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The influence of gender, dominant lower limb and type of target on the velocity of taekwon-do front kick

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Purpose: The current study aimed to quantify the main influences and the interactions (joint effects) of gender, leg and type of target on the biomechanics of front kick quality. Through the quantification, we tried to identify the relevant factors related to the kick accuracy and maximum velocity for coaching practice. *Methods*: A ten-camera NIR VICON MX40 motion capture system (250 Hz) was used to determine the kicking foot maximum velocity from two well-trained subject groups (8 males and 6 females). Each subject performed both left and right front kicks in a lateral standing position into the air (without a physical target), to a board, to a table tennis ball and to a training shield. The target were set on a height corresponding to a height of solar plexus of each participant. *Results*: The results showed that all the three factors (gender, leg and type of target) have significant influences on kicking speed ($p < 0.001$) and significant interaction (joint effect) was only found between gender and target ($p < 0.001$). Further analysis revealed that the males' kicking maximum velocity was affected more by board, while females' one was affected by the size of the target. *Conclusions*: The results would seem to suggest that, for males, kick-to-a-board may be the more effective method for increasing kick quality, compared to other type of target. For females, kick-to-a-small-ball appears to be effective method for increasing kick maximum velocity.

Key words: *interaction, kicking speed, kicking accuracy, factorial analysis*

1. Introduction

In general, for developing an effective kick in sports, two observable fundamentals must be kept in mind during trainings – kicking accuracy and force [1]–[3]. Motor control accuracy refers to the precision with which the kicking foot drives toward a target. This process start with preparation of movement in premotor cortex, and then all factors, including proprioception, spatial and visual stimuli and neural control over muscles. Power, on the other hand, is proportional to kick-foot velocity. An ideally effective kick is achieved when the target is struck accurately with maximum velocity. The increase of kicking velocity and kicking force may be the result of good training or may show a player condition [4], [5], accordingly, the decrease of the parameters may be caused by injury or performed surgery [6]. However, accuracy and power are non-autonomous variables – they naturally work against each other [7]. Especially for novice learners, this phenomenon can be dramatic.

Taekwon-do is a sport, dominated by kicking skills [8], [9], therefore, two fundamentals (accuracy and maximum velocity) are also vital factors contributing to its training as well as a win of a match. While there have been numerous studies exploring factors related to kicking maximum velocity [9], [10], there are few studies investigating accuracy [11]. There are reasons to think that features of an object (dimension,

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hardness, or the lack of it) during trainings may change the kinematics of a kick, and thus, the effects of training [12]. Additionally, even following an exact training procedure, kick with dominant or non-dominant leg may not reach the same kinematic parameters, as suggested by a pilot study [13]. The question is, whether the gender could cause dissimilarity of various kicks. The current study gives evidence that differences of motor control between male and female appear to be ambiguous [14]. If solid evidences could be obtained, as the case in soccer kicking studies, difference training programs should be applied for male and female athletes [15].

The training avenues leading towards the master level could be various. According to the rule of holism, nothing exists in the state of isolation and independency. For coaching Taekwon-do kicks, many factors that interact with each other would influence the training effects. Clearly, the interactions between different factors are mutual. In order to fully recognise these elements, one has to identify the relations existing among the influential factors [16]. Hence, a scientific quantification of the complex relationship among factors could have potential to develop efficient training programs for improving athletes' ability of controlling and managing complex task under numerous interactions of the influential factors [17]. Consequently, the current study selected 3 relevant factors: gender, dominant/non-dominant leg and type of target, and quantified their influences on the kinematics of taekwon-do front kick. The quantification focused on: 1) the main influence of gender, leg and type of target and 2) the interactions (joint effects) between gender and leg, gender and target, leg and target and among gender, leg and target. The aims of the quantification were: 1) to identify the relevant effects related to the kick accuracy and maximum velocity for coaches and athletes, and 2) to supply pedagogical guidance for their training programs.

2. Materials and methods

For identifying the influences of gender, leg and type of target as well as their interactions, two well-trained subject groups (male and female) were recruited from the local clubs. During the tests, they were performed both left and right front kicks (in taekwno-do: ap chagi) in a lateral standing position (in taekwon-do: niunja sogi palmok debi makgi) into the air (without a physical target), to a board, to a table tennis ball (a small ball hanging at personal preferred height) and to a training shield. This technique is executed by lifting the knee straight forward toward a target while keeping the foot and shin either hanging freely or pulled to the hip, and then straightening the leg in front of the target. After delivering the kick, leg is retracted to avoid the opponent trying to grapple the leg and to fighting stance. Kick-into-the-air is the fundamental exercise for skill acquisition and dynamic balancing training. Kick-to-a-shield and kick-to-a-board is the advanced training for gaining kick power. Kick-to-a-small-ball (small ball) tests the accuracy of a kick.

All participants were ITF taekwon-do athletes (International Taekwon-do Federation) and their preferred leg was the right one. The male group consisted of 8 subjects (age: 18.3 ± 1.7 years; body mass: 70.4 ± 6.0 kg; height: 176.2 ± 3.0 cm) and the female grove consisted of 6 ones (age: 19.8 ± 3.8 years; body mass: 57.7 ± 6.5 kg; height167.7 ± 6.4 cm). They have trained for at least 5 years. Their mastery level varies from 2 cup (red belt) to 3 dan. Among them there are medallist from World, Europe and Poland Championships.

The Human Subjects Research Committee of the host 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. The data collection was done in HML (Human Motion Lab).

During the test, each subject did an individualized warm-up first. Order of participants remain fixed, so the intervals between each of them were the same each time. The distance were adjusted by subjective measurement for every participant. Stages of preparation and execution of kicks during assessment:

1. Targets height were set individually, according to a height of participant. All targets were placed at subjective height corresponding to a height of solar plexus (middle of a trunk) of participant. Participants were told to strike as fast as they could. Targets were hanging on a line, which was attached to the rod under a ceiling. This implies, that only shape of a target have an influence, as targets were not solid-fixed, which might affect potential impact and change conditions of experiment.
2. Before the set of kicks, participant measured preferred distance with their leg (slow simulation of a kick in a manner to reach the target). Therefore, each participant stood in the same distance from the target, but this distance varied between participants. In this study, fixing the same distance for everyone will affect negatively the outcome,

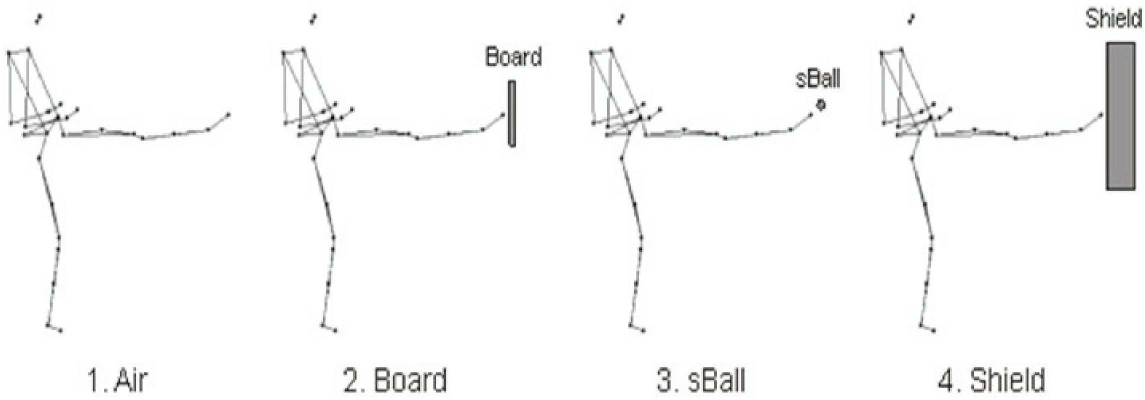

Fig. 1. Presentation of variants of the front kick:
1. without a physical target (into the air), 2. in a board, 3. in a ball, 4. in a shield

as the length of lower limb varies along with their height.

3. After one kick, participant returned to their standing position and performed another kick. At least 3 kicks succeeding in hitting a target were required for each circumstance. It results in collection data for 3–6 kicks for each participant, as not always first 3 kicks were in contact with the target. In some cases, there were more than 3 successive kicks captured, but for a data computing and statistical analysis, in a random way, there were picked for each person from raw data, so there were no preference in results. After finishing kick for one circumstance, participants were switching.

A ten-camera NIR VICON MX40 motion capture system (VICON Motion Systems, Oxford Metrics Ltd., Oxford, England) was used to track marker (diameter = 12 mm) placed right before metatarsophalangeal joint, tagged as toe of the kick foot at a rate of 250 frames/s. In this technique, the contacting area of body with the target is cushion foot, so marker placed on side of the joint did not have contact with a target in any circumstance, so the measurement were not disrupted. Resultant velocity were computed from movement of a marker in a function of time for 3 axis. For applied frequency, accuracy of measurement is 0.5 mm for marker placement, which corresponds to 0.06 m/s. This allows to present results with good accuracy, up to two decimal places. Maximum of kick velocity for each trial was calculated based on the collected 3D data. In total, 192 trials for males and 144 trials for females were collected and processed. Moreover, in contrary to other kinematic parameters, maximum velocity is characteristic for strikes analysis, as it can occur only once for analysed movement. Maximum velocity of a most distant marker in every strike occurs at the moment of contact with the target, therefore, it is reasonable measurement for kick in terms of its effectiveness in the case of contact with the target. Descriptive statistics (averages and standard deviation) and the multi-factor analysis using univariate analysis of variance (UNIANOVA) were derived using SPSS (v.22.0). Multiple comparisons as the post-hoc analysis (Scheffe test) were used to reveal significances related to the influences of gender, leg and the type of target for main and joint effects identification. Normal distribution were verified using Sharipo–Wilk test. Homogeneity of variances were verified by Lavene's test.

3. Results

Results of the current study revealed that, among the highly trained subjects, the front kick maximum velocity (resultant velocity for a marker on a foot) occurs always right before hitting the target. Obtained maximum velocity ranged from 9.4 to 11.0 m/s for males and from 7.1 to 8.6 m/s for females under the tested conditions (Table 1). For both genders, in all circumstances, the highest results were for kick into

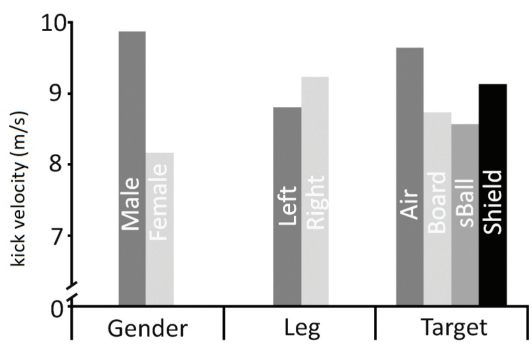

Fig. 2. The influences of gender, leg and target on kicking maximum velocity. sBall – small ball (pingpong ball)

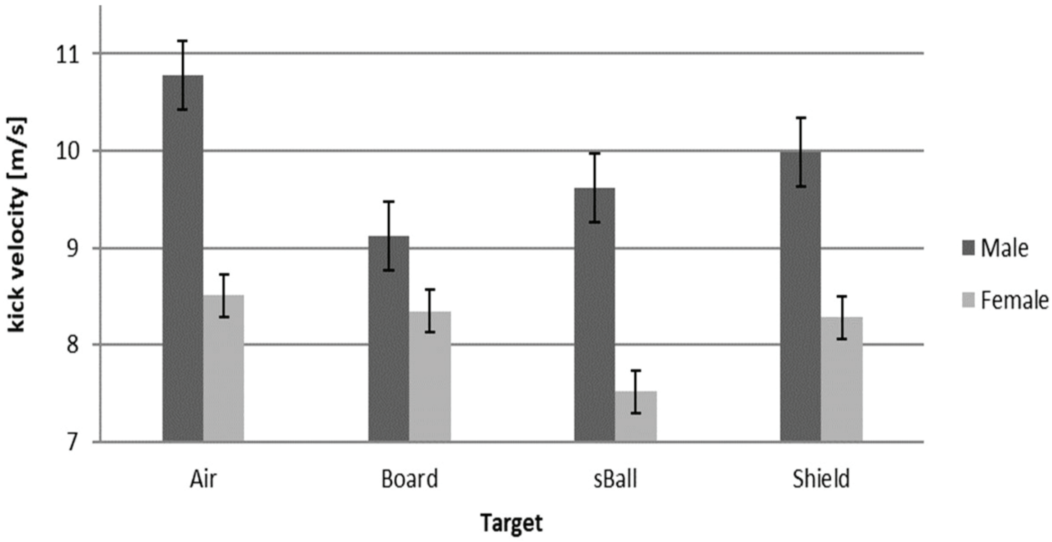

Fig. 3. The joint effect of gender and target on kicking maximum velocity. sBall – small ball (pingpong ball)

Table 1. The average and standard deviation of kicking resultant maximum velocity under various test conditions

		Maximum velocity of the kick [m/s]			
		Air	Board	sBall	Shield
Male	Left Kick	10.57 ± 1.39	8.88 ± 1.07	9.43 ± 0.84	9.86 ± 1.44
	Right Kick	10.99 ± 1.19	9.36 ± 0.89	9.81 ± 0.99	10.11 ± 1.33
Female	Left Kick	8.42 ± 1.12	8.16 ± 1.50	7.11 ± 1.06	8.01 ± 1.43
	Right Kick	8.60 ± 1.76	8.53 ± 1.32	7.92 ± 2.17	8.55 ± 1.65

an air, regardless kicking leg. In other circumstances, males obtained highest values for kick into a shield, while females results were highest for kicking a board. On the contrary, for men, lowest maximum velocities were obtained during kick to board, and into a small ball for females (Fig. 3). The UNIANOVA has revealed that all three factors (gender, leg and type of target) have significant influences on kicking speed ($p < 0.001$) (Fig. 2, Table 2). Significant interaction (joint effect) was only found between gender and target ($p < 0.002$) (Table 2). The results indicate that

Table 2. Results of factorial analysis for main and joint effects – based on using post-hoc tests (Scheffe)

		p-value
Main effects	Gender	0.000
	Leg	0.004
	Target	0.000
Joint effects (interactions)	Gender × Leg	0.748
	Gender × Target	0.002
	Leg × Target	0.907
	Gender × Leg × Target	0.831

* A × B – mutual comparison of specific factors with each other.

there are significant main effects for gender (i.e., males kick faster than females) and leg (the right leg, i.e., the dominant one kicks faster than left one). The significant interaction between gender and type of target
($p = 0.002$) indicates that the target effects is not the same for males and females.

4. Discussion

The purposes of the current study were to: 1) quantitatively describe the main effects of gender, leg and type of target on kinematic characteristics of taekwondo front kick, 2) examine and identify the interactions (joint effects) between gender and leg, gender and target, leg and target and among gender, leg and target, and 3) through the quantification and comparisons, identify the relevant effects (principal factors) that contributed to the kick accuracy and maximum velocity (the quality of the skill). Together, these findings have the potential to assist coaches and athletes in the teaching, learning and training the front kick. From the biomechanical aspect, correct movement reduces the loads in the joints, and thus, the risk of injury.

The results of the current study clearly indicate that there are two significant main effects, namely gender and leg, on kicking velocity regardless of what kind of target is presented. In general, males kick faster than females, so does the dominant leg kick over the non-dominant one. This confirms the empirical evidences. The question is what is the cause of the diversity of kick velocity often seen in practice. The factorial analysis of this study suggests that the interaction between gender and type of target could be responsible for the variation. It is known that interaction effects represent the combined/joint effects of factors on the dependent measure (e.g., kicking velocity). When an interaction effect is present, the impact of one factor (e.g., type of target) depends on the level of the other factor (e.g., gender).The statistical analysis in this study yielded a significant interaction between the type of target and the gender. This would suggest that the effect of target depended on the gender.

It is interesting to note that, for males, the lowest velocity was found in the kick-to-the-board, while, for females, in the kick-to-the-sBall (Fig. 3). For males, this is a typical situation where the compensation/trade-off for the kicking velocity (power = force × velocity) occurs [11]. The presence of a hard target (i.e., an additional stimulus) should logically lead the subjects to adjust their motor control pattern to increase/maximize their kick force at the impact to the hard object. The attention for maximization of muscle power for preparation of hitting the target would slow down the kicking velocity [18]. This psychological stimulus is absent in kick-into-the-air and not too strong in kick-to-a-shield.

For females, the result would suggest that they trade-off the kicking velocity for kicking accuracy. No studies exist for identifying the phenomenon. Biomechanically, the trade-off could be caused by less efficient dynamic balancing. Since the subjects are well trained (i.e. skilful athletes), the inefficient balance-control should not be an issue. A possible reason might be the anthropometrical difference between males and females. The effects of such differences could be hardly minimized by long-term training in some sports [15], [19]. Practice corroborated with increasing amount of scientific research shows that an interdisciplinary view on the problems connected with the improvement of an psychophysical functioning multiplies and strengthens effects [20]–[22]. Future studies are necessary to verify those findings in taekwon-do, especially the mechanism of velocity-precision related to gender in martial arts. Such gender-based studies could be multi-disciplinary in nature [23], [24]. Registered measurements can also be used to determine the loads in the joints of the lower limbs when kicking. Indication of the proper purpose for sports training can minimize possible injuries and joint exploitation.

5. Conclusions

The results obtained suggest different directives for males and females for a training process. Results indicate, that obtained lowest maximum velocities for studied technique were shown during kicking to board for males and during kicking to a small ball for females, exposing weakest circumstances of this kick technique for them. In shaping of maximum velocity of this technique, training should focus on those circumstances according to athlete gender. Depending of athlete results, training could be focused on precision while maintain high maximum velocity, or for maximum velocity itself, where there is no significant disproportion between obtained maximal velocities for different targets. Knowledge about disproportion between free kick (to the air) and to different targets maximum velocities for highly trained athletes gives good frame of reference to analyse degree of technique mastery, as complexity of task affect technique execution for novice, but should be minimized on master level. Results indicate that not only sole presence of target, but also the type of target affects maximum obtainable velocity. This is entry premise for further research in this topic.

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