quad D_{22} = m_2 p_2^2 \\ D_{11} = m_1 p_1^2 + m_2 p_2^2 + m_2 l_1^2 + 2 m_2 l_1 p_2 \cos\theta_2 \\ D_1 = (m_1 p_1 + m_2 l_1) g \sin\theta_1 + m_2 p_2 g \sin(\theta_1 + \theta_2) \\ D_{12} = m_2 p_2^2 + m_2 l_1 p_2 \cos\theta_2 \quad D_{21} = m_2 p_2^2 + m_1 l_1 p_2 \cos\theta_2 \\ D_{122} = -m_2 l_1 p_2 \sin\theta_2 \quad D_{211} = m_2 l_1 p_2 \sin\theta_2 \\ D_{112} = -2 m_2 l_1 p_2 \sin\theta_2 \quad D_{212} = D_{122} + D_{211} \quad D_2 = m_2 p_2 g \sin(\theta_1 + \theta_2) \end{bmatrix}$$

DATA ANALYSIS OF DOWNWARD KICK

Each step's analysis of downward kick

To find out the effective way for Chinese KTD players to knock down their opponents, video measurement was used to record the whole process of the player's action by DV and then put the action image from the DV into the XYZ, selecting the head, shoulder, hand, elbow, hip, knee all together 20 aris of the players for digitization. After getting the XYZ of each aris, ant aliasing, count and analyze them to achieve the analytic data for the player's downward kick [9, 10].

Tablet 1 show the time a player takes for downward kick in different steps.

Table 1: the time a player takes for downward kick in different steps

No	Initiation	Knee lifting	Kicking target	Draw back	Total time	marks
1	0.22	0.14	0.12	0.36	0.84	
2	0.24	0.14	0.10	0.32	0.80	
3	0.24	0.12	0.12	0.34	0.82	
4	0.20	0.12	0.10	0.26	0.68	A Team
5	0.20	0.10	0.10	0.32	0.80	
6	0.24	0.14	0.10	0.32	0.80	
$\bar{x} \pm s$	0.22 ± 0.02	0.12 ± 0.02	0.10 ± 0.02	0.32 ± 0.03	0.78 ± 0.06*	
7	0.20	0.10	0.10	0.30	0.70	
8	0.22	0.12	0.10	0.22	0.66	
9	0.20	0.12	0.10	0.22	0.64	B Team
10	0.18	0.10	0.10	0.26	0.64	
$\bar{x} \pm s$	0.20 ± 0.02	0.11 ± 0.02	0.10 ± 0.02	0.25 ± 0.04	0.66 ± 0.03*	
proportion（%）	29	17	14	40	100	
$\bar{x} \pm s$	0.22 ± 0.02	0.12 ± 0.02	0.10 ± 0.02	0.29 ± 0.05	0.73 ± 0.07	

*PS: Team A is amateur, Team B is the player, * is the statistic of A and B, so* $P < 0.05$.

We can see from Table 1 that when a player make downward kick, the initiation takes 295 of the total time, knee lifting takes 17%, kick target is 14% and draw back the leg takes the most time: 40%. The average time that teams A takes to finish downward kick is $\overline{T} = 0.78 \pm 0.06$ s, while the player's is $\overline{T} = 0.66 \pm 0.03$ s, in both of the data $P < 0.05$, which proves that the data is reasonable.

We can see from above data, more time the players take in initiation and knee lifting, less time they leave to the opponents for reaction. So the players can finish downward kick and have the upper hand before their opponents take actions. If they spend more time on initiation, the opponents can make clear their intention and lost their initiative. So the players should cut down the initiation time. Besides, if draw back the legs take too much time, the players might lose their gravity, leaving a chance for their opponents to counterattack. So the players should try their best to cut down the time of drawing back the leg and use the suitable attacks.

Analysis of the gravity change while downward kicking

Downward kick, expressed in KTD is to attack the opponent's head, shoulder and collarbones. So the players need to improve the gravity and make sure they themselves are stable when they take downward kick. Otherwise, the upper hand will turn to the opponents. Table 2 shows the gravity change of the player's downward kick.

Table 2: gravity change of the player's downward kick

No	Three dimensional gravity index（m）			Marks
	X	Y	Z	
1	0.56	0.25	0.28	
2	0.52	0.21	0.28	
3	0.49	0.22	0.29	
4	0.52	0.20	0.28	A Team
5	0.54	0.19	0.26	
6	0.57	0.20	0.29	
$\overline{x} \pm s$	$0.53 \pm 0.03^*$	$0.21 \pm 0.02^*$	0.28 ± 0.01	
7	0.41	0.15	0.29	
8	0.44	0.14	0.25	B Team
9	0.43	0.16	0.29	
10	0.42	0.17	0.23	
$\overline{x} \pm s$	$0.43 \pm 0.01^*$	$0.16 \pm 0.01^*$	0.27 ± 0.03	

PS: * is the statistic of A and B, so $P < 0.05$

When the player takes a downward kick, he thrusts against the ground with right feet, transferring the gravity to the left feet, finishing it under the lead of the hip joint and knee joint. Data from Table 2 shows: the maximum displacement of Team A on Y-axis is $0.25m$, the minimum one is $0.14m$. The data on X-axis changes a lot, with the maximum displacement being $0.56m$ and the minimum being $0.41m$. According to the gravity on X-axis and Y-axis, team B is more stable than team A. So the players need to hold themselves while improve the gravity in case the accident happens, losing the advantage.

Analysis on the displacement change of right leg swing in downward kick

In KTD, downward kick is of high degree-of-difficulty, not only requires high flexibility and coordination, but also requires the power of the player's abdomen, waist and leg. Figure 5 and Figure 6 are the curves for the time change and the displacement of hip, knee, ankle and the tiptoe collected by the time the players of Team A and B make downward kick.

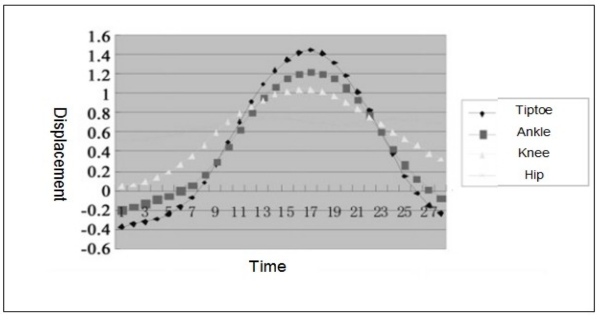

Figure 5: curve of the time and the right leg's swing displacement of Team A

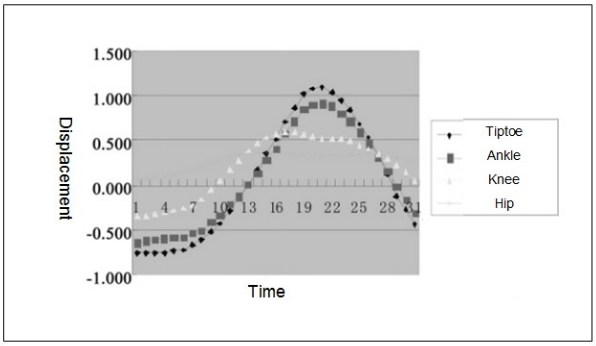

Figure 6: curve of the time and the right leg's swing displacement of Team B

We can see from Pic 5 and 6, the commutation of the hip joint is the steadiest of all the process in downward kick. But when the player lifts his leg, the knee joint changes fast, even beyond the hip joint. When it comes to the target attack, the ankle and tiptoe starts to go up over the knee joint. Finally the right leg falls, and the curve of the ankle and tiptoe fall sharply. Seen from the data, when downward kicking, the minimum displacement of the tiptoe is $1.89m$, which proves that the attack range of downward kick is much greater than that of the turning kick and side kick. Meanwhile, we can see that the swing distance of the tall player might not be farther than that of the short player. Because in the process of downward kick, the player can not make full use of their long leg due to the limit of the hip joint displacement and their own flexibility.

CONCLUSION

By analyzing the relationship between the mechanics and dynamics of the player's downward kick, the potential energy caused in it is achieved. Besides, the essay finds out the defects of downward kick by analyzing the data collected in the training: it takes too long time for the player to start and draw back the leg, leaving chance and crack for the opponents. When the player takes a right leg kick, reducing the angle of hip joint will improve the stability while the change of knee joint might influence the power and attack effect of downward kick.

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