A KINEMATIC ANALYSIS OF THE NAERYO-CHAGI TECHNIQUE IN TAEKWONDO

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The purpose of this study was to investigate the influence of selected kinematic parameters on the performance of the naeryo-chagi technique in taekwondo. Performance was quantified by the vertical velocity of the ankle at initial target contact (VIMP). METHOD: A sample of 19 competitive taekwondo athletes (17 males and 2 females) aged from 17 to 30 years (mean age = 19 ± 4), who were able to accomplish a correct naeryo-chagi technique, participated in this study. After warm up, participants were asked to perform several series of five naeryo-chagi kicks with their front leg at a kicking pad which was mounted on a frame at chin height. For data acquisition a motion tracking system comprising eight infrared cameras and a force plate were used. Only that series, which included the trial with the highest ankle velocity at initial target contact, was further processed. RESULTS: Significant differences between the best and worst performed kick of each athlete (p = 0.025) were found for the extension of the hip joint during the pull down phase (EHIP). No significant differences were found for the maximum ankle velocity during the strike out phase (AVSO; p = 0.28). Considering the best trials of each athlete only, Pearson correlation between EHIP and VIMP was significant (r = 0.542; p = 0.017), that between AVSO and VIMP was not (r = 0.354, p = 0.137). CONCLUSION: The magnitude of change of the hip flexion angle during the pull down movement seems to be an important factor for performing a kick featuring high velocity at initial target contact.

KEY WORDS: postural differences, motion analysis, kick-techniques, ankle velocity

INTRODUCTION:

Taekwondo is a combat sport, which originated out of Korea. It is especially well known for its fast, high and consecutive kicks. Since the year 2000 taekwondo is an official Olympic discipline. In competition, kicks and punches score points if the contact made to torso and/or head is sufficient to effect a displacement of body segments. A match can be won either by points or by knocking out the opponent. While punching on the head or kicking on the back head is not permitted, athletes can score by kicking torso, head or face or by punching torso. In taekwondo kicking techniques are most commonly used (Kazemi et al., 2006) and probably provide most efficiency.

The kicking technique naeryo-chagi is understood as a vertical taekwondo kick, which usually strikes the opponent's scull, face or clavicle. It can be described as follows: "The axe kick uses the rear of the heel to deliver a blow straight downwards. The kicking foot is swung up across the body until it is high in the air, then it is brought straight down onto the target." (Park, 1999). Aggeloussis et al. (2007) provide another description: "From the initial position, the knee is raised in an arc up and forward in front of the body, the leg is then extended and pulled down with the heel pointed downward. The arc can be performed in either a clockwise or counter-clockwise direction."

The first phase of the kick is initiated through a short preparation phase in which the athlete tries to move his centre of gravity forward for initiating the second phase. This phase is an upwards directed strike-out phase and ends with the top of stroke (reversal point of foot). During the downwards directed kicking phase the target is hit. The movement ends in the restoration of posture for either preparing a defence or attacking action.

For scoring in a competition the impact effects of kicks and punches are of high importance. Impact effect can physically be described by a linear momentum or via the kinetic energy. In both terms velocity takes a major role. It can be assumed that a higher maximum velocity at

initial target contact gains more impact effect than punches or kicks with less velocity. Falco et al. (2009) investigated execution time and impact force in a roundhouse kick. Their findings approved significant differences in maximum impact force between expert and novice competitors. The purpose of this study was to analyse differences in selected kinematic variables with regard to the kick performance assessed by the ankle velocity at impact.

METHODS: Data Collection: A sample of 19 competitive taekwondo athletes (17 males and 2 females) aged from 17 to 30 years (mean age = 19 ± 4), who were able to accomplish a correct naeryo-chagi technique, participated in this study. After warm up, participants were asked to perform five naeryo-chagi kicks with their front leg onto a kicking pad which was mounted on a frame at chin height. A force plate was used to measure ground reaction forces. Athletes started from a normal standing position (supporting leg behind kicking leg). Each participant performed one to five series with five successive maximum-effort kicks onto the kicking pad. Athletes were allowed to choose the distance to the target. A motion tracking system (Vicon Motion Systems Limited, Oxford, UK) was used for analysis. The system consisted of eight infrared cameras (six cameras with a resolution of 1.3 Mega Pixels, and two cameras with a resolution of 4.0 Mega Pixels), an acquisition station system (Vicon MX Net) connected to a personal computer and 3D reconstruction software (Vicon Nexus 1.2 and Polygon 3.1). Data were collected with 250 Hz. After raw data acquisition, data were smoothed using a GCV-Auto Woltring filter routine, provided by Vicon Nexus 1.2 (see Woltring, 1986). The series which included the trial with the highest ankle velocity at initial target contact was selected for further processing.

Data Analysis: Movement was classified into three phases: start of the first phase was determined by loss of contact to the force plate by the kicking leg. The end was defined as the top of stroke (reversal point: ankle velocity in vertical direction = 0 m/s). The start of the second phase was defined by the reversal point and ended at initial target contact. Third phase started with initial target contact and ended with the first contact to ground of the kicking leg. Figure 1 illustrates the defined phases:

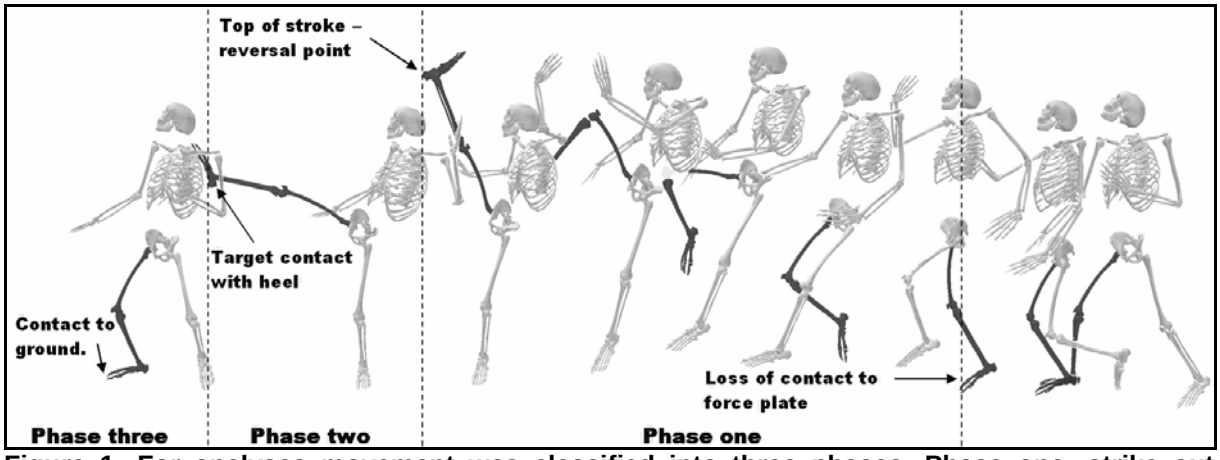

Figure 1: For analyses movement was classified into three phases. Phase one: strike out movement, phase two: target contact, phase three: restoration of posture.

Several kinematic parameters have been investigated on their influence on performance. Two of them will be discussed in more detail within this paper. Variable AVSO was defined as the maximum value of the vertical ankle velocity of the kicking leg during the phase one. The variable which represented EHIP was defined as the extension angle of the hip joint (for the kicking leg) during phase two. Values for both variables (ASVO and EHIP) were determined for the best and worst performed kick (best kick = maximum ankle velocity; worst kick = minimum ankle velocity at initial target contact (VIMP)) of each athlete within the series

selected. Statistics were calculated using Student's t-test for dependent variables and the Pearson correlation coefficient considering $p < 0.05$ to be significant.

RESULTS: Figure 2 shows a typical curve progression of the ankle velocity and the hip angles of the kicking leg exemplarily plotted for one athlete.

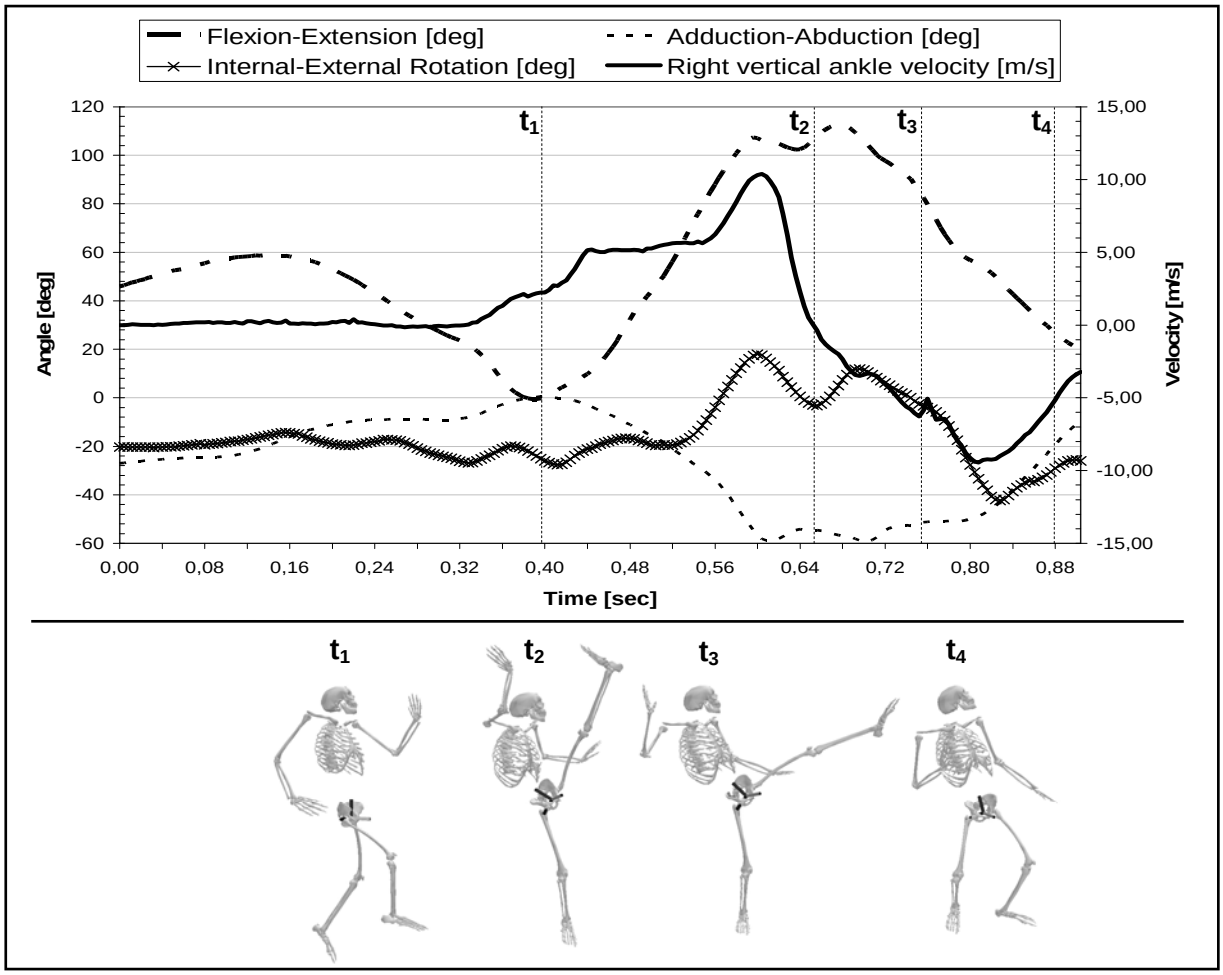

Figure 2: Vertical ankle velocity and hip angles of the kicking leg exemplarily plotted for one athlete: Flexion, adduction and internal rotation feature positive values; Extension, abduction and external rotation feature negative values; t_1: take-off from force plate; t_2: reversal point of ankle; t_3: initial target contact; t_4: contact to ground.

Table 1 shows descriptive statistics for variables AVSO, EHIP and VIMP:

Table 1 Descriptive statistics for variables AVSO, EHIP and VIMP.

BEST (n=19)				WORST (n=19)			
	AVSO [m/s]	EHIP [°]	VIMP [m/s]		AVSO [m/s]	EHIP [°]	VIMP [m/s]
Mean	10	13	8	Mean	10	9	7
± SD	1	12	1	± SD	1	13	1

Statistical analyses showed no significant differences between the best and worst performed kicks in their values for maximum ankle velocity during strike out (AVSO; $p = 0.28$). Significant differences ($p = 0.025$) were found for the extension of the hip joint (EHIP). A positive correlation between EHIP and VIMP could be found ($r = 0.542$; $p = 0.017$) whereas no significant correlation was found for AVSO and VIMP ($r = 0.354$; $p = 0.137$).

DISCUSSION: Two different variables were defined for statistical analyses: maximum ankle velocity during strike out (kicking leg) and range of hip extension before initial target contact. Although EHIP is not the only crucial factor for acceleration towards the target, it significantly ($r = 0.542$, $p = 0.017$) correlated with VIMP. Moreover, significant differences between the best and worst performed kicks could be found (p=0.025). An increase of acceleration distance seems to be a reliable predictor for an increase of kicking velocity. It should, however, be taken into account that longer acceleration paths go along with longer times to initial target contact thus raising the chance for the opponent to anticipate the movement.

Contrary to expectations no significant differences between the best and worst performed kicks could be found for AVSO ($p = 0.28$) and no significant correlation with VIMP could be shown ($r = 0.354$, $p = 0.137$). We would suggest that velocities of the kicking leg during the stretch phase above a certain individual threshold could have negative effects on the efficiency of the stretch-shortening cycle, thereby resulting in a reduced ankle velocity at target contact. Ishikawa et al. (2005) analysed the stretch-shortening cycle in short-contact drop jumps. They observed that the efficacy of elastic recoil decreased with increasing drop intensity. Their conclusions might also apply to the results of the present investigation. Less storage of elastic energy may occur at larger strain rates, the duration of the stretch-shortening cycle may not be enough for efficient elastic storage and recoil.

CONCLUSION: A significant difference between the best and worst kicks for the extension of the hip joint (EHIP) and a positive correlation for EHIP and the vertical velocity of the ankle at initial target contact (VIMP) was found. This indicates that the range of strike out movement is a crucial factor for performing the naeryo-chagi technique. On the other hand longer acceleration paths increase the risk of the opponent anticipating the attacker's actions. No significant difference and correlation were found for AVSO. It is possible that too high velocities during strike out effect negatively on athlete's performance as too low velocities do.

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