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# MECHANICAL ANALYSIS OF THE ROUNDHOUSE KICK ACCORDING TO HEIGHT AND DISTANCE IN TAEKWONDO

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**ABSTRACT:** Competition regulation in taekwondo has experienced several changes during the last few years, for example, kicks to the head score more points than kicks to the chest. In addition, some external factors such as the height of target and execution distance seem to affect the kick performance. The aim of this study was to analyse selected biomechanical parameters (impact force, reaction time, and execution time) according to the height and execution distance in two different male groups (experts ($n = 12$) and novices ($n = 21$)). Athletes kicked twice from every execution distance (short, normal and long) and towards two different heights of target (chest and head) in a random order. Novices kicked to the head with a longer reaction time than to the chest ($p < 0.05$) but experts were able to kick with similar performance for both heights. From short and normal distances experts kicked with similar performance; whereas from the normal distance novices had longer reaction and execution time than from the short distance ($p < 0.05$). In conclusion, in counterattacking situations, experts should perform the roundhouse kick to the head instead of to the chest, because it produces better scores with similar performance; whereas novice athletes should avoid kicking to the head because they are not able to kick with similar performance. Moreover, it is recommended that during counterattacks higher-level taekwondo athletes should intend to kick from normal distances.

**KEY WORDS:** Biomechanics, taekwondo combat, kick, execution distance, height

## INTRODUCTION

Since its introduction in the Games of the XXVIII Olympiad (2000, Sydney, Australia), taekwondo has experienced some changes in its competition rules and regulations [4,19]. One of them is related to the fact that kicks to the chest score one point while kicks to the head score three points [29]. During competition, athletes use the type of kicks that allow them to score with the greatest efficacy [16] with the roundhouse kick carried out as the fastest one [26,27]. In this line, the roundhouse kick can be performed to both low and high targets. However, even though the only technique difference between a roundhouse kick to the chest and to the head is the height of the target [23], kicks to the chest are more common than kicks to the head [11,20].

Studies that analysed the effect of the height of the target on the performance of the roundhouse kick found higher impact forces [2,24] and shorter execution time [14,17] in kicks directed towards a lower target, which could explain the major frequency in using this technique. More recently, some authors [8] also analysed the effect of the height of the target but taking into account the level of the taekwondo athletes (expert or novices). They found that lower level athletes were not able to kick with similar impact force and execution time in kicks to a higher height whereas higher-level athletes were able to do so. These findings point to the need to take into account not only the height of the target but also the athletes' competitive level when the execution technique is analysed.

When addressing the core factors that can affect the kick performance, different researchers have highlighted the execution distance [5, 6,10,12,16,23]. Concretely, it seems that higher-level athletes kick with similar performance independently of the execution distance whereas lower-level athletes are not able to adapt their execution when the distance varies [5,10,12]. Supporting these results, Kim et al. [16] suggested that the roundhouse kick is the action that most easily allows athletes to adapt the technique to execution distance. Thus, it might be one of the reasons why this type of kick is the most frequently used in training and competition [20].

Lastly, adding to the execution distance, the height of the target and the athletes' competitive level, another factor that affects the kick performance is the way to score (attacking or counterattacking) [11]. Generally, studies in the taekwondo field have been carried

out in an attacking context [9,16,24]. Only a few studies have analysed kick performance during counterattacking situations and most of them did not take into account all the factors that the literature suggests can affect the kick performance [6,12,28]. Among the studies that analysed the execution technique when counterattacking, Estevan et al. [6] found that from large distances athletes spent longer total time and reached a lower impact force than from shorter distances. Other authors [12,28] did not find similar results when athletes were grouped according to their competitive level. That is, when athletes were placed in one group, Falco et al. [12] found that from the short distances athletes had shorter reaction and execution times whereas when athletes were split according to their competitive level no differences were found between higher and lower level athletes. Despite that, Vieten et al. [28] pointed out that fast reactions are essential for success in taekwondo. Nonetheless, no study has reported data on the effect of the execution distance and the height of the target on the kick performance for different competition levels in taekwondo during counterattacks.

Thus, the overall aim of this study was to analyse biomechanical performance according to the height and the execution distance in two different competitive levels (experts and novices) of taekwondo athletes, who have to react to a stimulus using the roundhouse kick. It is hypothesized that, in the experts, neither the height of the target nor the execution distance affects the kick performance. But in lower-level taekwondo athletes it is hypothesized that both the height of the target and the execution distance affect the kick performance.

## MATERIALS AND METHODS

*Subjects.* Thirty-three healthy and trained male taekwondo athletes, selected through convenience sampling, participated in the study. They were divided into two groups according to results obtained in official competitions: an expert group and a novice group. The expert group (n = 12) was composed of medal winners in official national and international events; their average ± SD age was 24.3 ± 3.0 years, with weight between 64.7 and 95.0 kg (77.9 ± 10.3) and height between 1.69 and 1.87 m (1.79 ± 0.06). The novice group (n = 21) consisted of taekwondo athletes who had not won medals in official competitions; their average ± SD age was 25.7 ± 7.0 years, with weight between 60.3 and 100.5 kg (75.7 ± 11.8) and height between 1.60 and 1.93 m (1.78 ± 0.09). All athletes had competition experience of at least 4 years and had trained for at least 3 hours per week. They signed the informed consent voluntarily. The protocol was approved by the University Ethics Committee and performed in accordance with the principles of the Declaration of Helsinki of 1964.

*Instruments*

The data acquisition system was composed of a force platform and LEDs, both located in a dummy, a contact platform, an analogue-to-digital (A/D) microcontroller and a PC. The dummy (706 FSD ®, USI Universal Company, India) allowed the force platform to be freely adjusted to the athlete's chest and head height. The force platform was built with nine piezoresistive pressure sensors (Flexiforce® A201 model by Tekscan Company Inc., South Boston, USA) positioned in series in groups of three in a triangular structure.

The calibration of the force platform was carried out following recommendations by Falco et al. [10] in a three-sensor by three-sensor series [6]. The sampling rate for the force platform was 2000 Hz. The sensor system's force resolution was 22.2 N, whereas its internal consistency measured by Cronbach's α [3] was 0.99. The mechanical variables were registered by a computer, and the Visual Basic 6.0 program was used to develop the software.

*Measurements*

The kicking height (the athlete's sternum and chin heights) and three execution distances (short, normal and long distances) were determined for each athlete based on his anthropometric measures (sternum and chin heights, and dominant leg length). The remainder of the protocol was executed according to Estevan et al. [7,9] regarding the three execution distances (ED) in a specific order (also reproduced in later studies [5-8,11,12]; firstly from the normal (ED2: 1.06 ± 0.06 m), secondly from the short (ED1: 0.70 ± 0.04 m), and lastly from the long distance (ED3: 1.41 ± 0.08 m) and with regard to the height of the kick, the order was randomized. After a 20 min warm-up, the subject stood still in the guard position and waited for the blue signal. The onset position was characterized by a static disposition without the need for the heel of the back foot to rest on the floor. When the blue light signal changed to red, in a randomized period between 0.99 and 10.99 s, the taekwondo athlete kicked twice from each ED with the back foot (dominant lower limb; 27 right-footed and six left-footed) in the indicated area of the dummy.

Reaction time (RT) was defined as the time period from the LED signal to the instant when the kicking foot left the contact platform. The execution time (ET) was the normalized time from when the kicking foot left the contact platform to the instant when the kicking foot hit the target, raising the maximum impact force [12] divided by the athlete's length of the dominant leg. The impact force (IF) was a normalized estimation of the impact force according to the athlete's body weight [6].

The intra-class correlation coefficients (ICCs) for the mechanical variables were computed using the mean of the six kicks performed (two heights from each of the three target distances). The ICCs for the normalized impact force were 0.84 (95% CI, 0.74–0.91), for the reaction time 0.88 (95% CI, 0.81–0.94), and for the total response time 0.91 (95% CI, 0.86-0.95).

*Statistical analysis*

Statistical analyses were carried out using the SPSS 19.0 computer package. The preliminary analysis (Kolmogorov–Smirnov) showed a normal distribution of the three considered variables. A mixed-model repeated measures analysis of variance 2 (height [chest & head]) x 3 (distance [short, normal & long]) was conducted for the RT, ET and IF in both groups (experts and novices) and to calculate

observed statistical power (SP) of the test. Partial $\eta^2$ values below 0.01, 0.01–0.06, 0.06–0.14, and above 0.14 were considered to have trivial, small, medium, and large effect sizes, respectively [1]. The Greenhouse–Geisser correction was used to provide a more conservative analysis, where necessary, to compensate for violations of the sphericity assumption. The level of significance was set at 0.05 for all statistical analyses. Significant factor effects and interactions were subsequently examined using the Bonferroni adjustment for multiple comparisons.

## RESULTS

In the expert group, a main effect of distance was observed in RT ($F(1, 11) = 26.34$; $p < 0.001$; $\eta^2 = 0.71$; SP = 1.00) and ET ($F(1, 11) = 114.49$; $p < 0.001$; $\eta^2 = 0.54$; SP = 0.98). That is, kicks from the short and normal distance showed a lower RT ($p < 0.001$ and $p < 0.02$, respectively) and ET ($p < 0.01$) than kicks from the long distance. No main effect of height or significant height-distance interaction effect was observed.

In the novice group, a main effect of the height was observed in RT ($F(2, 20) = 5.98$; $p < 0.02$; $\eta^2 = 0.23$; SP = 0.64). That is, the novices kicked to the chest with a lower RT than for kicks to the head ($p < 0.02$). Moreover, a main effect of distance was also observed in RT ($F(2, 20) = 72.40$; $p < 0.001$; $\eta^2 = 0.78$; SP = 1.00), ET ($F(1.5, 20) = 34.45$; $p < 0.001$; $\eta^2 = 0.64$; SP = 1.00) and IF ($F(1.9, 20) = 10.22$; $p < 0.001$; $\eta^2 = 0.34$; SP = 0.98). That is, when novices kicked from the short distance they had a lower RT and ET than for kicks from the normal ($p < 0.03$ and $p < 0.001$, respectively) and long distances ($p < 0.001$). Likewise, novices kicked from the normal distance with a lower RT and ET than for kicks from the long distance ($p < 0.001$). Moreover, from the short and normal distances they kicked with higher IF than for kicks from the long distance ($p < 0.001$ and $p < 0.01$, respectively). No significant height-distance interaction effect was observed ($p > 0.05$). Table 1 shows descriptive and standard deviation data of selected biomechanical variables for both groups.

## DISCUSSION

The aim of this study was to analyse selected biomechanical parameters (reaction time, execution time and impact force) according to the height and distance of the target in a counterattack context using the roundhouse kick in a sample of two different groups of male taekwondo athletes (experts and novices). In line with previous studies in the field [6,9,12,16], our results suggest that in the novice group both the height and the execution distance affected the kick performance, whereas in experts only the execution distance affected the performance. That is, regarding the effect of the height of the target, novices kicked to the head using a longer reaction time than for kicks to the chest. The effect size of these differences was large [1]. On the other hand, we observed that experts kicked with similar reaction time for both types of kick (to the chest and to the head). That is, it seems that experts were able to react in a similar time independent of the height of the target. This is in line with Mori, Ohtani and Imanaka [21], who found superior anticipatory skills in higher-level karate athletes. Taking into account that in both groups no differences have been found in the execution time according to the height of the target and in counterattacks, novices do not seem to be able to react but perform kicks in a similar time when they hit two different heights; our results support the comments by Vieten et al. [28], who stated that fast reactions are essentials in taekwondo, being interpreted as a key point for success in combats.

Regarding the impact force according to the height of the target, and in line with previous studies [9], taekwondo athletes (experts and novices) kicked with similar force in both types of kick (to the chest and head). This is, however, in contrast to findings by other researchers when studying an attacking context [18,24], where kicks to a lower height showed higher impact forces than kicks to a higher height. The fact that results reported from these two last studies were different to the results of our study could be due to the method of data analysis. That is, in the two other studies [18,24] the impact forces were not normalized according to the body weight. In this line,

**TABLE 1.** DESCRIPTIVE DATA OF THE ROUNDHOUSE KICK TO THE CHEST AND TO THE HEAD ACCORDING TO THE EXECUTION DISTANCE FOR ALL THE SUBJECTS, EXPERTS AND NOVICES

| | | Experts (n = 12) | | Novices (n = 21) | |
|---|---|---|---|---|---|
| | | Chest | Head | Chest | Head |
| RT (s) | ED1 | 0.461 ± 0.015 | 0.477 ± 0.022 | 0.492 ± 0.018 | 0.538 ± 0.016 |
| | ED2 | 0.498 ± 0.021 | 0.508 ± 0.027 | 0.541 ± 0.020 | 0.556 ± 0.022 |
| | ED3 | 0.575 ± 0.027 | 0.593 ± 0.026 | 0.630 ± 0.025 | 0.675 ± 0.021 |
| ET ($s \cdot m^{-1}$) | ED1 | 0.238 ± 0.075 | 0.287 ± 0.077 | 0.264 ± 0.057 | 0.263 ± 0.031 |
| | ED2 | 0.275 ± 0.081 | 0.283 ± 0.043 | 0.297 ± 0.071 | 0.308 ± 0.076 |
| | ED3 | 0.311 ± 0.063 | 0.330 ± 0.059 | 0.359 ± 0.101 | 0.375 ± 0.105 |
| IF ($N \cdot kg^{-1}$) | ED1 | 19.81 ± 5.67 | 18.65 ± 3.54 | 15.56 ± 5.51 | 14.81 ± 4.86 |
| | ED2 | 15.67 ± 7.12 | 18.06 ± 5.17 | 13.93 ± 5.58 | 13.91 ± 4.70 |
| | ED3 | 16.15 ± 5.86 | 16.46 ± 4.47 | 11.55 ± 4.68 | 11.42 ± 4.77 |

**Note:** Data represents mean ± SD; ED = Execution distance ($ED_1$: short; $ED_2$: normal; $ED_3$: long); Chest = Roundhouse kick to the chest; Head = Roundhouse kick to the head. RT = Reaction time (s); ET = Normalized execution time ($s \cdot m^{-1}$); IF = Normalized impact force ($N \cdot kg^{-1}$). No pairwise significant difference was found ($p > 0.05$).

Falco et al. [12] encouraged authors to normalize force data when athletes with different weights are involved in the same analysis. Many researchers in the field have highlighted the relationship between impact force and body weight, and the mechanism to use this weight to produce higher impact forces [5,10,24,25]. In order to be able to compare and discuss data future researchers should normalize mechanical data.

With regard to the influence of distance on kick performance, from short and normal distances experts were able to react and to execute the kick in a similar time and also to kick with similar impact forces; meanwhile from the normal distance novices kicked with similar impact force but in longer reaction and execution times than from the short distance. Thus, it seems that lower-level athletes are not able to adapt their technique when the distance changes from short to normal because the reaction and execution times increase. In line with Kim et al. [16], who stated that a key factor for success is the ability to adapt the technique to the distance, coaches should orient the training for novices so that they would be able to kick with similar performance (time and impact force) from every execution distance. This suggestion to focus training on adaptations according to the execution distance is also supported by results regarding the influence of the long distance in the kick performance. That is, from long distances novices kicked with lower impact force whereas experts kicked with similar force as for shorter distances. Moreover, both groups (expert and novice) kicked from the long distance using a longer time (reaction and execution time) than from the short and normal distances. Taking into account these results, it seems that experts should also focus their training to improve the time needed to kick to the target (time variables) instead of the force since they can kick with similar impact force independent of the distance they kick.

From a practical perspective, according to the height of the target and with the aim of decreasing possible concussions in taekwondo, regulations were changed in 2012 regarding the necessary impact force of kicks to the head to score [29]. It is established that kicks to the head score when the foot just gets in contact with the head (no impact threshold is needed). Thus, bearing in mind our results that experts and novices did not vary the impact force according to the height of the target but novices used a shorter reaction time in kicks to the chest than to the head, novices should avoid kicking to the head because they are not able to kick with similar performance. Nonetheless, if novices would expect counterattack kicking to the head, it could be suggested to coaches that they should orient novices to improving their reaction time in kicks to the head, because they are just able to generate enough impact force to score in both kicks.

Regarding the effect of the height of the target and the execution distance on counterattacking kick performance, no significant interaction effect (height x distance) was found. That is, similar performance was observed between kicks to the chest and to the head in every execution distance (short, normal and long). The results of the present study are, partially, contrary to the results reported in an attacking context by Estevan et al. [9], who found that the efficacy of kicks to a different height of the target seemed to be compromised by the execution distance. Even though the sample size could be noted as a limitation of the study at least in the expert group, power calculations indicate that the number of participants is sufficient to identify significant differences between the two groups [22]. One limitation of this study is found in the procedure. Before kicking athletes must be in a static position with their rear foot on the contact platform. In taekwondo, athletes must react and move constantly in order to be able to score and to make it more difficult for the opponent [16]. Nonetheless, the static position was used in the present study because our purpose was to assess the effect of the distance and the height of the target on kick mechanical performance. Another limitation of this study is related to the fact that it was not possible to measure the ground reaction force during the reaction to the signal. Recently, it has been stated [7] that when athletes have to react to a signal they generate sudden and sufficient power to allow them to kick with the performance desired. In this sense, Lystad et al. [19] suggested that strength and speed are among the attributes needed for a successful kick in taekwondo competition. Although these factors have not been measured specifically in our study, our procedure allows coaches and researchers to analyse the technique taking into consideration these two factors: strength for impact and speed to react to a signal. Thus, in taekwondo, athletes have to hit their opponent with as much speed and power as possible [13] and some authors [15] have recommended inverse dynamic calculation as one of the best ways to analyse strength performance by computing power output as the main variable of consideration. Future research in the field should integrate force plates in the ground in order to analyse power output in taekwondo kicks according to the external factors addressed in this study (i.e. the height of the target and the execution distance), as the power output is likely to affect the performance. Further, it could contribute new practical orientations for training and competition.

## CONCLUSIONS

This is the first study to analyse the effect of the height of the target and the execution distance on kick performance in a counterattack context in taekwondo. In line with orientations in attacking contexts, our results suggest that in counterattacking situations, expert athletes should kick to the head because this kick is developed with similar performance as the kick to the chest. Moreover, it is recommended that during counterattacks higher-level taekwondo athletes should intend to kick from normal distances because they are able to react and execute the kick in a shorter time than from long distances kicking with similar impact force.

Regarding novice athletes, even though a new rule for scoring when kicking to the head has been introduced, they should avoid kicking to the head because they are not able to kick with similar performance (kicks to the head need a longer reaction time than kicks to the chest). That is, when novices kick to the head they spend much more time than kicking to the chest.

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