The structure of the roundhouse kick on the example of a European Champion of taekwon-do

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Jacek Wąsik

Institute of Physical Education, Jan Długosz University of Częstochowa, Częstochowa, Poland

Source of support: Departmental sources

Received: 21 October 2010; **Accepted:** 26 November 2010; **Published online:** 6 December 2010

Abstract

Background and Study Aim: The roundhouse kick is a kick most often used in a fight. The tactics of a fight in taekwon-do is to hit a chosen point of the opponent's body as fast as possible. The efficiency of the impact sometimes depends on the speed of the foot, which is itself influenced by the speed and strength of the attacker and the technique applied to perform the attack.

Material/Methods: A 17-year-old competitor weighing 75 kilograms and measuring 179 cm with the International Master Class was analysed. For the purpose of this case study he performed a roundhouse kick. A system of complex analysis of movement called Smart-D, made by the Italian company BTS Spa was used for this research.

Results: At the first stage of the movement, the competitor rotates his torso, which is going to give the energy to his leg. At the second stage the leg is straightened in the knee joint until reaching the target.

Conclusions: The dynamics of the kick depends on the speed of take-off of the foot and the speed of the rotation movement of the arms. Duration of the kick comprises the time of foot take-off, which is influenced by the speed and acceleration of the jump, and the time of rising resulting from the power of raising muscles and the technique of the movement.

Key words: taekwon-do • power test • kinetics of kick • biomechanics of martial arts • analysis of movement

Author's address: Jacek Wąsik, Institute of Physical Education, Jan Długosz University of Częstochowa, Armii Krajowej 13/15 Str., 42-200 Częstochowa, Poland, e-mail: jwasik@konto.pl

Background

First sports and fighting arts shaped skills and abilities that were to be decisive as far as warrior's life and death were concerned.

At present martial arts has become a significant element of physical activity all over the world. Martial arts and sports are recommended since, when competently used in young people's education, they can reduce aggression and anxiety levels and improve social responsibility and respecting ethical standards [1–4]. Most well-known martial arts which originated in the Far East have introduced some kind of sports competition system. Some of them have been included in the Olympic Games (judo and taekwon-do). Thus, the aim of practising fighting arts has changed, which necessitated a change in training methods and adjustment of training process and teaching programmes to sports competition standards [5–8]. Traditional taekwon-do ITF (International Taekwon-do Federation) sports competition comprises four events: sparring, patterns, power test and special techniques [9,10]. Power test involves breaking a declared number of boards with the use of five different techniques: using the punch and the outer edge of the hand and also using kicks: a side kick, roundhouse kick and turning kick. Each broken board scores 2 points and the total of scored points decides who the winner is. The roundhouse kick (in taekwon-do terminology referred to as *dollyo chagi*) has a considerable influence on the final score in a competition. In breaking events a competitor is expected to have well

Taekwon-do – a Korean martial art based mainly on punches and kicks.

Power test – a sports event in taekwon-do ITF.

prepared breaking surfaces, ability to achieve required breaking stress energy as well as an excellent technique. Appropriate technique must comply with human biomechanical principles.

The roundhouse kick is the most frequently used kick in sports competition [11–14]. The tactics in taekwon-do as well as in other fighting arts and sports aims at the fastest possible way of reaching the chosen point on the opponent's body, and thus, reaching a knockout stage or scoring a point. However, organization of self-defence used by experienced competitors does not allow for simple solutions. When following self-defence tactical principles and predicting the attacking opponent's behaviour as well as continuously assessing and interpreting the developing situation, a taekwon-do practitioner is able to predict what is going to happen and tackle an attack. However, there is always difficulty in dealing with exceptionally fast and powerful strikes. When the striking velocity of a fist or foot is relatively significant, the competitor who is being attacked might not be able to adjust the movements of his limbs and/or his body quickly enough in order to succeed in defending himself. In such situation the decisive factor is the striking speed of a fist or foot. The momentum which a foot shall gain depends on the speed and strength which the attacking competitor can develop, and also on the attacking technique employed. In the analysis of a sport fight the first scientific examinations have been done [15–17], however only a biomechanical analysis will reveal the effectiveness of techniques that ought to be used in the attack.

Adopting previously used criteria for sports technique biomechanical analyses [18], and especially the ways of measuring taekwon-do techniques [19,20] in this case study four phases of a particular technique have been analysed: starting posture, take-off of the foot, lifting the leg and knee extension. Next, the following questions have arisen:

1. Can the applied method of analysing the segments in a particular taekwon-do technique be found useful in improving instruction programme?
2. What biomechanical factors affect efficient performance of the kick?
3. At which moment exactly is the momentum of the foot the greatest and what elements affect increasing or decreasing the speed of the foot?

Addressing the last question necessitated determining the kinetic values of the technique.

Material and Methods

The analysis was carried out on the example of a 17-year old competitor (weight – 75 kg and height – 179 cm) with the International Sports Master Class. During the case study the competitor performed a roundhouse kick starting from the L-stance forearm guarding block (in taekwon-do terminology: niunja so palmok daebi maki). The structure of the movement is presented in Figures 1 and 3.

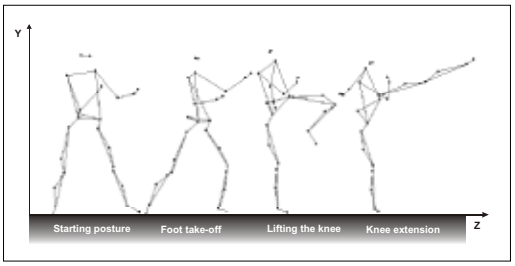

Figure 1. Phases of the movement: *dollyo chagi* shown with the help of the BTS Smart system.

In this case study Smart-D system for complex movement analysis made by BTS S.p.A., an Italian company, was used. The system comprised six cameras emitting infrared rays, which in real time localized the markers fixed to the competitor's body. These markers reflected the infrared rays emitted by the cameras. The system facilitated recording the picture of the movement of the competitor's body and evaluation the kinetic data obtained. The picture was recorded with accuracy of 0.3–0.45 mm and frequency of 120 Hz.

The data related to the movement and the speed of the characteristic points on the competitor's body obtained in the recording was analysed with reference to the factors specifying the spatial and time structure of the movement. The competitor's task was to perform the kick in a way which was most typical for the competitor. In the analysis of particular segments of the technique the following factors were taken into consideration: v_x – speed of the foot with regard to X axis, v_y – speed of the foot with regard to Y axis, v_z – speed of the foot with regard to Z axis, α – knee joint angle, F_n –the ground reaction force of the plant foot.

Findings

Starting posture: the competitor adopts the L-stance forearm guarding block (in taekwon-do terminology: niunja so palmok daebi maki). According to the rules provided in Taekwon-do handbooks in this particular guarding block the heel of the left foot is approximately in line with the toes of the right foot; both knees are slightly bent and about 70% of the body weight is supposed to rest on the back foot and 30% on the front one (in taekwon-do terminology: niunja so palmok daebi maki with the left foot moved to the front). Starting posture term comprises information on the stance and the place where the attack starts.

Foot take-off: the competitor rests his body weight on the front foot and he rotates his trunk and his arms in the direction opposite to the direction of the intended movement. Next he takes off his right foot (of the back leg) shifting his whole body weight to the left foot. The arms aid the rotation of the whole body. The travelling right arm and hand necessitates movement of the right side of the trunk and helps to move the foot from its take-off. This phase of the roundhouse kick witnesses the greatest velocity of the foot with the foot take-off lasting 0.22 s.

Lifting the knee: the moment the foot take-off ends, the segment of lifting the knee starts taking 0.53 s. As a result of pushing the foot off the floor the force drives the foot upwards and a maximum flexion in the knee joint follows. The next movement is a result of the movement function being taken over by the lower limb muscles. Extension of the hip and knee joints follows.

Knee extension: the leg performing the kick is extended in the knee joint. The arms and hands make a movement opposite to the extension of the lower limb so that the body does not perform a full turn. The competitor tried to balance his body in such way so as not to let any other part of his body except his left foot touch the floor.

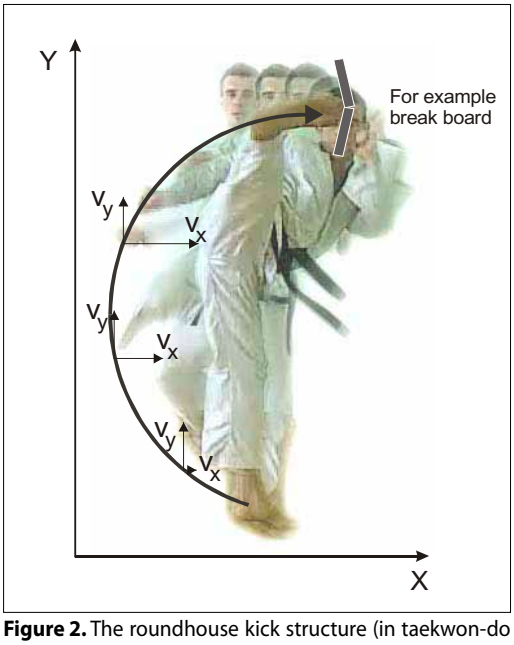

Figure 2. The roundhouse kick structure (in taekwon-do terminology – dollyo chagi) – front view.

Figures 2 and 3 present in a Cartesian coordinate system the changes of the foot velocity while performing a roundhouse kick. When following these changes it can be noticed that they all start from the point of 0 m/s, which is the starting posture, in which both feet are on the floor. The velocity v_x refers to the speed at which the

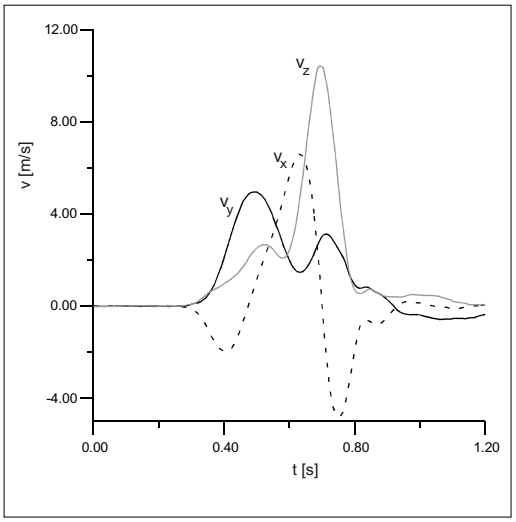

Figure 3. Change of the linear velocity of the kicking foot in time.

foot is moving directly towards its target. At the moment of the take-off the foot slightly goes back so as to gain the energy required for the kick. This is shown by the negative velocity value with regard to X axis. Next, this value rises distinctively until it reaches the maximum of 6.6 m/s. Then, the process of braking starts and the velocity reaches the negative value of –4.82 m/s. Speed v_y is the speed at which the foot goes up and it reaches its maximum value of 4.95 m/s in the phase of the foot take-off. When this phase of the technique closes, the foot velocity decreases as the function of lifting the leg is taken over by the muscles of the lower limb. The speed at which the leg is lifted rises to 3.11 m/s just before the extension of the knee. Velocity v_z is the speed at which the foot reaches the target with its highest value being 10.42 m/s just before this last segment of the roundhouse kick technique finishes.

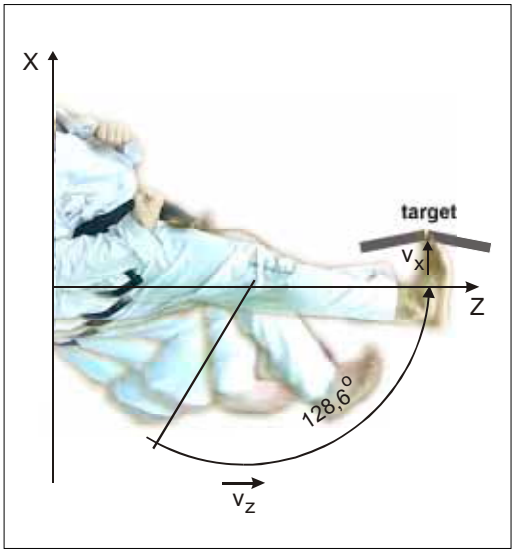

Figure 4. The roundhouse kicks structure – top view.

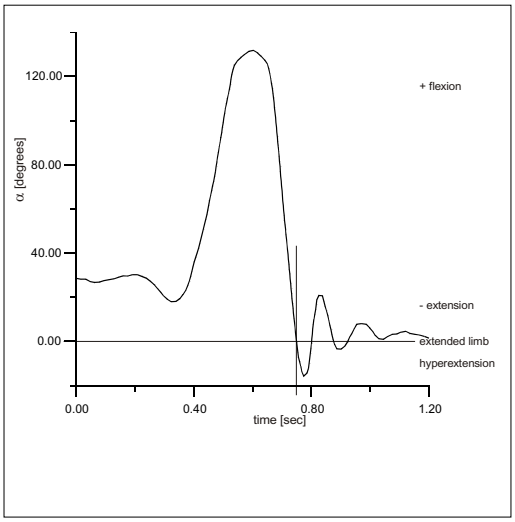

Figure 5. The roundhouse kick – change of the knee joint angle.

Figure 4 presents a top view of the roundhouse kick structure. Figures 4 and 5 allow following the changes of the knee joint angle. The knee joint is bent at an angle of 36.2 degrees as the competitor starts the technique from the niunja so palmok daebi maki, which such posture necessitates. The moment of the foot take-off requires a certain degree of leg extension, which shows in the reduction of the angle to 17.8 degrees. This is followed by a rapid flexion reaching the maximum value of 128.6 degrees, and next starts the last segment of the technique – the knee extension, which ends in slight hyperextension at 15.8 degrees.

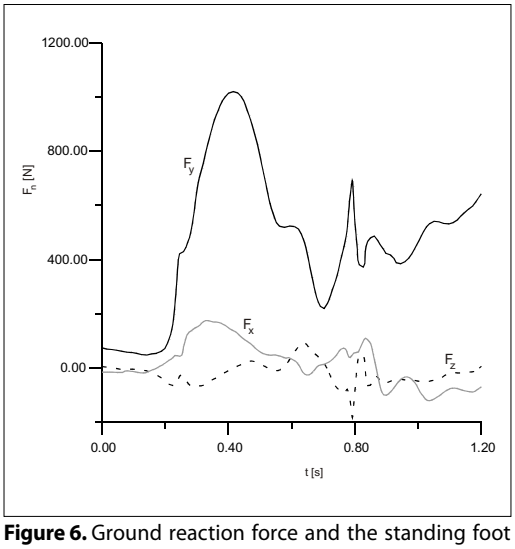

Figure 6. Ground reaction force and the standing foot while performing dollyo chagi.

Figure 6 presents the ground reaction force under the plant foot while performing the roundhouse kick. The curves show it clearly that the greatest force is directed downwards and is represented by curve F_y. The maximum value of the force on the floor exceeding 1 kN is reached at the moment of the foot take-off. The pressure subsides when the knee is lifted, and then, when the knee is extended, it rises again and reaches 200 N. Biomechanical factors affecting the efficiency of the roundhouse kick are presented in Table 1.

Table 1. Biomechanical factors affecting the efficiency of the roundhouse kick.

Roundhouse kick	
Maximum velocity OX	6.60 m/s
Maximum velocity OY	4.95 m/s
Maximum velocity OZ	10.42 m/s
Maximum velocity in the segment of the lift OY	3.11 m/s
Maximum knee joint angle	128.60°
Foot take-off time	0.22 s
Length of kicking time	0.75 s
Maximum floor reaction force OY – the non-kicking foot	1020.52 N

Discussion

The above considerations show that the form of observation used in this case study with application of modern movement analysis systems allows achieving precise information on the kicking process. It can be noticed that in the roundhouse kick technique there are two stages: 'drawing a bow' and 'releasing the bowstring', known in the subject literature as a cycle of stretch-contraction [21]. The first stage witnesses a screw-like rotation of the trunk which is supposed to provide energy for the leg. In the second stage the leg is extended in the knee joint until the very moment of reaching the target. The speed of the foot take-off and the speed of the rotation of the arms decide about the dynamics of the kick. The swing of the arms is meant to:

– transfer the momentum and put the body in rotation, and
– increase the force of the foot take-off.

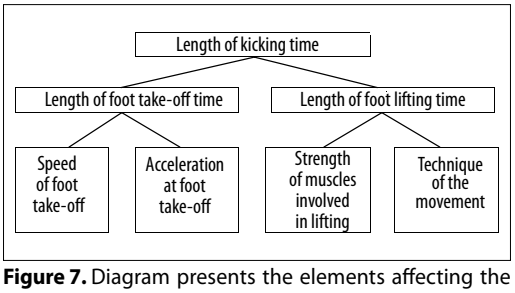

Figure 7. Diagram presents the elements affecting the length of the time of the roundhouse kick.

Figure 7 shows which elements affect the length of the time of the roundhouse kick. It is clear that the length

of the time of the whole kick comprises the time of the foot take-off (which is affected by the speed and acceleration of the take-off) and also the time of lifting of the foot (which depends on the strength of the muscles responsible for the lifting and the employed technique of the movement). The technique of the movement, among others, also depends on the change of the knee joint angle.

An interesting piece of information among other findings is the fact that the foot travelling towards the target does not gain the maximum lifting speed at the very moment preceding the knee extension, but in the segment of the foot take-off, and so is the fact that the difference is so significant. Thus, it can be assumed that the higher the kick is, the slower it will reach its target. Therefore, it is worth considering whether there are any biomechanical reasons for increasing the lifting speed as well as the other velocities of the travelling foot. For instance, will the greater speed in the segment of the foot take-off increase the speed in the segment of the knee extension? How does the change in the knee joint angle affect the speed of the travelling foot? This kind of knowledge will allow for biomechanical optimization of the roundhouse kick.

In anti-terrorist units there are individuals with extraordinary skills and abilities and it is their task to deal with a variety of potentially dangerous situations. We increasingly often hear of untypical forms of attack which require an instantaneous reaction and such reactions often need to go beyond the set standards. There are situations in which a split second when an attacker is destroyed decides about life or death of other people. Hence, our 'defenders' are expected to be exceptionally fit and to be able to take necessary actions to extremes. Power test of taekwon-do can be further included in the evaluation system of psychomotor competences [22]. Sports competition system makes it possible to achieve mastery and development to one's maximum abilities. This kind of competition prepares an individual to do what he possibly can.

Sweeping hip throw is meant to show advantage in judo. The roundhouse kick shows advantage over the opponent in taekwon-do, karate or kick boxing. Comprehending the importance of the means of action is an introduction to understanding the clue, which is the intended choice and system of actions that create complex actions, arranged in time with regard to the set target and which take into account the actions required to achieve the target [23]. The ways to perform throws, strikes, kicks or dodges, etc. (these are referred to by practitioners as techniques) are described in combat sports handbooks.

Many scientists are searching for new ways of biomechanical movement optimization [24–26]. Whether it be a description of the way of walking or jumping all scientists are looking for the way which will ensure the best movement parameters with the least work input. This case study is only a small section of that problem.

It is certain that a bigger number of competitors should be studied. The results and considerations presented herein can be used for comparative purposes for other studies and help to shape further development of such case studies.

Conclusions

Given the above considerations it is concluded that:

1. The method used for analysing *dollyo chagi* (roundhouse kick) can be used to measure the mechanics of movement in other taekwon-do techniques.

2. Comparison of individual characteristics of movement mechanics in experienced taekwon-do practitioners will allow verifying whether the dynamics of the kick depends on the speed of the foot take-off and the speed of the rotation of the arms.

3. The findings obtained in this case study show that the total time of the roundhouse kick comprises the time of the foot take-off being a result of the speed and acceleration in the segment of the foot take-off and also the time of lifting of the foot, which depends on the strength of the muscles involved in the lifting process and the employed technique of the movement.

References:

1. Cynarski W, Lothan S, Sieber L: Trening wschodnich sztuk walki – koncepcja holistyczna. Sport Wyczynowy, 2006; 11–12: 5–15 [in Polish]
2. Kalina R: Teoria sportów walki. COS. Warszawa, 2000 [in Polish]
3. Kalina R: Utilitarny wymiar współzawodnictwa w sportach walki. Trening, 2001; 3: 90–96
4. Maroteaux R, Cynarski W: O filozofii Japońskich sztuk walki – pytania i odpowiedzi. Ido-Ruch dla Kultury/Movement for Culture (IRK-MC), 2002; 3: 48–55 [in Polish]
5. Bujak Z: Wybrane aspekty treningu w taekwon-do. AWF Warszawa ZWWF Biała Podlaska, 2004 [in Polish]
6. Cynarski W, Momola I: Dalekowschodnie sztuki walki – ewolucja celów i metod nauczania. Sport Wyczynowy, 2005; 3–4: 48–53 [in Polish]
7. Lee KM, Nowicki D: Taekwondo. Almapress, Warszawa, 1988 [in Polish]
8. Tokarski S: Sztuki walki. Ruchowe formy ekspresji filozofii wschodu. Glob, Szczecin, 1989 [in Polish]
9. Choi HH: Taekwon-do. The Korean Art of Self-Defence. ITF, New Zealand, 1995
10. Choi JH, Bryl A: Taekwon-do. Koreańska sztuka samoobrony. SC Iglica, Wrocław, 1990 [in Polish]
11. Lee SK: Frequency analysis of the Taekwondo techniques used in a tournament. Journal of Taekwondo, 1983; 46: 122–30
12. Grądzielewski A: Struktura treści walki sportowej karate. Praca dyplomowa – maszynopis. Biała Podlaska, IWFiS, 1998 [in Polish]

13. Kępa J: Porównanie sposobów rozstrzygania walki na poziomie mistrzowskim przez zawodników karate Kyokushin. In: Litwiniuk S, Bujak Z, Litwiniuk A (eds.): Optymalizacja struktury treningu i współzawodnictwa w sportach walki. Biała Podlaska, IWFiS, 2000; 43–48 [in Polish]
14. Wąsik J, Ślęzak A: The evaluation of the efficiency of various techniques in taekwon-do female sparring over 70 kg. Sport training in interdisciplinary scientific reserches. In: Szopa J. & Gabryś T. WWZPCz, Częstochowa, 2004
15. Litwiniuk A, Litwiniuk S, Bujak Z: The composition of sparring in taekwon-do. Wychowanie Fizyczne i Sport, 1999; XLIII: 233–34
16. Litwiniuk A, Wałach M, Jedut J: Ocena działań techniczno-taktycznych zawodników taekwon-do w walkach drużynowych na Mistrzostwach Świata w Rimini w 2001. Wychowanie Fizyczne i Sport, 2002; 46 (1): 91–92 [in Polish]
17. Litwiniuk A: Próba oceny działań technicznotaktycznych zawodników taekwon-do podczas Mistrzostw Świata w Argentynie. In: Wychowawcze i utylitarne aspekty sportów walki. Kalina RM, Jagiełło W (eds.), Warszawa, 2000; 120–24 [in Polish]
18. Hay James G. "The biomechanics of sport techniques" Prentice Hall Englewood Cliffs, New Jersey 07632, 1993
19. Wąsik J: Performance of the twimyo nopi ap chagi test. Archives of Budo, 2006; 2: 15–18
20. Wąsik J: Structure of movement of a turning technique used in the event of special techniques in Taekwon-do ITF Archives of Budo, 2009; 5: 111–15
21. Bober T, Zawadzki J: Biomechanika układu człowieka. BK, Wrocław, 2001 [in Polish]
22. Ashkinazi S, Jagiełło W, Kalina RM et al: The importance of hand-to-hand fights for determining psychomotor competence of antiterrorists. Archives of Budo, 2005; 1: 8–12
23. Pszczołkowski T: Mała encyklopedia prakseologii i teorii organizacji. Ossolineum 1978, Wrocław [in Polish]
24. Sorenson H, Zacho M, Simonsen EB et al: Dynamics of the martial arts high front kick. Journal of Sport Sciences, 1996; 14, 483–95
25. Schwartz ML, Hudson AR, Fernie GR et al: Biomechanical study of full-contact karate contrasted with boxing.Journal of Neurosurgery, 1986; 64: 248–52
26. Serina ER, Lieu DK: Thoracic injury potential of basic competition taekwondo kicks. Journal of Biomechanics, 1992; 24(10): 951–60