KINETIC AND KINEMATIC DIFFERENCES BETWEEN TARGET AND FREE KICKING IN TAEKWONDO

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The purpose of this study was to evaluate the kinematic and kinetic (EMG) changes induced by varying kicking target sizes and the absence of these in Taekwondo kicking. Peak velocities and intersegmental timing and coordination variables were used to assess the kinematic of kicking executions. The kinetics of kicking executions were assessed from muscle co-contraction indexes obtained from EMG recording from selected muscles. Expert participants (n = 20) performed a set of ten Ap chagi (front kick) and Dollyo chagi (round house kick) to a set of target paddles of different sizes and masses. Significant differences were found between kicking conditions in the intersegmental timing of Ap chagi (p = 0.02) and Dollyo chagi (p = 0.04). Peak linear velocity of the ankle joint of Ap chagi (p = 0.63) and Dollyo chagi (p = 0.12) executions showed no significant differences. Differences in the thigh and leg angular velocities ratio were however significant for Ap chagi (p =0.01) and Dollyo chagi (p = 0.03) kicks. A strong correlation between muscle co-contraction and the mass of the kicking target (r = 0.95) was found.

KEY WORDS: Taekwondo, target paddle, co-contraction, kinematics.

INTRODUCTION:

Taekwondo techniques have started to feature in the scientific literature in recent times. Kicking actions were studied with the purpose of assessing their repeatability (Aggeloussis, 2007), the development of protective equipment (Matsubayachi et.al., 1993, Serina, 1991), and to obtain a greater understanding of the dynamics of their performance (S∅rensen, 1996). The execution of Taekwondo techniques and that of any other skill has a high dependency on the conditions under which these are executed (Aggeloussis, 2007). Thus, the findings reported in these studies are inherently limited to that of the conditions under which they performed and recorded.

The standard sequencing in skill acquisition in Taekwondo on the other hand, suggests that a novice practitioner should master the free execution of each Taekwondo technique, solo training method, before target kicking, focus training, is introduced into the training regime (Shaw, 2006). It has been reported that the absence of a ball kicking target in soccer can elicit specific muscle activation that differ to that exhibited when a target ball is present (Landeo, 2008). On light of these findings it is plausible to suggest that solo kicking represents at best a different skill to that of target kicking. Hence the idea of a transition from solo kicking to target kicking may need to be reconsidered.

The aims of this study were therefore to evaluate the differences in muscle function and intersegmental coordination when 1) a kicking target is present, focus versus solo kicking, and 2) varying target sizes are used.

Methods: Following approval from the Human Research Ethics Committee (University of New South Wales and the University of Queensland) a sample of convenience of 30 male and female expert participants, aged 23 ± 4.2 years was recruited for the study. With the purpose of reducing individual ability to perform better in any of the kicking techniques, the participants' cohort was randomly split into three groups of ten participants. Participants of the first group performed 10 set repetition of Ap chagi; participants from the second group performed a ten set repetition of Dollyo chagi and participants of the third group performed a ten repetition set of both kicking techniques. Kicking actions were performed under four conditions a) non target free kicking condition (solo), b) to a standard Daedo ® hand held

target paddle (TP); c) a hand held Daedo® coaching mit (Mit), and d) a large Daedo ® arm shield (AS) of 0.75x0.35 x0.1 dimensions. Two dimensional saggital views of the execution of Ap chagi were recorded by a high speed camera (Phantom ®) with a 500 Hz sampling frequency and digitized using WinAnalyse ® software. A standard marker set; shoulder, hip, knee, ankle and fifth metatarsal, was used for this tests. Dollyo chagi executions were recorded by using a 200 Hz, 3-D Expert Vision video system. Data were processed using user derived codes written in Matlab ®. Concurrently, electromyographic signal from Rectus Abdominis (RA), Rectus Femoris (RF), Vastus Medialis (VM), Semitendinosus (ST) and Gastrocnemius (GAS) muscle groups were collected using an 8 channel Bortec ® EMG system and amplified using an ATM8 amplifier. Similarly, EMG signals were collected from maximum voluntary contraction (MVC) for knee extension, knee flexion and hip flexion on a purpose built adapted dynamometer using a 5000 N Mecmesin ® force gauge.
To investigate the kinematics of kicking execution peak ankle linear velocity was calculated from each kicking condition. Other variables used to estimate kinematic performance of each kicking condition were the angular velocity ratio between segments (ω_{ratio}), and a normalised inter-segment timing index (t_i). The t_i is calculated as the time in between peak angular velocity of the proximal segment and the peak angular acceleration of the distal segment.
EMG data were rectified and band pass filtered at 15 Hz and 50 Hz, and normalised. Percentage of co-contraction was calculated from processed EMG data for muscles crossing the hip and knee joints using standard formulas formulated by Winter (2003).
The criteria used to determine the t_i ,ω_{ratio} and muscle co-contraction are shown below:
t_i→ Normalised time between ωThi and Leg maximum angular acceleration

$$\%co-contraction = 2\times\left(\frac{common\_areaA\&B}{area\_A+area\_B}\right) \quad \omega_{ratio} = \frac{\omega Leg - \omega Thi}{\omega Leg}$$

RESULTS AND DISCUSSION:
Once the Kolmogorov-Smirnov test for normal distribution with Lilliefors' significance correction (Peat & Barton, 2005) was satisfied for the selected kinematic variables, an average over the 10 trial execution for each participant was obtained. These averages were then group averaged and are presented in table 1.

Table 1. Peak linear and angular velocities reached during target and solo kicking techniques in Ap chagi and Dollyo chagi techniques.

	Variable	Solo Mean (SD)	TP Mean (SD)	Mit Mean (SD)	AS Mean (SD)	P value
Dollyo Chagi	ωThi(rad/s)	8.92 (2.44)	9.17 (4.37)	9.02 (3.59)	9.5 (4.11)	0.67
	ωLeg (rad/s)	16.65 (4.54)	16.80 (2.28)	16.58 (2.43)	16.9 (3.13)	0.85
	*v*K (m/s)	4.12 (2.72)	4.58 (1.29)	4.45 (1.23)	5.01 (1.58)	0.91
	*v*A (m/s)	11.35 (2.65)	12.18 (3.66)	11.90 (4.37)	12.3 (4.19)	0.12
Ap Chagi	ωThi(rad/s)	10.32 (3.17)	11.05 (2.98)	11.58 (2.68)	10.95 (3.45)	0.24
	ωLeg (rad/s)	19.25 (2.34)	19.58 (4.51)	20.14 (5.68)	19.51 (6.01)	0.23
	*v*K (m/s)	5.71 (2.79)	5.54 (3.21)	5.64 (1.57)	5.97 (3.08)	0.57
	*v*A (m/s)	11.74 (2.83)	11.35 (3.6)	11.50 (4.97)	11.90 (5.29)	0.63

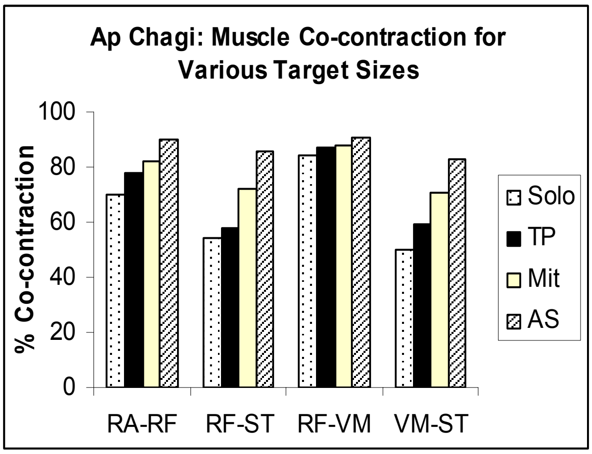
Data from this table, suggest that values for peak linear and angular velocities are not sensitive to the absence of a kicking target nor to the dimensions of the kicking target when this is present. There is however the tendency to reach slightly higher peak velocities when a kicking target is present. This apparent increase in peak velocities however has not reached statistical significance. This may result from the fact that most of these athletes do not find target kicking an unfamiliar practice and hence are equally equipped to perform with and without them. It also suggests that the attributed benefits of focus training as a way of increasing kicking speed may need to be reviewed.

Kinematic coordination variables are shown in table 2. There is a strong correlation between ω_{ratio} and T*i* to target size (-0.95, -0.96) for Dollyo chagi and Ap chagi kicks.

Table 2. Timing and coordination variables from target and solo Ap chagi and Dollyo chagi kicking.

	Variable	Solo Mean (SD)	TP Mean (SD)	Mit Mean (SD)	AS Mean (SD)	P value
Dollyo Chagi	ω_{ratio}	0.47 (0.08)	0.44 (0.06)	0.41 (0.03)	0.38 (0.03)	0.01
	T*i*	3.61 (2.87)	3.78 (2.35)	4.11 (3.01)	4.14 (3.35)	0.04
Ap Chagi	ω_{ratio}	0.48 (0.09)	0.42 (0.12)	0.40 (0.09)	0.36 (0.16)	0.00
	T*i*	2.24 (1.24)	3.58 (1.64)	3.61 (2.1)	3.95 (2.01)	0.02

As the target size increases the ratio between the angular velocity of the proximal relative to the distal segment decreases for both kicking techniques. This indicates that as the kicking target increases in size there is less interplay between segments. This increased joint stiffness, particularly at the knee joint, indicates that there is a target induced technique change. Based on the available data it can be inferred that the presence of a kicking target would require greater contribution from hip flexion rather than from knee extension moments for execution of these two kicking techniques. There is also a strong correlation between timing and kicking target size for a Dollyo chagi (0.96) and an Ap chagi (0.98). This suggests that the interplay between proximal and distal segments is target size sensitive and that depending on the size of the target different coordination motor patterns can be induced and developed.



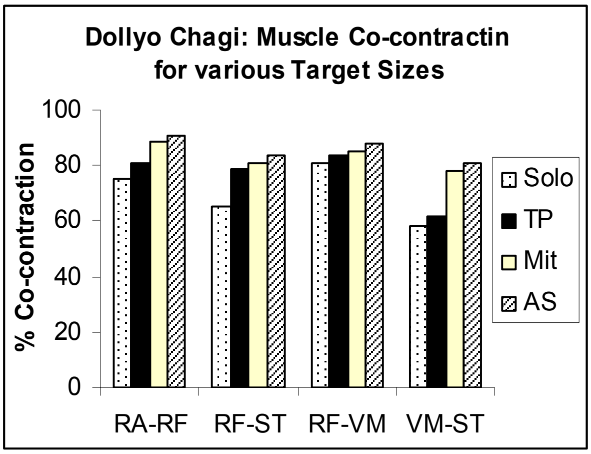


Fig 1. Co-contraction percentage values for different muscle pairs crossing the hip and knee joints.

The available data on percentage of muscle co-contraction indicates that a strong correlation exists between higher co-contraction and target dimensions for both forms of kicking execution and for all the selected muscles pairs. A mean (SD) correlation of 0.86 (0.03) for all muscles pair and for both kicking conditions can be reported. It becomes apparent that the reduction in the angular velocity ratio between the proximal and distal segments and the change in timing between segments in the presence of kicking targets are linked to the increased muscle co-contraction reported here. This suggests that "locking' the joints in the presence of a high mass target may be a mechanism by which the kicking impact is optimized as it increases the ability to respond more efficiently to the reaction forces that arise from impact.

It has also became apparent that target kicking is an entirely different affair when compared to solo or non target kicking and even between target sizes differences exist. Using of different sizes of kicking target should take these findings into account to ensure adequate muscle adaptations to movement coordination and load response during impact. Findings from this study may also assist in the selection of appropriate testing protocols when evaluating kicking performance in Taekwondo athletes.

CONCLUSION:
Data from this study indicates that some neuromuscular features of the kicking action such as; level of segments interplay, intersegmental coordination and muscle co-contraction are modulated by the conditions under which the kicking actions are performed. This plasticity of the central nervous system may be an advantageous trait in reducing the risk of injury when performing kicking actions at high intensities under varied settings. It becomes apparent that challenges exist when attempts to transfer the training gains achieved under specific settings to different kicking conditions are made, for example the transfer from training to competition in Taekwondo. The need for a more scientific based approach in establishing a time sequence in the use of target sizes during general, pre competitive and competitive training in Taekwondo is also manifested. From a methodolical perspective it can be added that data obtained under laboratory settings may not faithfully reflect the various components that make up a kicking action if considerations for target sizes and masses are not thoroughly assessed in line the main objectives of the study for which data are collected.

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