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The kinematics of taekwon-do back kick

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Abstract

Background: The back kick (in taekwon-do terminology referred to as dwit chagi) is considered a powerful weapon in taekwon-do sparring. This paper attempts to identify the kinematic factors affecting the efficiency of the back kick on the basis of values obtained for foot and knee velocities and the duration of the kick. Material/Methods: The study was based on 3 taekwon-do athletes (aged 16.3 ±0.6 years; weight 66.0 ±7.9 kg; height 172.0 ±7.0 cm). The case study relied on an Italian system called Smart-D, manufactured by BTS S.p.A., used for complex movement analysis. Results: The mean resultant velocity of the dwit chagi determined in this study was 6.00 ±1.39 m/s, and the kick's duration was 0.77 ±0.46 s. The mean maximum velocity was developed at the length of the leg equal to ca. 80% of its maximum length value. Conclusions: The study shows that the resultant velocity of the kick correlates with the location of the foot (r = -0.86) and its velocity when aiming at the target (r = 0.98). Duration of the kick depends on the velocity of chambering up the knee (r = -0.65) and its extension directed at the target (r = -0.73) as well as the foot take-off (r = -0.69) and its lifting (r = -0.50) velocities.

Keywords

taekwon-do, analysis of movement, kick kinematics, biomechanics of martial arts

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ORIGINAL

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Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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Material/Methods The study was based on 3 taekwon-do athletes (aged 16.3 ±0.6 years; weight 66.0 ±7.9 kg; height 172.0 ±7.0 cm). The case study relied on an Italian system called Smart-D, manufactured by BTS S.p.A., used for complex movement analysis.

Results The mean resultant velocity of the dwit chagi determined in this study was 6.00 ±1.39 m/s, and the kick's duration was 0.77 ±0.46 s. The mean maximum velocity was developed at the length of the leg equal to ca. 80% of its maximum length value.

Conclusions The study shows that the resultant velocity of the kick correlates with the location of the foot (r = -0.86) and its velocity when aiming at the target (r = 0.98). Duration of the kick depends on the velocity of chambering up the knee (r = -0.65) and its extension directed at the target (r = -0.73) as well as the foot take-off (r = -0.69) and its lifting (r = -0.50) velocities.

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INTRODUCTION

Taekwon-do sports competition rules and regulations favour kicks rather than hand strikes [1]. Therefore, the fighting strategy makes athletes concentrate on being able to deliver frequent kicks. Depending on the very situation in an on-going fight, an experienced taekwon-do practitioner uses such kicks which result in achieving the set goals with the least effort possible. That is the reason why an increasingly growing number of researchers set out to determine biomechanical optimization and identification of factors affecting performance of strikes and kicks [2, 3, 4]. Such expertise makes it possible to increase their efficiency and to facilitate and enhance the learning process. These issues are especially important in taekwon-do, where the result of a fight often depends on a single strike or kick.

The back kick (in taekwon-do terminology referred to as *dwit chagi*) is considered a powerful weapon in taekwon-do sparring. Research shows [5] that, apart from the roundhouse kick, the back kick is the most frequently used technique in sports competitions.

However, contrary to the roundhouse kick, the back kick has not had such in-depth or frequent research conducted into it. Pędzich et al. [6] and Wąsik [7] conducted studies on how the turn affects the kicks' kinetics. Investigations conducted on karate athletes showed that there were no significant differences in this kick between men and women [8]. It was observed that turning kicks develop greater speed than kicks without turning [9]. That was proved by different research [10] which reported that the power values in *dwit-chagi* were greater than those in *yop-chagi*. It was also reported that during taekwon-do competitions the roundhouse kick landing on the opponent's head is the most frequent reason for concussion [11]. Yet another research produced a biomechanical analysis of the *jump back kick* [12].

The objective of this paper is to make an attempt at identifying kinematic factors affecting the efficiency of the *back kick* on the basis of the recorded foot and knee velocity values and the duration of the kick. Having adopted the sports technique biomechanical analysis criteria used so far [13], and especially the techniques used in taekwon-do [14], the research investigation was based on five stages of the movement: the initial stance (starting position), foot take-off, lifting the leg while pivoting the body, the final phase and the finishing posture. The following research questions were raised:

1. At which moment is the foot velocity the greatest?

2. Which selected kinetic factors influence the velocity of the kick and the execution time of the kick?

3. How does the knee velocity affect the foot velocity?

The answers to these questions might help to choose a better and more efficient method of performing this type of strikes when breaking hard objects, sports sparring or self-defence.

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MATERIAL AND METHOD

PARTICIPANTS

The study was based on 3 taekwon-do ITF (International Taekwon-do Federation) athletes (aged 16.3 ±0.6 years; weight 66.0 ±7.9 kg; height 172.0 ±7.0 cm). The researched group included one advanced athlete (European Junior Champion, black belt) and one medium advanced athlete (red belt) and one less advanced athlete (green belt). The athletes, had practised taekwon-do for a period of 2 to 6 years. They train regularly 2 to 5 times a week.

The Human Subjects Research Committee of the University scrutinized and approved the test protocol as meeting the criteria of Ethical Conduct for Research Involving Humans. All subjects in the study were informed of the testing procedures and voluntarily participated in the data collection.

PROCEDURE

The case study relied on an Italian system called Smart-D, manufactured by BTS S.p.A., used for complex movement analysis. The system comprises six cameras reflecting infrared rays, which in real time located the markers fixed to the athlete's body. The system made it possible to record the picture of the athlete's moving body and evaluate the obtained kinetic parameters. The movement was recorded with the accuracy of 0.3–0.45 mm and the frequency of 120Hz. The obtained data concerning the movement and the speed of characteristic points on the athlete's body were analysed, which allowed specifying the indicators which define the structure of space and time of the athlete's movement. In the analysis of particular segments of the technique, the following factors were taken into consideration: foot velocity and knee axes X, Y and Z (Fig. 1).

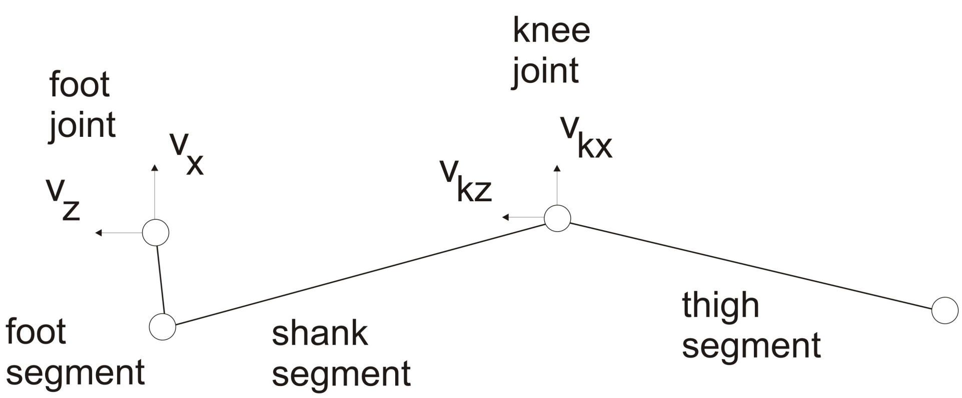

Fig. 1. General view presenting relevant joints and segments of the kicking leg

For the purpose of the experimental part of the study the subjects were asked to adopt the same initial stance (in taekwon-do terminology called Niunja So Palmok Degi Maki) and perform three times the dwit chagi. The structure of the movement is presented in Figure 2.

STATISTICS

Statistical analyses are reported as mean values and standard deviation (SD). All correlations were evaluated using MS Excel 2000.

RESULTS

Fig. 2. The subsequent movement stages and example linear velocity changes of the foot marker during the performance of the *dwit chagi*

Starting posture: The athlete adopts the L-stance forearm guarding block (in taekwon-do terminology referred to as *niunja sogi palmok debi maki*) with the right foot at the front. According to the taekwon-do rules [15], in this stance 70% of the body weight should rest on the back foot and 30% should rest on the front leg. Both feet should be slightly pointed inwards, and the toes of the front leg should be aligned with the heel of the back leg. Both knees are slightly bent. The term “initial stance”, i.e. “starting posture”, comprises information on the stance and the place where an attempted kick starts.

Foot take off: The athlete pivots their body with the back first. Next they take their left foot (the one at the back) off the floor transferring the whole weight of the body onto the right leg. The arms stay close to the trunk.

Lifting the leg: On the very completion of the foot take-off, the stage of lifting the leg starts. Pushing the left foot off the floor results in the force making the foot travel upwards. Further movement is facilitated by the force of inertia and the movement is controlled by the muscles of the lower extremity. The extension of the muscles at the hip joint follows.

Finishing posture: Having turned the body by 180 degrees, the athlete has to balance their body in such a way so as to maintain only one point of contact (the foot of the supporting leg) with the floor. Next, by making the reverse movement (to the movement of the leg extension) the athlete adopts the finishing posture.

The mean values of the kinetic parameters are presented in Table 1. The values of the correlation coefficients between selected factors are given in Table 2.

Table. 1. Selected kinetic parameters of the *dwit chagi* kick

	Mean	SD	Range
Foot resultant velocity [m/s]	6.00	1.39	4.01-7.34
Foot location * [%]	79.8	7.1	68.0-89.9
Maximum foot velocity [m/s] OX	2.25	0.76	1.28-3.33
Maximum foot velocity [m/s] OY	5.69	0.59	4.61-6.50
Maximum foot velocity [m/s] OZ	4.93	0.83	3.46-5.80
Maximum knee velocity [m/s] OX	2.79	0.81	1.85-4.30
Maximum knee velocity [m/s] OY	4.05	1.30	2.82-6.29
Maximum knee velocity [m/s] OZ	5.08	1.07	3.65-6.59
Time of achieving the maximum velocity [s]	0.71	0.56	0.60-0.76
Duration of the kick [s]	0.77	0.46	0.67-0.82

* % location of the foot marker (100% full extension of the leg) at the moment of the foot developing the maximum velocity

Table 2. Correlation coefficients (r) between the selected factors and the resultant velocity and the duration of the *dwit chagi* kick

	Foot resultant velocity [m/s]	Duration of the kick [s]
Foot resultant velocity [m/s]	-	0.01
Foot location * [%]	-0.86	-0.08
Maximum foot velocity [m/s] OX	0.13	-0.69
Maximum foot velocity [m/s] OY	-0.36	-0.50
Maximum foot velocity [m/s] OZ	0.98	0.07
Maximum knee velocity [m/s] OX	0.65	-0.01
Maximum knee velocity [m/s] OY	0.52	-0.65
Maximum knee velocity [m/s] OZ	-0.19	-0.73
Time of achieving the maximum velocity [s]	-0.33	0.84
Duration of the kick [s]	0.01	-

* % location of the foot marker (100% full extension of the leg) at the moment of the foot developing the maximum velocity

DISCUSSION

Pieter [10] reported that the velocity of the *dwit chagi* kick is within 6.71–9.14 m/s. The mean resultant velocity measured in this study is lower, as it is 6.00 ±1.39 m/s. This lower value is thought to have been affected by the fact that two of the athletes under the study were less advanced taekwon-do practitioners. The weakest one achieved the resultant velocity of 4.01 m/s while the most advanced one developed the velocity of 7.34 m/s. Moreover, the differences in the recorded velocities might result from various ways of delivering the kick as well as the age differences between the athletes taking part in the study. In Pieter's study the kicks were aimed at a boxing punch bag. In this study the kicks had no physical target determined. It is known that this fact is quite significant for developed velocities [16]. Different conditions might affect the patterns of kick delivery, which could actually provide material for further studies. The recorded duration of the kick was 0.77 ±0.46 s. This value is close to the values obtained in other research. Kim et al. [17] reported that the duration of the back kick was 0.75 s.

On the basis of the data provided in Table 2, it can be noted that the resultant velocity of the kick correlates with the location of the foot (r = -0.86) and its velocity when aiming for the target (r = 0.98) and also with the speed of chambering up the knee (r = 0.52). Hence, in the initial stages of the technique it is not the foot, but the movement of the knee that provides the momentum for the kick. Interestingly, the velocity does not depend on the duration of the kick (r = 0.01). The duration of the kick (Table 2) depends on the velocity of chambering up the knee (r = -0.65) and its extension directed at the target (r = -0.73) as well as the foot take-off (r = -0.69) and its lifting (r = -0.50) velocities, which, needless to say, strongly correlates with the time of developing the maximum velocity (r = 0.84). This shows that the factors which are responsible for affecting velocity and the factors affecting the duration of the kick are different with the only exception of chambering up the knee, which affects both factors.

It is known that the force depends on the achieved velocity [18]. Adequately assessed distance affects the achieved force of the kick [19]. In this study the mean maximum velocity was obtained at the maximum value of 80% of the leg length (an advanced athlete usually at 79%). However, depending on how advanced an athlete was and their individual features it ranged from 68% to 90%. It can be assumed that the optimum value of this distance should be assessed individually.

CONCLUSIONS

When summing up the conducted study it should be noted that the initial stage should witness a really fast chambering up of the knee. It should also be emphasised that an athlete must stay focused on moving the foot in one specific direction so as to preserve the integrity of the energy produced. Figures 3 and 4 provide graphic illustrations of the factors affecting the foot velocity and the total duration of the back kick delivery.

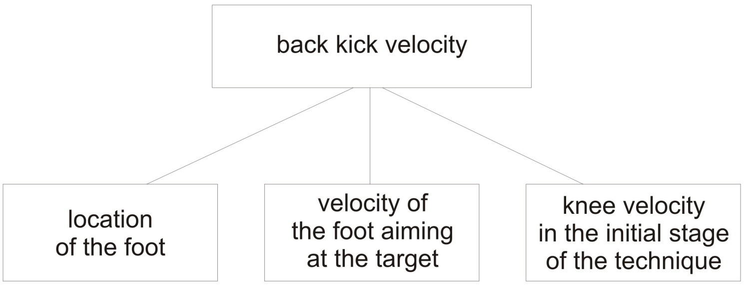

Fig. 3. Diagram representing factors affecting the velocity of the *back kick*

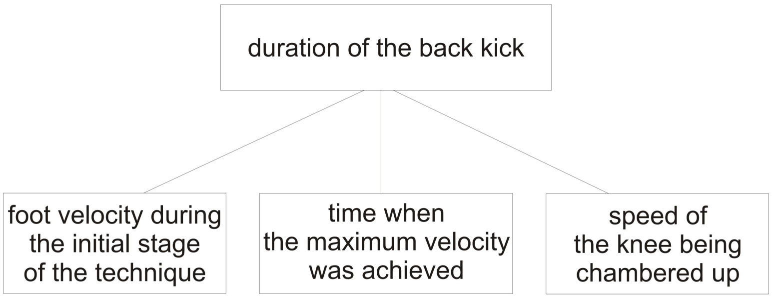

Fig. 4. Diagram representing factors affecting the total duration of the *back kick*

It is clear that further research is much needed so that the factors affecting efficiency of the *back kick* could be specified. It would be very interesting to conduct such an analysis during an actual sparring event, which would make it possible to understand which variables of the movement do affect the kick efficiency. This paper covers only a selected part of the problem. However, it should allow both competent coaches and athletes to optimise their training practice. The results and conclusions presented in this paper provide comparative material for other researchers and can be used as a springboard for further research.

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