Results

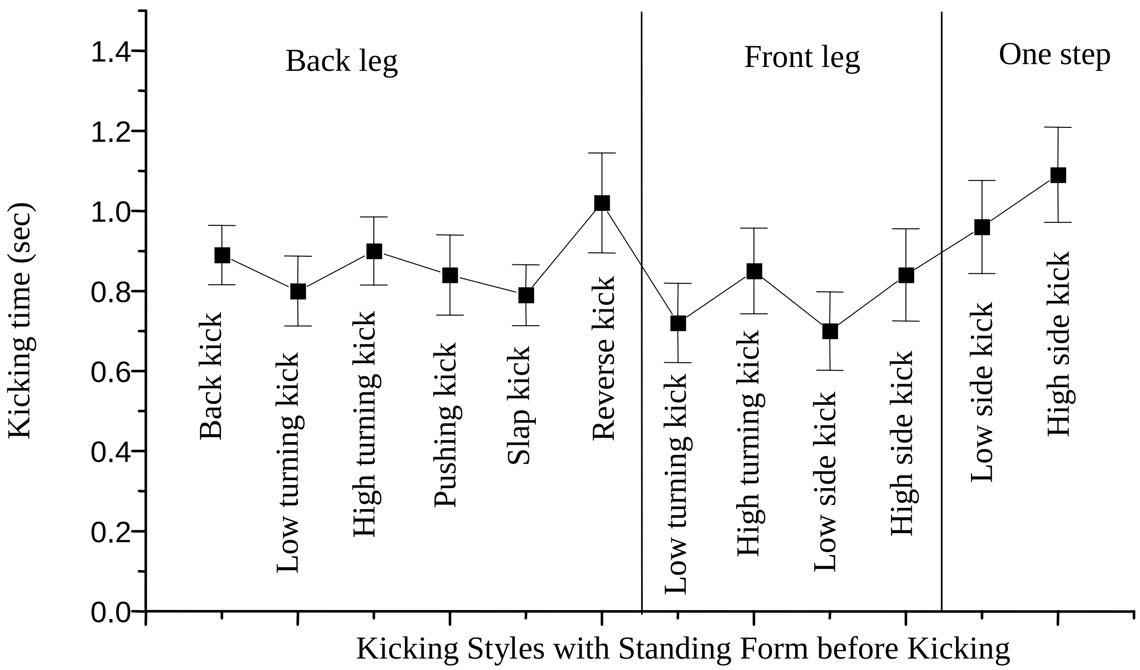
Part I

Biomechanical analysis of kicking

Kicking analysis

ANOVA was employed to examine the difference in the timing of kicks of different styles and heights.

The results showed that there were significant differences in kicking time for different styles of kicking ($p<.001$) and different kicking heights ($p<.001$). However, there were no significant differences in kicking time between different preparation forms (Table 3). Table 4 shows the descriptive statistics of the kicking time for different preparation forms and styles. The graphical presentation of the kicking time for different preparation forms and styles is demonstrated in Figure 11.



<u>Figure 11.</u> The graphical presentation of kicking time (±SD) for different kicking styles.

Table 3

Results of ANOVA in Kicking Time for different Kicking Styles, Leg Forms, Kicking Height Levels and Preparation Forms

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.390	18	0.133	14.665	0.000
Intercept	136.743	1	136.743	15105.941	0.000
FORM	0.000	1	0.000	0.005	0.941
LEG_FORM	1.031	2	0.516	56.967	0.000
KICKING	0.249	5	0.050	5.493	0.000
KICK_LEV	0.350	1	0.350	38.710	0.000
FORM * LEG_FORM	0.007	2	0.004	0.404	0.668
FORM * KICKING	0.002	4	0.000	0.047	0.996
LEG_FORM * KICKING	0.000	0	.	.	.
FORM * LEG_FORM * KICKING	0.000	0	.	.	.
FORM * KICK_LEV	0.000	0	.	.	.
LEG_FORM * KICK_LEV	0.002	2	0.001	0.117	0.890
FORM * LEG_FORM * KICK_LEV	0.000	0	.	.	.
KICKING * KICK_LEV	0.000	1	0.000	0.004	0.953
FORM * KICKING * KICK_LEV	0.000	0	.	.	.
LEG_FORM * KICKING * KICK_LEV	0.000	0	.	.	.
FORM * LEG_FORM * KICKING * KICK_LEV	0.000	0	.	.	.
Error	1.892	209	0.009		
Total	167.216	228			
Corrected Total	4.282	227			

Note. Df = degree of freedom; F = F value; FORM = the preparation form of kicking that consists of jumping and standing; LEG_FORM = the position of kicking leg before kicking that consists of front and back; KICKING = the styles of kicking that is shown in Table 2; KICK_LEV = the height level of kicking that consists of subject's head height and waist height.

Table 4

Descriptive Statistics of the Kicking Time for different Kicking Styles

Kicking Styles		Height level	Mean (sec) N=12	S. D.
Jumping				
	Back leg			
	Back kick	Low	0.870	0.065
	Turning kick	Low	0.770	0.070
	Pushing kick	Low	0.830	0.076
	Slap kick	Low	0.780	0.084
	Front leg			
	Turning kick	Low	0.740	0.073
	Side kick	Low	0.730	0.091
	One step			
	Side kick	Low	0.960	0.114
Standing				
	Back leg			
	Back kick	Low	0.890	0.074
	Turning kick	Low	0.800	0.087
		High	0.900	0.085
	Pushing kick	Low	0.840	0.100
	Slap kick	Low	0.790	0.076
	Reverse kick	High	1.020	0.125
	Front leg			
	Turning kick	Low	0.720	0.099
		High	0.850	0.107
	Side kick	Low	0.700	0.098
		High	0.840	0.115
	One step			
	Side kick	Low	0.960	0.116
		High	1.090	0.119

The front turning kick to the waist level with standing preparation form was significantly faster (0.70 ± .098s) than the other styles of kicking. The one-step side kick to the head level with standing preparation form was significantly slower (1.09 ± .119s) than the other styles of kicking.

Moreover, the use of the front leg was significantly faster than the use of the back leg for kicking ($p<.001$). The kicking time, when kicking to the subject’s waist level, was significantly shorter than a kick to the subject’s head level ($p<.001$).

The kicking height showed significant effects on kicking time. The kicking time to a higher level was significantly longer than that to a low level ($p<.001$).

EMG analysis

Table 5 shows the descriptive statistics of muscle activity in terms of %MVC for each selected muscle during kicking.

Table 5

Descriptive Statistics of Each Selected Muscle Activity (%MVC) During Kicking

	Mean (%MVC) N = 228	S. D.
CH1	42.33	14.98
CH2	66.84	31.31
CH3	75.98	41.19
CH4	133.12	77.55
CH5	250.44	182.28
CH6	43.53	15.43
CH7	47.14	28.29
CH8	77.50	52.46

Note. CH1 = Sartorius; CH2 = Rectus femoris; CH3 = Vastus medialis; CH4 = Tensor fasciae latae; CH5 = Vastus lateralis; CH6 = Semitendinosus; CH7 = Biceps femoris; CH8 = Gastrocnemius.

ANOVA was employed to examine the difference in muscle activity during kicking (Table 6).

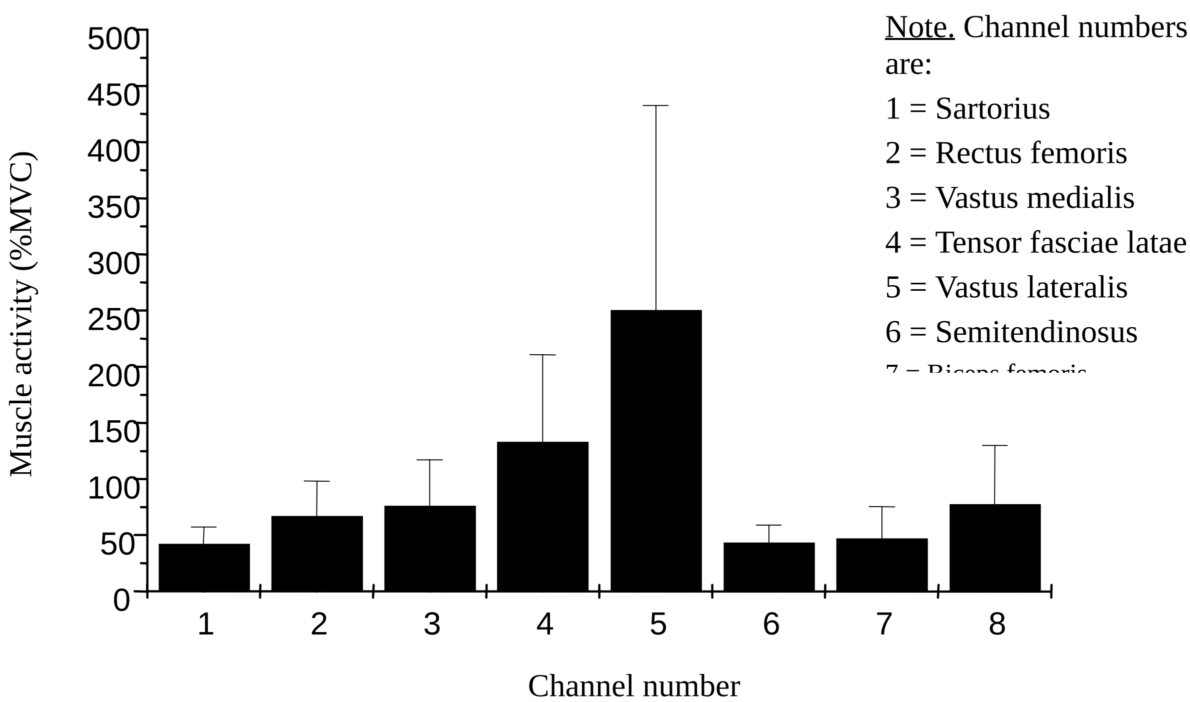
The statistical analysis showed that there was a significant difference in muscle activity among the selected muscles during kicking ($p<.001$).

The vastus lateralis and tensor fasciae latae showed significantly higher muscle activity during kicking when compared with other selected muscles. The muscle activity of the tensor fasciae latae was 133.12 ± 77.55%MVC and the muscle activity of the vastus lateralis was 250.44 ± 182.28%MVC during kicking.

The muscle activity of sartorius, rectus femoris and vastus medialis was 42.33 ± 14.98%MVC, 66.84 ± 31.31%MVC and 75.98 ± 41.19%MVC, respectively, during kicking.

Muscle activity of the hamstrings during kicking can be represented by the semitendinosus muscle and the biceps femoris, with the activity level of these muscles 43.53 ± 15.43%MVC and 47.14 ± 28.29%MVC, respectively.

Figure 12 is the graphical presentation of muscle activity among selected muscles during kicking.



<u>Figure 12.</u> The graphical presentation of muscle activity %MVC (±SD) during kicking.

Table 6

Results of ANOVA in Activity (%MVC) among Selected Muscles During Kicking

Source	FACTOR1	Type III Sum of Squares	df	Mean Square	F	Sig.
FACTOR1	Linear	38164.95	1	38164.95	23.14	0.000
	Quadratic	2377499.31	1	2377499.31	240.69	0.000
	Cubic	41730.89	1	41730.89	28.89	0.000
	Order 4	2222649.56	1	2222649.56	267.33	0.000
	Order 5	379819.04	1	379819.04	128.09	0.000
	Order 6	1442389.26	1	1442389.26	237.22	0.000
	Order 7	1414565.28	1	1414565.28	212.97	0.000
Error(FACTOR1)	Linear	374399.21	227	1649.34		
	Quadratic	2242314.66	227	9878.04		
	Cubic	327906.05	227	1444.52		
	Order 4	1887336.09	227	8314.26		
	Order 5	673115.69	227	2965.27		
	Order 6	1380244.64	227	6080.37		
	Order 7	1507788.46	227	6642.24		

Note. FACTOR1 represents the different activity level among different selected muscles during kicking.

Training programme

According to the results of the analysis of kicking, relatively low muscle activity was found in the quadriceps and hamstrings. It is likely that the lower muscle activity of the quadriceps is due to the rapid movement of knee extension during kicking that, in turn, results in less muscle fibres being recruited. On the other hand, the quadriceps seems to be the prime mover in knee extension during kicking. According to this finding, we designed a training protocol that contains special training of knee extension and flexion under high-speed condition, in order to increase the muscle activity of the quadriceps during kicking.

The isokinetic training protocol contained knee concentric extension/flexion contraction at 240°/s, 20 repetitions in each set, 5 sets for each session, 3 sessions weekly.

Part II

Training effect

Table 7 shows the descriptive statistics of the isokinetic concentric contraction peak torque at 240 deg/s of knee extension before and after training for the control and training groups.

The isokinetic concentric knee extension peak torque at 240 deg/s changed from 108.00 ± 14.93 Nm in the pre-test to 103.50 ± 11.43 Nm in the post-test for the control group. The isokinetic concentric knee extension peak torque at 240 deg/s showed significant increase, from 108.83 ± 16.95 Nm in the pre-test to 117.83 ± 18.99 Nm in the post-test for the training group.

Table 7

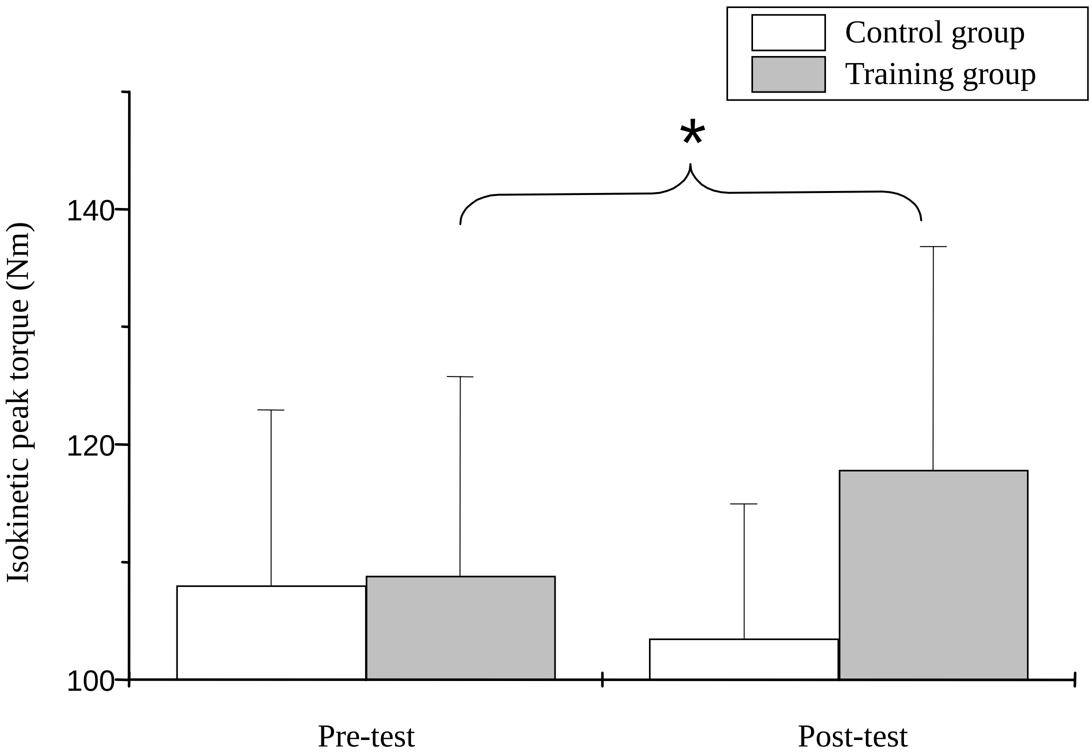
Descriptive Statistics of Isokinetic Concentric Contraction Peak Torque at 240 deg/s of Knee Extension Before and After Training for the Control and Training Groups

GROUP	Mean (Nm) N = 6	S. D.
PRE		
Control	108.00	14.93
Training	108.83	16.95
POST		
Control	103.50	11.43
Training	117.83	18.99

Note. PRE = result from the pre-test; POST = result from the post-test; Nm = Newton meter.

ANOVA was employed to examine the effect of the training programme on the isokinetic strength of knee extension at 240 deg/s. The results of the statistical analysis showed that there was a significant increase in the peak torque of the isokinetic concentric contraction at 240 deg/s at knee extension ($p<.05$).

Figure 13 shows the graphical presentation of isokinetic concentric contraction peak torque at 240 deg/s of knee extension before and after training for the control and training groups.



<u>Figure 13.</u> Graphical presentation of isokinetic concentric contraction peak torque at 240 deg/s of knee extension before and after training for the control and training groups.

Table 8 shows the results of ANOVA in isokinetic concentric contraction peak torque at 240 deg/s of knee extension with significant change ($p < .05$).

Table 8

<u>Results of ANOVA in Isokinetic Concentric Contraction Peak Torque at 240 deg/s Knee Extension</u>

Source	PREPOST	Type III Sum of Squares	df	Mean Square	F	Sig.
PREPOST	Linear	30.375	1	30.375	0.879	0.371
PREPOST * GROUP1	Linear	273.375	1	273.375	7.907	0.018
Error(PREPOST)	Linear	345.75	10	34.575		

Discussion and Conclusion

The results of this study were divided into two parts. The first part was the biomechanical analysis of Taekwondo kicking and the second part was the evaluation of the isokinetic training..

In the biomechanical analysis of Taekwondo kicking, the kicking time and the muscle activity were measured and ANOVA was employed to examine the difference among different kicking styles. The kicking time between different preparation forms showed no significant difference, indicating that, to perform a kick, different preparation movements will not result in different kicking times.

In the real Taekwondo competition, athletes always keep their body moving during the game. If the kicking time was the same for different preparation forms, then why do athletes move their body before attacking? Can they perform the same kicking performance with standing or jumping preparation form before kicking? It is common knowledge that in order to keep moving before kicking, the athletes spend a considerable amount of energy. If there was no any benefit from keeping the body moving before attacking, then the standing form would be a good choice, because it can save energy during the competition.

During kicking the muscle activity of the quadriceps was relatively low when comparing the tensor fasciae latae muscle with the vastus lateralis muscle. This phenomenon may be explained by the speed of the kicking motion. Since kicking involves a fast knee extension movement, the recruitment of the quadriceps muscle fibre may reduce. In such case, the ability to recruit muscle fibre under rapid movement becomes the most important factor affecting the exercise performance. To increase the exercise performance, the ability to recruit muscle fibre when moving rapidly should be enhanced. In order to enhance the ability to recruit muscle fibre during high speed contraction, a high speed isokinetic exercise programme was designed. The training protocol contained knee concentric extension/flexion at 240deg/s, 20 repetitions in each set, 5 sets for each session, 3 sessions weekly.

The constant preselected velocity during isokinetic movements allows the training to improve the muscular performance in dynamic conditions (Baltzopoulos and Brodie, 1989). Isokinetic training at a specific angular velocity increases the maximum torque of the muscle groups involved at that velocity (Lesmes et al. 1978). Numerous studies have also proved the training effects of isokinetic exercise (Baltzopoulos, 1989; Perrin, 1989; Perrin, 1993; Ewing, 1990; Johnson, 1976; Lesmes, 1978; Perrine, 1981 and Coyle, 1981). In our study, the speed of 240 deg/s was chosen as the training velocity.

To increase the muscle strength under high angular velocity, isokinetic exercise training with a pre-selected speed for the dynamometer seems to be an effective way. In this study, the isokinetic concentric knee extension peak torque at 240deg/s was significantly increased after the isokinetic training at that angular velocity. The results show that, in order to increase the muscle strength in high-speed movement such as Taekwondo kicking, a relatively high angular velocity in isokinetic training should be selected.

In future, different training programmes could be designed for different muscle groups. The training exercise may contain isokinetic concentric, eccentric contraction, or isotonic contraction on specific muscle groups. Feedback from the subjects indicates that hip flexor and hip adductor seem to be important in Taekwondo kicking. Research work could focus on these muscle groups to see the possible changes in kicking performance. Moreover, information about the force applied to the kicking target is very useful for both researchers and coaches. Finally, a more reliable system should be developed to measure the actual force during the impact time.

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