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Kinematics of taekwon-do front kick

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Abstract

Background & Study Aim: Taekwon-do according to the theory of combat sports qualify for category consisting of in hits (strokes). This is of particular importance especially in the case of the traditional version of taekwon-do, in which a single kick might reveal the winner. The aim of the paper is knowledge about the influence of chosen kinematic factors on the front kick technique.

Materials & Methods: In the study 6 taekwon-do ITF athletes were examined (age:16.5±1.0 year; body mass: 64.14±10.9 kg; height: 176.5±7.5 cm). According to the criteria commonly used in biomechanical analysis of combat sports athletes were asked to execute the front kick (in taekwon-do terminology referred to as ap chagi). The foot and knee velocities in chosen movement phases were determined in the Cartesian coordinate system and so were the duration of particular phases of movement and the total duration of the complete kick.

Results: The maximum average foot velocity obtained was 10.40 ±0.77 m/s. The correlation and dependence values of the determined kinematic parameters and the maximum velocity of the kick denote that the maximum front kick velocity ($p<0.05$) is affected by the following factors: maximum knee velocity ($r = 0.92$), total kick duration ($r = 0.73$), total time of foot takeoff ($r = 0.61$).

Conclusion: The conducted research shows that in order to achieve the maximum foot velocity in the execution of the front kick an athlete needs to increase the velocity of the knee traveling towards the target and to decrease the duration of the foot takeoff.

Key words: analysis of movement • biomechanics • combat sports

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Taekwondo – a Korean martial art and combat sport where it uses kicks and punches with a heavy emphasis on kicks. The fights are individual and standing.

Parameters – the variable inputs to a generalized motor program, such as speed or amplitude of the movement, which result in different surface features [22, p. 135]

INTRODUCTION

Taekwon-do according to the theory of combat sports qualify for category consisting of in hits (strokes) [1]. Biomechanics of taekwon-do techniques facilitates the possibility of identifying the factors which affect the success which an athlete might achieve in a competition, a show or in a real fight. Having such knowledge and understanding how it works can improve an athlete's ability to learn how to deliver the fastest and most powerful kicks. There are a number of factors which add to an efficient kick execution. Choi [2] put forward the "theory of power". In the 1960s and 1970s the kinematic aspect of strikes and the process of breaking hard objects with bare hands were analyzed [3-4]. The following years witnessed continuation of those studies [5-6], in which attempts were made at describing the dynamic theory of strikes and a more detailed registration of kinematics of strikes. There are also other studies describing the biomechanical aspects of the kicking [7-8].

It is relatively easy to learn how to execute the front kick (in taekwon-do terminology referred to as ap chagi) and to execute it quite efficiently; however, it is very difficult to bring it to perfection. The kick comprises rotational movements whose aim is to produce high velocities of the kinematic chain segments. Body segment length determines the radius of the rotational motion, thus affecting the linear velocity of the kick. The front kick was analyzed in a few aspects [9], namely a) hip, knee and ankle muscle torque arrangement, b) sequence of actions of the dominant muscle group, c) muscle contraction type, and d) range of movement phases in regard to the efficient muscle torques applied. It was observed that in the case of the high front kick thigh deceleration takes place as a result of a movement dependent on the initial movement in the lower extremity and not the braking action as such [10]. Other researchers' interests concerned the acceleration of the center of gravity, changes in the angles of body segments as well as changes in the momentum during execution of the roundhouse kick [11]. The mean roundhouse kick execution time was 0.35 and 0.30 second for male and female athletes respectively of the Singapore top taekwon-do practitioners [12]. However, no connection between the shortest trajectory and the peak velocity was found. The mean maximum velocity of this kick is between 12.84-16.26 m/s [13].

The aim of the paper is knowledge about the influence of chosen kinematic factors on the front kick technique.

The following research questions arise:

- What kinematic factors affect the foot velocity in the execution of the front kick?
- Does the foot and knee movement technique affect the kinematics of the kick?

MATERIALS AND METHODS

Subjects

The study was based on 6 taekwon-do ITF (International Taekwon-do Federation) athletes (age:16.5±1.0 year; body mass: 64.14±10.9 kg; height: 176.5±7.5 cm). The researched group included three European Junior Champions – black belt holders (1st Dan), two Polish Junior Champions – red belt holders (1st-2nd kup) and one athlete who had practised taekwon-do for a minimum of 4 years (grades 4th kup). They train regularly 3 to 5 times a week. This study was approved by Bioethics Committee in Rzeszow and was performed in accordance with the international ethical standards.

Protocol

Pursuant to the criteria of sports technique biomechanical analyses [14], and the measurement methods applied in taekwon-do research in particular [15-17] four movement phases of the side kick have been specified in the present paper: starting posture (the initial stance), foot takeoff, bringing the knee/foot up and the final phase of leg extension.

For the purpose of the experimental part of the study they were asked to adopt the same initial stance (in taekwon-do terminology called niunja so palmok degi maki) and perform the front kick three times. The analysis covered 18 attempts altogether. The structure of the movement is presented in figures 1 and 2.

The study relied on an Italian system called Smart-D, made by BTS S.p.A., used for complex movement analysis. The system comprised 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 kinetic parameters obtained. The movement was recorded with the accuracy of 0.3 – 0.45 mm and the frequency of 120 Hz. Obtained data concerning the movement and speed of the characteristic points on the athlete's body were analyzed, which allowed to specify the indicators which define the space and time structure of the athlete's movement. In the analysis of particular segments of the

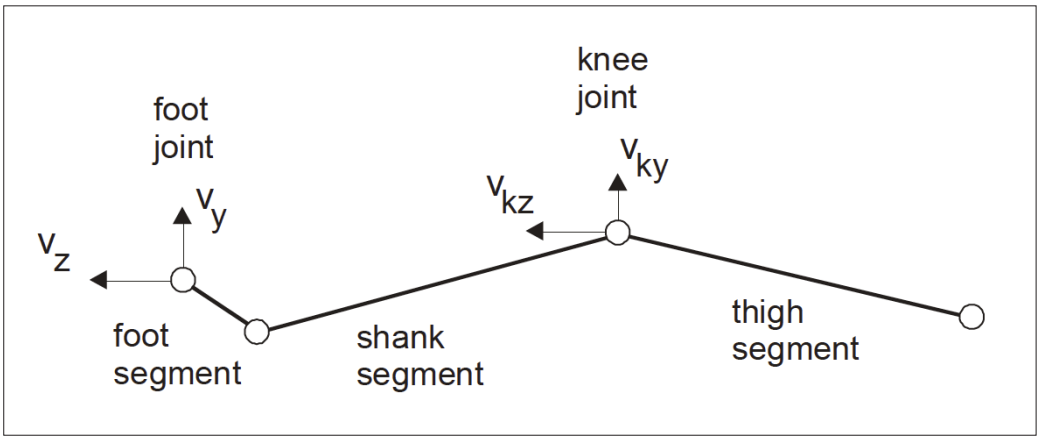

Figure 1. General view presenting relevant joints and segments of the kicking leg.

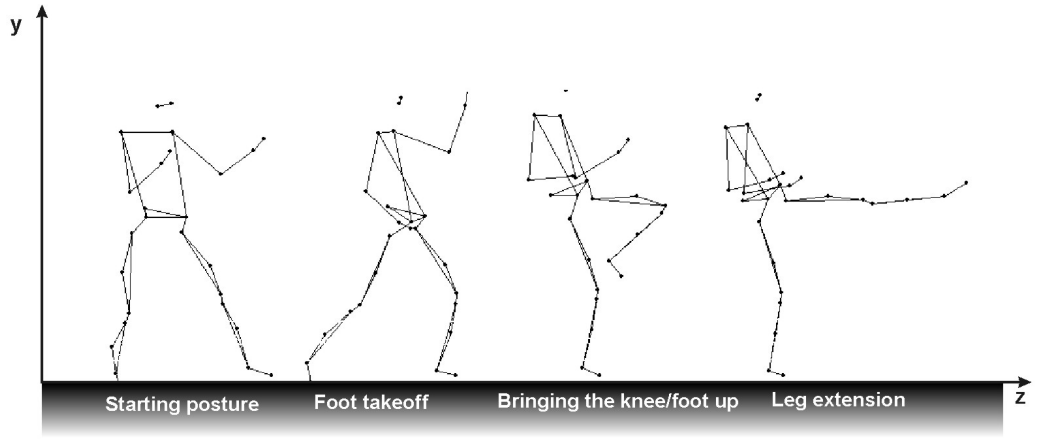

Figure 2. Front kick movement phase.

technique the following factors were taken into consideration: V_z [m/s] – the maximum foot velocity in relation to axis OZ, V_y [m/s] – the maximum foot velocity in relation to axis OY, V_{kz} [m/s] – the maximum knee velocity in relation to axis OZ, V_{ky} [m/s] – the maximum knee velocity in relation to axis OZ, V_{tz} [m/s] the maximum foot velocity in the takeoff phase OZ, V_{ty} [m/s] – the maximum foot velocity in the takeoff phase OY, T[s] total duration of the kick, $t_{takeoff}$ – total time of the foot takeoff, $t_{bringing}$ – total time of bringing the foot up.

Statistics

For the recorded parameters the average values and standard deviations (SD) were calculated. Correlation coefficients were determined between the factors obtained and the maximum foot velocity. This correlation was verified at the significance level where $p<0.05$. All the statistical calculations were carried out with the use of MS Excel.

RESULTS

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 left foot moved forward. According to taekwon-do rules [2] in this stance 70% of the body weight should rest on the back foot and 30% on the front one. Both feet should be slightly pointed inwards and the toes of the foot at the front should be lined up with the heel of the back foot. Both knees are slightly bent. The term 'starting posture' comprises information on the stance and the place where the attempted attack starts.

Foot takeoff: The athlete rests his/her body weight on the front foot and moves his/her torso and the arms in the direction of the intended movement. Next he/she takes off the right foot (the back foot) while transferring the total body weight onto the left foot. The velocity of the foot being brought up in this phase was the highest in this study and it was 0.34 ±0.03 s.

Table 1. Biomechanical variables affecting the efficiency of the kick

Variables	Average ± SD	Range
V_z [m/s] maximum foot velocity OZ	10.40 ± 0.77	8.99±11.50
V_y [m/s] maximum foot velocity OY	8.72 ± 1.34	6.61±10.35
V_{kz} [m/s] maximum knee velocity OZ	5.06 ± 1.19	3.56 ±6.79
V_{ky} [m/s] maximum knee velocity OY	5.95 ± 1.24	4.11±7.67
V_{tz} [m/s] maximum foot velocity in the takeoff phase OZ	4.33 ± 0.50	3.55±5.04
V_{ty} [m/s] maximum foot velocity in the takeoff phase OY	4.58 ± 0.51	3.92±5.65
T[s] total duration of the kick	0.63 ± 0.03	0.58± 0.66
$t_{take\ off}$ total time of the foot takeoff	0.34 ± 0.03	0.29±0.36
$t_{bringing}$ total time of bringing the foot up	0.28 ± 0.02	0.25±0.33

Table 2. Correlation coefficient (r) between parameters influencing the efficiency of the kick (* p<0.05)

Variables	V_z [m/s] r
V_y [m/s] maximum foot velocity OY	–0.07
V_{kz} [m/s] maximum knee velocity OZ	0.36
V_{ky} [m/s] maximum knee velocity OY	0.92*
V_{tz} [m/s] maximum foot velocity in the takeoff phase OZ	0.02
V_{ty} [m/s] maximum foot velocity in the takeoff phase OY	–0.31
T [s] total duration of the kick	0.73*
$t_{take\ off}$ [s] total time of the foot takeoff	0.61*
$t_{bringing}$ total time of bringing the foot up	–0.11

Bringing the knee/foot up: Completion of the foot takeoff commences the next phase, which is bringing the knee/foot up and it lasts 0.28 ±0.02 s. The takeoff of the back foot provides the force which facilitates the upward movement of the foot. Next follows the maximum bending in the knee joint. Further movement is a result of the leg muscles taking control over the movement, and next a full flexion in the knee joint occurs.

Leg extension: The kicking leg is fully flexed in the knee joint. The torso leans slightly back and the arms move a little so as to balance the extension of the leg. The athlete needs to balance his/her body in such a way so as to make sure that the only point touching the ground is his/her standing foot.

Figure 3 presents how the foot velocities change in the Cartesian coordinate system during the execution of the front kick. It can be observed that all these velocities start from 0 m/s, which denotes the starting posture (in which both feet are stationary on the ground). Velocity v_z is the velocity at which the foot is approaching the target of the strike while velocity v_y is the velocity at which an athlete brings the kicking foot up. The takeoff foot accelerates to reach the mean takeoff velocity v_{tz} = 4.42 ± 0.52 m/s and then to become v_{ty} = 4.58 ± 0.51 m/s. This is followed by a significant increase in this velocity when its value reaches the maximum velocity of the whole kick and whose mean value is v_z = 10.40 ± 0.77 m/s and the velocity of the foot being brought up v_y = 8.72 ± 1.34 m/s. Next, starts the deceleration process, in which the velocity falls to its minimum value. The kinematic parameters specifying the front kick are presented in Table 1.

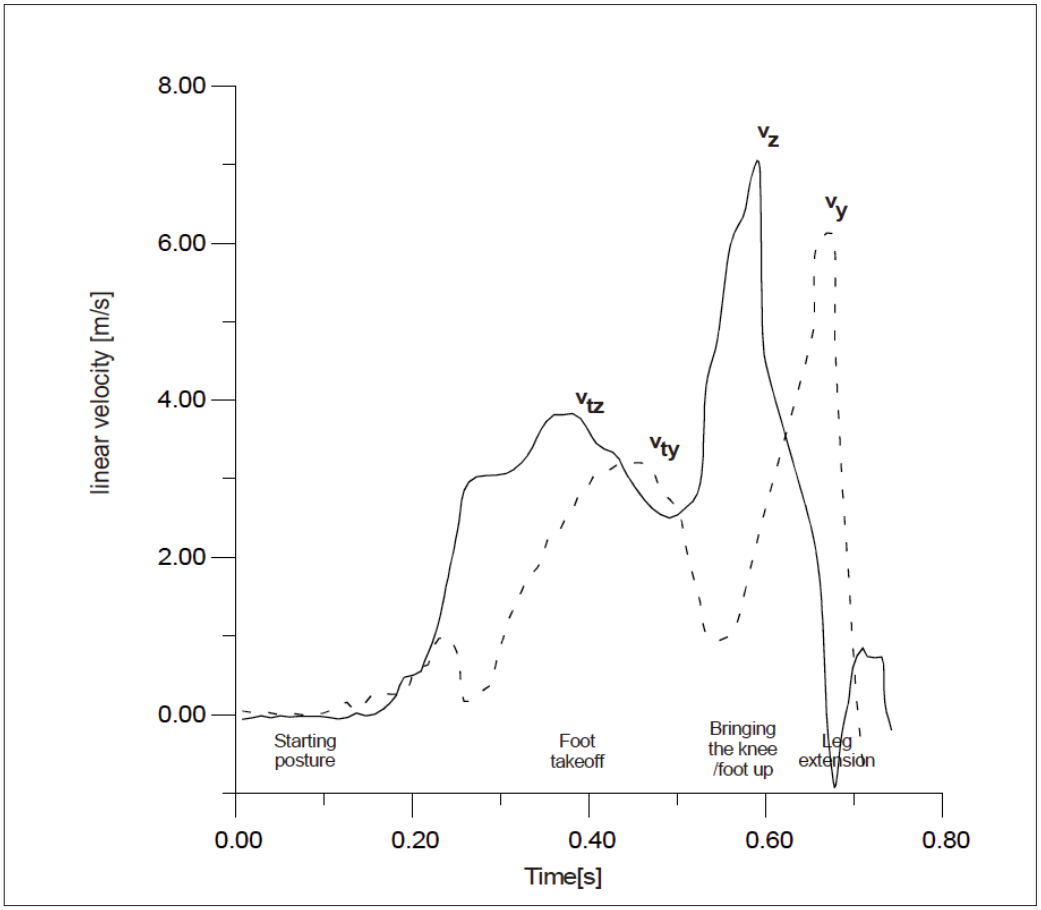

Figure 3. Sample progress in changes of the foot velocity during execution of the front kick in relation to axes Y and Z.

DISCUSSION

The front kick velocity determined in a research conducted by Wilk et. al. [5] on karate practitioners (no specific karate style was indicated) was between 9.9-14.4 m/s. The mean maximum velocity of the front kick obtained in this study was 10.4 ±0.77 m/s. These above values are not significantly different. When comparing the obtained average velocity value to the velocitites achived during execution of other kicks, e.g. side kick: 5.20-6.87 m/s [6]; spinning back kick: 5.95-8.35 m/s [13], it can be said that the front kick is a straightforward kick in which great velocities are obtained. Front kick, turning kick and axe kick show a degree of similarity in the kick velocities obtained [18-19]. In this study the athletes were asked to execute kicks which did not have a physical target so they were kicks striking the air. It is known that the formula used for movements which do not have a physical target is significantly different from the formula used for movements which do have a target [20-21].

When the athlete's body mass is constant, a high value of the foot velocity is connected with a change of momentum. High momentum informs us about a high impulse of force [14]. Thus, the higher the velocity, the higher impulse of force affecting the object.

Table 2 shows the correlation and dependence values between the determined kinematic parameters and the maximum kick velocity. The data presented in the Table indicates that the maximum velocity of the front kick is affected by the following factors: the maximum knee velocity, the total duration of the kick, total time of the foot takeoff. The other factors do not show significant correlation. Consequently, great knee velocity in the initial phase of lifting the leg clearly increases foot velocity.

In conclusion of the conducted study it needs to be emphasized that an athlete wishing to obtain the maximum velocity in the front kick execution needs to focus on the velocity of the knee being brought upwards. The shorter the foot takeoff time and the total time of the kick duration, the higher the maximum foot velocity is. Figure 4 shows factors affecting foot velocity.

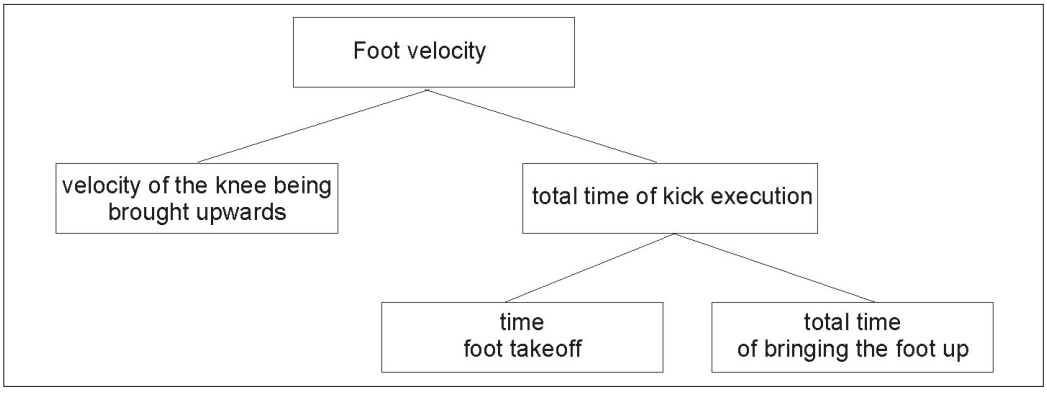

Figure 4. Factors affecting the front kick velocity

The presented method of analyzing taekwon-do techniques (as well as other martial arts and combat sports) makes it possible to obtain precise information on the course of movements made. This study, however, comprises only a modest part of this extensive issue. Nevertheless, both coaches and athletes are likely to optimize the training processes which they follow by competent implementation of the findings of this study as they should add to achieving a better efficiency of the front kick execution.

CONCLUSIONS

The conducted research shows that in order to achieve the maximum foot velocity in the execution of the front kick an athlete needs to increase the velocity of the knee traveling towards the target and to decrease the duration of the foot takeoff.

The results and considerations presented herein might be used in comparative studies and indicate a way forward for further research. Providing answers to these questions may result in developing a more efficient method of executing this particular kind of kick in taekwon-do ITF sports competition power tests as well as in self-defense.

COMPETING INTERESTS

Authors declare no conflicts of interest.

REFERENCES

1. Kalina RM. Teoria sportów walki. COC. Warszawa; 2000 [in Polish]
2. Choi HH. Taekwon-do. The Korean Art of Self-Defence. International Taekwon-do Federation. New Zealand; 1995
3. Walker JD. Karate Strikes. Am J Phys 1975; 43: 845–49
4. Blum H. Physics and the art kicking and punch. Am J Phys 1977; 45: 61–64
5. Wilk S, McNair R, Feld M. Strikes. Am J Phys 1982; 51(9):783–90
6. Pieter F, Pieter W. Speed and force of selected taekwondo techniques. Biol Sport 1995; 12(4): 257-266
7. Wąsik J. Kinematic the flaying frontal rising kick. Am J Phys Conference Serial, 2007; 79
8. Wąsik J. The physical basis of the twimyo nomo yop chagi test in taekwon-do ITF. Arch Budo 2007; 3: 82-85
9. Hwang IS. Analysis of the kicking leg in taekwondo, In: J. Terauds, B. Gowitzke and L. Holt (eds.). Biomechanics in sports III & IV. Proceedings of ISBS, Del Mar, CA: Academic Publishers, 1987; 39-47
10. Sørensen H, Zacho M, Simonsen EB et al. Dynamics of the martial arts high front kick. J Sport Sci 1996; 14(6): 483-495
11. Lee SH, Jung CJ, Sin SH et al. An analysis of the angular momentum of dolyeo chagi in taekwondo. Int J Appl Sport Sci 2001; 13(1): 18-32
12. Boey LW, Xie W. Experimental investigation of turning kick performance of Singapore National Taekwondo players. In: Proceedings of the 20th International Symposium on Biomechanics in Sport. Caceres, Spain, 2002; 302–305
13. Pieter W. Modeling velocity and force of selected taekwondo techniques, In: Song, J. K. and Yoo, S. H. (eds.), 1st International Symposium for Taekwondo Studies, Beijing: Capital Institute of Physical Education, 2007; 65-71
14. Hay JG. The biomechanics of sport techniques. 4th edition. Prentice Hall. Englewood Cliffs NJ., 1993
15. Wąsik J. The structure of the roundhouse kick on the exampleof a European Champion of taekwon-do. Arch Budo 2010; 6 (4): 211-216
16. Wąsik J. Kinematic analysis of the side kick in taekwon-do. Acta Bioeng Biomech 2011; 13(4): 71-75
17. Wąsik J. Kinetics of the knife-hand strike used in power breaking in ITF Taekwon-do, Phys Activ Rev 2015; 3:37-43
18. Jakubiak N, Saunders DH. The feasibility and efficacy of elastic resistance training for improving the velocity of the Olympic Taekwondo turning kick. J Strength Cond Res 2008; 22: 1194-1197
19. Sung TY. A biomechanical analysis of selected taekwondo kicks. J Taekwondo 1987; 61: 106-115
20. Nistico VP. A kinematic investigation of two performance conditions of the karate counter-punch technique. Unpublished master's thesis, University of Oregon, Eugene; 1982
21. Nien Y-H, Chang J-S, Tang W-T.The kinematics of target effect during roundhouse kick in elite taekwondo athletes. The Proceedings of the XXI Congress of International Society of Biomechanics. Taipei, Taiwan, July 1-5, 2007
22. Schmidt RA, Wrisberg CA. Motor Learning and Performance. A Situation-Based Learning Approach. Fourth Edition. Human Kinetics; 2008

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