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"IDO MOVEMENT FOR CULTURE. Journal of Martial Arts Anthropology",
Vol. 19, no. 1 (2019), pp. 34–50
DOI: 10.14589/ido.19.1.4

KINESIOLOGY / COACHING

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An Estimation Model for Anaerobic Power of Taekwondo Athletes Based on Field Tests

Submission: 2.07.2018; acceptance: 20.08.2018

Key words: estimation using the measurement, field testing, Wingate test, isokinetic muscle test

Abstract
Background. Anaerobic power is measured in Taekwondo with short-term explosive kicking and the muscle strength and endurance needed to push an opponent, has become extremely high. In previous studies, anaerobic power tests were developed but are inconvenient and somewhat lacking for Taekwondo athletes.
Problem and Aim. In order to design an estimation model to measure variables in Taekwondo roundhouse kick field tests, the Wingate anaerobic power test was applied to the kicking speeds of 20 male elite-level Taekwondo players' in laboratory and field tests over a three-week period.
Methods. To estimate anaerobic power capability, laboratory tests included 30- and 90-second Wingate tests, and field tests included standard fitness tests and performing one set of Taekwondo roundhouse kicks at peak speed on three consecutive days for 30, 60, and 90 seconds, respectively. Variables were subjected to mean comparison, correlation, and multiple regression analysis by subjects' weight class. The Wingate test was used to estimate anaerobic power capability.
Results. Anaerobic power measured by the Wingate test significantly affected Taekwondo kicking performance for 0-5 seconds and 10-15 seconds, 50m running, and standing long jump tests.
Conclusions. The results of this study suggest that utilizing 30 seconds of continuous kicking at peak speed, 50m running, and standing long jump are possible field tests components for an estimation model to determine anaerobic power capability in Taekwondo athletes.

Introduction

Taekwondo sparring competition requires a variety of physical strength factors. The importance of anaerobic power, which is measured in Taekwondo with short-term explosive kicking and the muscle strength and endurance needed to push an opponent, has become extremely high as the game mode has changed. In previous studies, anaerobic power tests were developed, including a step test for quantitative evaluation of the anaerobic power in the 1960s [Margaria, Aghemo, Rovelli 1966], a running test utilizing treadmill in 1969 [Cunningham, Falulkner 1969], and an isokinetic muscular strength test [Baltzopoulos, Estou, MaClaren 1988].

Various anaerobic power tests have been performed using a cycle ergometer [Bar-Or, Inbar 1978; McCartney, Heigenhauser, Jones 1983]. However, the most commonly used method to evaluate anaerobic exercise capability is the 30-second Wingate anaerobic power test using a cycle ergometer [Inbar, Bar-Or, Skinne 1996]. In this test, a phosphagen system is used to evaluate the peak power expression of the muscles and the power derived from the combination of the anaerobic corresponding process and the phosphagen system after 10 seconds of exercise. Inbar *et al.* [1996] reported that the Wingate anaerobic power test is the most sensitive and reliable test for anaerobic exercise for many athletes. Cooper *et al.* [2004] reported that such values are generally related to the adenosine triphosphate (ATP) supply capability through the anaerobic metabolic process along with the ATP decomposition rate. For such advantages, the Wingate anaerobic athletic performance test has been used more widely than other tests [Jung J.H. 2011].

While the Wingate test is known to be an optimal method for anaerobic power analysis of athletes, expensive equipment and skilled inspectors are required, and it is inconvenient to measure only in a specific laboratory space. From this viewpoint, J.H. Kim *et al.* [2010] attempted to evaluate the anaerobic exercise capability directly on the field by measuring jumping ability, speed ability, muscle strength, and throwing ability in the field. As a result of their field and laboratory tests for power evaluation on short-distance athletes in the field, J.H. Kim *et al.* [2010] showed that maximum power and average power among Wingate test results were related to back strength and the throwing of a Madison ball. There was also a relevance to maximum power and average power for weight during a 30m running test. Yet, there is a lack of understanding and adaptation by coaches and athletes of the isokinetic muscular function test despite a possibility of application in the actual sports field [Kim J.H. *et al.* 2010].

In order for athletes to perform effectively, various factors must work independently or in combination affect each other, and each sport places unique demands on the human body, thus necessitating proper evaluation methods to be developed according to the needs of each sport. Take Taekwondo sparring competitions for instance. Korean Taekwondo sparring players can no longer dominate the international stage as the level of Taekwondo competition of all the players of the world is now leveled [Nam 2014]. This may be due to various factors, but the past experience-based training methods and systematic sports science approaches are somewhat lacking. Previously, Oliveira *et al.* [2015] correlated results from an anaerobic kick test and Wingate anaerobic test. The differences from that study and the current research is that the measurement method (i.e., kicking time, Wingate test method, and isokinetic myopathy test) were added to obtain scientific evidence. In addition, we have developed an estimation model.

Currently, Korean Taekwondo athletes undergo a demanding combination of technical and physical training, while coaches are tasked with finding excellent athletes and effectively managing them. A method for determining anaerobic exercise capability designed specifically for Taekwondo athletes would therefore be a valuable tool for coaches to choose and evaluate their Taekwondo players. As a consequence, this study intends to create an anaerobic power estimation model for Taekwondo athletes that incorporates established field tests.

Methods

Research subjects

The subjects of this study were 20 male Taekwondo athletes from a Korean university aged 19-20 years and with 5 years or more elite athletic experience. Subjects were informed of the purpose and details of the study and were accepted on a voluntary basis. The physical characteristics of the subjects is shown in Table 1.

Experiment design

Subjects' height, body weight, and body fat mass were measured inside a university sports science laboratory. All subjects performed the Wingate test and the Biodex isokinetic muscle test to evaluate their anaerobic exercise

Table 1. Subjects' physical characteristics (Mean±SD)

Age (yrs)	Height (cm)	Weight (kg)	Fat (kg)	LBM (kg)	Fat (%)
19.80±0.95	179.6±5.63	73.58±1.04	11.44±2.67	58.22±7.80	15.42±1.98

LBM: Lean body mass

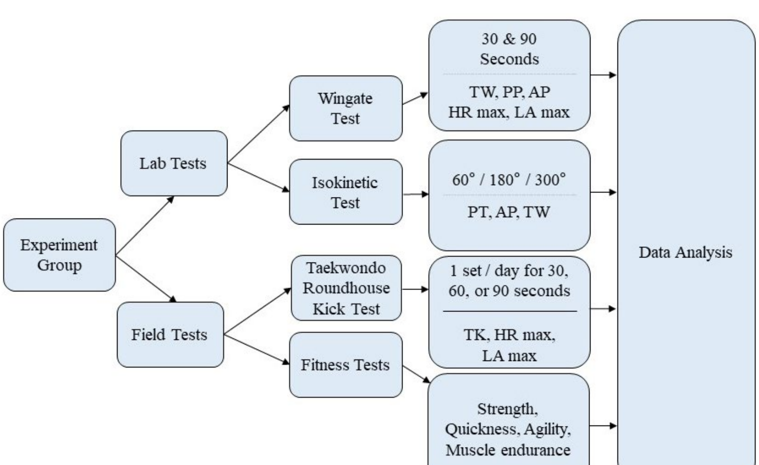

Figure 1. Experiment design

TW: total work, PP: peak power, AP: average power, HR Max: maximum heart rate, LA max: lactate acid max, PT: peak torque, TK: Taekwondo roundhouse kick ability. Field performance was performed with physical strength and Taekwondo roundhouse kick tests. The field performance tests measured muscle strength, agility, and flexibility, and Taekwondo roundhouse kicks were performed continuously at athletes' peak speed (Figure 1).

Body composition and physical force measurement
An extensometer (InBody, Seoul, Korea) was used to determine the stress placed on subjects' bodies, and InBody 3.0 (InBody, Seoul, Korea) was used to measure their body weight, body length, body fat, and muscle mass. Physical strength was measured with grip strength, back strength, 30m running, 50m running, standing long jump, sit and reach, and sit up tests.

Wingate test
Anaerobic exercise tests were carried out using a bicycle ergometer and the Wingate test for 30 and 90 seconds to subjects' maximum exercise output. The relative load given to test subjects was set at 0.075kp per body weight during the 30-second test and 0.05kp during the 90-second test. Subjects warmed up by pedaling for 2 minutes at 50rpm and at 4-6 seconds at maximum speed. After a 5-minute rest, subjects were asked to pedal as quickly as possible to overcome the inertia of the bicycle, and they continued to pedal at peak speed after reaching the final load. Examiners provided verbal encouragement at this time. Subjects' maximum speed, average power, peak power, and fatigue index were measured, and the number of times subjects pedaled was recorded with a video camera (Sony FDR-AXP35, Japan) at this time. In order to analyze subjects' fatigue index, blood lactate concentration was measured before and immediately after the maximum pedaling exercise as well as after 3, 5, and 10 minutes of rest for both the 30- and 90-second tests. During the exercise, subjects' heart rates were measured before, immediately after the Wingate test, and during the recovery time at 3, 5, and 10 minutes using a polar heart rate monitor (Polar Vantage NV, Finland).

Taekwondo roundhouse kick test
Subjects were instructed to wear an electronic foot protector and perform the Taekwondo roundhouse kick on an electronic chest protector (Figures 2 & 3) that would record the number of kicks performed. The electronic chest protector was worn by an assistant of approximately the same height. The assistant was instructed to turn into the subject's roundhouse kick to ensure kicks were recorded accurately and for their own protection (Figure 2). The Taekwondo roundhouse kicks were performed in the manner of Olympic or Kukkiwon Taekwondo at the height of subjects' stomachs, so that subjects kicked the sides of the electronic chest protector (i.e., where an opponent's abdomen or ribs are located). Kicks were executed by alternating feet in a manner that when one foot kicked the target, the subject would immediately jump with the standing leg to kick the other side of the electronic chest protector with that foot. Subjects were thus in a constant state of motion during the test.

The impact strength of the electronic chest protectors (KP&P, Korea) was preset according to the established parameters used in Taekwondo competitions according to athletes' weight classes The impact strength of the electronic chest protector was set in advance according to the same method set in various competitions in the identical manner for each weight class; i.e., when the weight of the athlete is entered by the equipment company, the strength is automatically set, otherwise the impact will not be counted. Prior to the actual tests, subjects were instructed to relax and then kick the electronic chest protector slowly with minimum force for 20 seconds and then at maximum speed for 5-6 seconds with no resistance. After this warm-up period, subjects rested for 5 minutes and then performed the experiment.

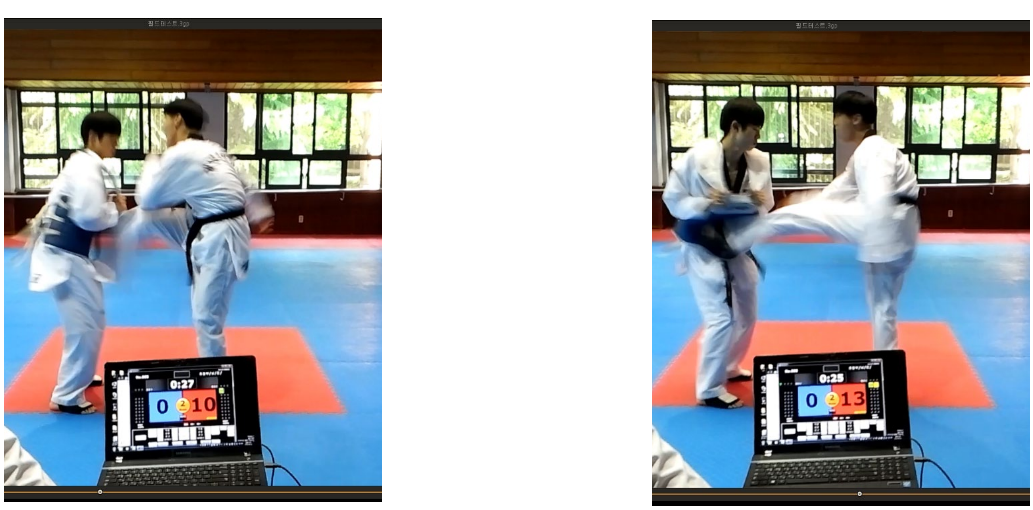

Figure 2. Taekwondo roundhouse kicks performed on electronic chest protector

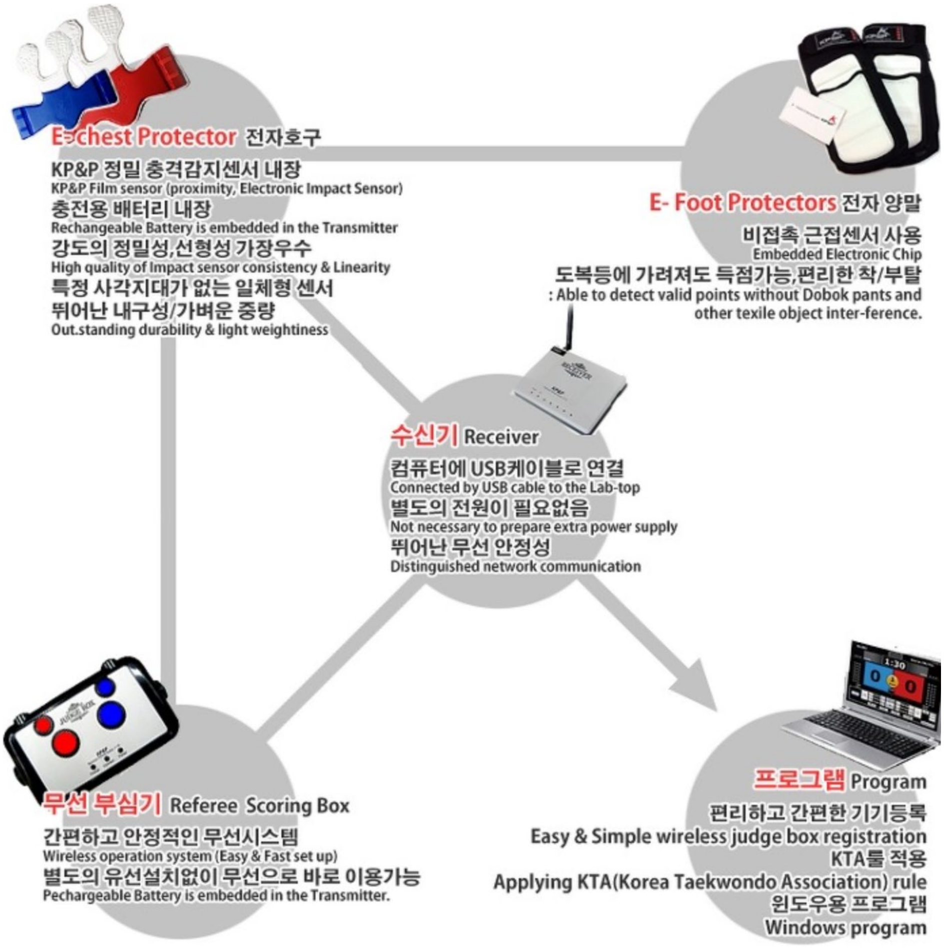

Figure 3. Taekwondo roundhouse kicks performed on electronic chest protector

Subjects kicked at their maximum velocity in 3 sets for 30 seconds each with a 45-second rest period between each set. In order to measure the number of kicks, the impact coefficient was recorded and videoed (KP&P, Korea) and then evaluated on an electronic protector (Figure 3). Kicking fatigue was calculated as the ratio of the lowest kicking reduction rate to the maximum average number of kicks for 5 seconds. The calculation was:

AMax per session
- AMin per session
/ AMax per session
x 100
= Kicking fatigue index (unit: %)

where Amax is the average maximum number of kicks and Amin is the average minimum number of kicks.
Blood lactate concentration was measured before, immediately after the Taekwondo roundhouse kick tests, and after 3, 5, and 10 minutes of rest. Heart rate was measured before, immediately after the Taekwondo roundhouse kick tests, and after 3, 5, and 10 minutes of rest using a polar heart rate monitor (Polar Vantage NV, Finland).

Isokinetic muscle function measurement
To measure isokinetic muscle function, the Biodex isokinetic muscle test (Biodex Systems, USA) was used to measure the isokinetic angular velocity of the knee. Tests were performed 3 times at 60°/sec and 10 times at 180°/sec and at 300°/sec, respectfully. Subjects repeated the tests 25 times to derive the total exercise quantity. The rest interval between sets was 60 seconds.

Grip strength test
A Grip-D Digital Grip Dynameter (CNP-5401, Japan) was used to measure subjects' grip strength. The subjects maintained a standing position. The width was adjusted so that the second joint of the second finger was at a right angle. Measurements for the right and left hands were taken. The higher measurement was measured in units of 0.1 kg.

Back strength test
To measure subject's back strength, they stood on the foothold of Back Muscle Dynamometer (TKK-5402, Japan) with their legs spread approximately 15cm apart. They then tilted their upper body about 30° forward and gripped the handle of the dynamometer. Subjects gradually raised their upper bodies to pull the dynamom-

eter handle upward. Scores were recorded in 0.1 kg. Subjects were allowed two attempts and the best score was recorded for analysis.

30m sprint test
Subjects' speed was measured with the 30m running test. Starting and ending points were placed in a straight line 30m apart. Subjects sprinted from the starting point to the ending point and their time was recorded in sec. Two measurements were made, and the highest score was used for analysis.

50m dash test
Subjects' speeds were further evaluated with 50m sprint test. Starting and ending points were placed in a straight line 50m apart. Subjects sprinted from the starting point to the ending point and their time was recorded in sec. Two measurements were made, and the highest score was used for analysis.

Standing long jump
Power was assessed using the standing long jump test. Subjects stood behind a line marked on the floor with their feet shoulder-distance apart. They swung their arms and propelled themselves forward using both feet equally. Measurements were made from the starting line to the point of nearest contact the subjects' bodies made to it. Two attempts were allowed. Scores were recorded in cm. and the highest score was used for analysis.

Sit and reach test
Subjects bent their upper bodies forward and pushed the measuring bar with their outstretched fingertips as far as possible. The distance of their maximum distance was measured in 0.1cm increments. Two measurements were taken, and the better record was used for analysis.

Sit-up tests
Sit-up tests were performed to gage subjects' physical fitness. Subjects sat on the floor with their feet immobilized about 10 cm apart, knees flexed at 90°, and hands behind their neck so their fingers interlaced. They performed sit-ups for one minute. A successful score was recorded only when subjects' backs lifted off the floor and their elbows touched their knees. Subjects' maximum score was recorded and used for analysis.

Side-step test

Subjects tried a side-step test for measuring speed, agility, and quickness. A test that moves two lines, left and right 120cm based on the center line, quickly to the side step. For 20 seconds, the right line was stepped on the right foot and the left line on the left foot. The number of times that each line was crossed was measured. analysis.

Statistical analysis
The mean and standard deviation of each measurement variable was calculated using SPSS (version 20.0). One-way ANOVA tests were performed for correlation analysis. Difference tests were performed to investigate the significance between the laboratory tests (i.e., Wingate and isokinetic muscle function tests) and field performance tests (i.e., grip strength, back strength, 30m running, 50m running, standing long jump, sit and reach, and sit up tests). Results from the taekwondo roundhouse kicking test and the field performance tests were examined.

In order to devise a Wingate estimation model for anaerobic power, a multiple regression analysis was performed using the results of the field performance and taekwondo roundhouse kicking tests. T-tests were performed on the Wingate and isokinetic muscle function results to verify the model. Then, estimated values of the subjects' anaerobic power were calculated. The significance level was set to $p<.05$.

Results

Wingate test results
The Wingate test results of the athletes by weight class are shown in Table 2. There was a significant difference between the 30-second Wingate test and weight class in the relative average power ($F(2, 17)=4.569$, $p<.026$) and the relative total work ($F(2, 17)=4.578$, $p<.026$). Table 3 shows the results of the post analysis of relative average power and relative total work, which were significantly different from the weight class analysis results. The results of the analysis of the difference in weight class of the 90-second Wingate test also showed a significant difference in the relative average power ($F(2, 17)=8.427$, $p<.003$) and relative total work ($F(2, 17)=8.421$, $p<.003$) (Table 4). The results of the analysis of the relative average power and the relative total weight showed a significant difference from the results of the analysis by weight class and are also shown in Table 4.

Isokinetic muscle function test results
The results of the isokinetic muscle function test (60°/sec, 180°/sec, 300°/sec) for subjects in each weight class are shown in Table 5. The results of the analysis of the difference of mean isokinetic muscle function per body weight showed a significant difference in the power ($F(2, 17)=4.316$, $p<.030$) at 180°/sec knee strength and total work ($F(2, 17)=5.972$, $p<.011$) at 300°/sec arm strength. The results of the mean isokinetic muscle function variance analysis by weight class are shown in Table 6.

Table 2. Wingate test measurement results by weight class

Variables	Wingate test (30 sec)				Wingate test (90 sec)			
	Groups				Groups			
	A (n=7)	B (n=7)	C (n=6)	M±SD	A (n=7)	B (n=7)	C (n=6)	M±SD
PP/kg	10.0± .5	10.5± .6	10.1± .7	10.2± .6	7.9± .8	7.3± .7	7.2± .4	7.5± .7
AP/kg	8.8± .2	8.9± .6	8.2± .3	8.6± .5	15.5± .9	14.7± .5	13.6± 1.0	14.7± 1.1
TW/kg	27.4± .7	27.7± 2.0	25.6± .9	26.9± 1.6	48.3± 2.9	45.9± 1.5	42.6± 3.0	45.8± 3.4
FI	31.1± 9.2	34.4± 8.2	39.6± 8.1	34.8± 8.8	61.3± 11.5	55.7± 8.9	65.2± 7.3	60.5± 9.8
HR	161.1± 8.2	165.4± 12.8	162.0± 11.6	162.9± 10.6	167.1± 7.5	167.7± 11.2	166.5± 10.0	167.2± 9.2
LA	9.0± 1.5	7.9± 1.7	7.9± 1.4	8.3± 1.6	10.2± .9	9.3± 1.8	8.4± 1.8	9.4± 1.6
PP	620.4± 30.5	782.9± 69.3	866.7± 91.0	751.2± 122.0	491.0± 45.2	547.2± 68.6	618.3± 52.7	548.9± 74.9
AP	543.1± 24.7	664.8± 66.5	703.1± 48.3	633.7± 84.3	959.0± 79.0	1102.0± 71.6	1170.6± 101.4	1072.5± 120.0
TW	1694.0± 77.0	2073.6± 207.6	2193.0± 150.8	1976.5± 263.0	2991.4± 246.4	3437.5± 223.3	3651.4± 316.3	3345.5± 374.3

PP: peak power, AP: average power, TW: total work, FI: fatigue index,
HR: heart rate, LA: lactic acid
A: -68 kg group, B: -80 kg group, C: +80 kg group

Table 3. Wingate test (30 sec) variance analysis results by weight class

	SS	df	MS	F	post-hoc
PP/kg	.744	2	.372	1.005	ns
AP/kg	1.719	2	.859	4.569*	C<B, A
TW/kg	16.741	2	8.371	4.578*	C<A, B
FI	239.471	2	119.736	1.634	ns
HR	71.229	2	35.614	.296	ns
LA	5.336	2	2.668	1.125	ns

ns: not significant; *p<.05

Table 4. Wingate test (90 sec) variance analysis results by weight class

	SS	df	MS	F	post-hoc
PP/kg	2.137	2	1.068	2.418	ns
AP/kg	10.932	2	5.466	8.427*	C<B, A
TW/kg	106.339	2	53.170	8.421*	C<B, A
FI	296.520	2	148.260	1.631	ns
HR	4.764	2	2.382	.025	ns
LA	10.758	2	5.379	2.298	ns

*p<.01

Field test by weight class

1. Physical strength

Table 7 shows the results of the field performance tests (i.e., 30m running, 50m running, back muscle strength, grip strength, sit up, forward bending, and standing long jump) performed to determine the applicability of the fitness field tests to the anaerobic power test. Only the grip strength test showed a significant difference by weight class ($F(2, 17)=4.388$, $p<.029$). The results of the physical strength field tests by weight class are shown in Table 8.

2. Kicking performance capability

The maximum heart rate and lactate concentration during exercise were measured to identify the athletes' kicking performance capability by weight class and physiological changes manifested during measurement. The corresponding results of the measurements are shown in Table 9. The results showed a significant difference in one set of kicking ($F(2, 17)=5.694$, $p<.013$) and total number of kicks ($F(2, 17)=4.626$, $p<.025$). Those results and the post analysis results are shown in Table 10.

Table 5. Isokinetic muscle function test results

Variables			Absolute				% BW			
			Groups			M±SD	Groups			M±SD
			A (n=7)	B (n=7)	C (n=6)		A (n=7)	B (n=7)	C (n=6)	
60°/sec	PT (nm)	Ext	199.7	250.9	261.1	236.1	332.9	352.3	311.9	333.4
			±13.8	±29.3	±27.3	±35.9	±36.5	±32.4	±22.0	±34.0
		Flex	108.6	133.1	140.6	126.8	181.2	185.8	172.8	180.3
			±11.0	±27.7	±23.6	±25.0	±14.7	±31.7	±25.8	±24.3
180°/sec	AP (w)	Ext	234.5	298.1	298.6	276.0	380.1	399.2	347.7	377.1
			±16.1	±30.6	±26.8	±39.3	±39.4	±43.4	±17.1	±40.2
		Flex	162.4	217.9	192.2	190.8	262.5	291.1	223.9	260.9
			±21.9	±40.3	±34.1	±39.2	±33.9	±49.9	±37.5	±47.8
300°/sec	TW (j)	Ext	2273.2	2669.9	2743.6	2553.2	3676.9	3566.6	3205.2	3496.8
			±124.2	±253.8	±189.7	±282.9	±239.1	±242.2	±283.8	±313.6
		Flex	1713.3	2324.2	2024.0	2020.3	2767.1	3102.5	2369.2	2765.1
			±420.4	±523.9	±342.5	±492.0	±651.7	±652.6	±448.1	±642.6

A: -68 kg group, B: -80 kg group, C: +80 kg group

BW: Body weight, PT: peak torque, Ext: extension, Flex: flexion

Table 6. Analysis of mean isokinetic muscle function variance analysis results by weight class

Variables			SS	df	MS	F	post-hoc
60°/sec	PT (nm)	Ext	5275.747	2	2637.874	2.681	ns
		Flex	552.286	2	276.143	.440	ns
180°/sec	AP (w)	Ext	8667.999	2	4333.999	3.338	ns
		Flex	14643.642	2	7321.821	4.316*	C<A
300°/sec	TW (j)	Ext	771199.016	2	385599.508	5.972*	C<B, A
		Flex	1737509.344	2	868754.672	2.418	ns

*p<.05

Table 7. Results of the field performance tests

Variables	Groups			M+SD
	A (n=7)	B (n=7)	C (n=6)	
30m (sec)	4.1±0.3	3.9±0.1	4.0±0.1	4.0±0.2
50m (sec)	6.3±0.1	6.1±0.2	6.4±0.2	6.3±0.2
BS (kg/kg)	1.7±0.2	1.7±0.2	1.4±0.2	1.6±0.2
HG (kg/kg)	0.6±.1	0.6±0.1	0.5±0.1	0.6±0.1
SU (num)	5.4±5.1	52.3±4.8	47.3±8.7	51.4±6.6
SR (cm)	22.2±8.9	22.3±5.3	19.8±10.7	21.5±8.1
ST (num)	44.1±4.9	42.0±7.3	43.3±4.4	43.2±5.5
SJ (cm)	243.6±13.4	248.9±11.3	242.5±11.9	245.1±11.9

30m: 30-meter run, 50m: 50-meter run, BS: back strength, HG: hand grip, SU: sit-up, SR: sit-and-reach, ST: side step, SJ: standing long jump

3. Relevance between field tests and laboratory tests following weight class

Correlation between kicking performance and stamina variables

As shown in Table 11, there was a significant negative difference between the kicking performance capability and the field performance tests by weight class. In performing the Taekwondo roundhouse kick for 0-30 seconds, a significant positive correlation for back muscle strength was shown, whereas in conducting the Taekwondo roundhouse kick for 30-60 seconds, a significant negative correlation with the standing long jump was shown.

Table 8. Field performance test results by weight class

	SS	df	MS	F	post-hoc
30m	.136	2	.068	1.305	ns
50m	.206	2	.103	2.761	ns
BS/kg	.241	2	.120	3.009	ns
HG/kg	.052	2	.026	4.388*	C<A, B
SU	152.038	2	76.019	1.932	ns
SR	25.026	2	12.513	.175	ns
ST	16.360	2	8.180	.251	ns
SJ	155.729	2	77.864	.519	ns

*p<.05

30m: 30-meter run, 50m: 50-meter run, BS: back strength, HG: hand grip, SU: sit-up, SR: sit-and-reach, ST: side step, SJ: standing long jump

Table 9. Kicking performance measurement results

Variables		Groups			M+SD
A (n=7)		B (n=7)	C (n=6)		
TK1 (30s)	5s	12.0±0.6	11.4±1.0	10.7±0.8	61.3±3.4
	10s	10.9±0.7	10.6±1.0	10.3±0.5	
	15s	10.4±1.3	10.4±0.5	10.3±0.5	
	20s	10.6±0.8	10.0±1.2	9.7±1.2	
	25s	9.9±1.2	10.0±0.6	8.7±0.5	
	30s	9.6±1.4	9.6±0.8	8.5±1.9	
	Total	63.3±3.0	62.0±2.7	58.2±2.6	
TK2 (60s)	5s	10.6±1.0	10.3±0.5	9.8±0.8	55.8±3.9
	10s	10.7±0.8	10.0±1.0	9.7±0.5	
	15s	10.0±1.2	9.4±0.8	8.5±0.8	
	20s	9.1±0.9	9.4±1.0	9.0±0.6	
	25s	9.7±0.5	9.0±1.0	8.2±1.2	
	30s	8.0±2.2	7.3±1.1	8.2±1.3	
	Total	58.1±3.6	55.4±3.4	53.3±3.5	
TK3 (90s)	5s	10.3±0.5	9.7±0.8	9.5±1.0	54.2±3.5
	10s	10.3±1.0	10.3±1.4	8.7±1.6	
	15s	9.6±0.5	9.1±0.9	9.0±0.6	
	20s	9.0±1.0	8.7±1.0	8.0±0.9	
	25s	8.7±0.8	8.3±0.8	8.5±0.5	
	30s	8.6±1.1	7.7±1.0	8.3±0.8	
	Total	56.4±2.7	53.9±3.5	52.0±3.4	
TK Total (90s)		177.9±8.8	171.3±8.1	163.5±8.5	171.3±10.0
HR (beats/min)		174..7±7.2	178.6±7.2	172.5±8.7	175.4±7.7
LA (mmol)		12.8±2.0	11.8±1.7	11.2±1.1	12.0±1.7

A: -68 kg group, B: -80 kg group, C: +80 kg group

TK1: Taekwondo roundhouse kick for 0-30 sec, TK2: Taekwondo roundhouse kick for 30-60 sec, TK3: Taekwondo kick 60-90 sec, HR: heart rate, LA: lactic acid, mmol: millimoles per liter

Correlation between kicking performance and anaerobic power variable

As shown in Table 12, there was a significant negative correlation between the kicking tests and Wingate test power variables. The 30-second anaerobic power measurement variables showed a significant positive correlation with the 30-second Taekwondo roundhouse kicking test. The 90-second anaerobic power measurement variables showed a significant positive correlation with all kicking performances.

Correlation between kicking performance and isokinetic muscle function variables

Table 13 shows the Taekwondo roundhouse kicking test by weight class and isokinetic muscular function measurement variables were not significant in the 300°/sec extension total work variable. In the 30-second Taekwondo kick test, there was a positive correlation between 180°/sec extension average power and 300°/sec extension total work among the isokinetic muscular function measurement variables only when Taekwondo kicks were performed for 0-30 sec.

Table 10. Kicking performance variance analysis results by weight class

	SS	df	MS	F	Sig.	post-hoc
TK1	89.938	2	44.969	5.694	.013*	C<B, A
TK2	75.845	2	37.923	3.071	.073	ns
TK3	64.629	2	32.314	3.147	.069	ns
TK Total	665.964	2	332.982	4.626	.025*	C<A
HR	124.157	2	62.079	1.057	.369	ns
LA	8.088	2	4.044	1.480	.256	ns

*p<.05

TK1: Taekwondo kick 0-30 sec, TK2: Taekwondo kick 30-60 sec, TK3: Taekwondo kick 60-90 sec, TK Total: Taekwondo kick Total, HR: heart rate, LA: lactic acid

Table 11. Correlations between Taekwondo roundhouse kick performance and field performance test variables

Variables	WD	TK1	TK2	TK3
WD	1	-.607**	-.514*	-.517*
30-meter run	-.194	-.322	-.313	-.308
50-meter run	.130	-.068	-.027	-.033
Back strength/kg	-.452*	.475*	.061	.089
Hand grip/kg	-.420	.356	.211	.069
Sit-up	-.413	.011	-.087	-.225
Sit-and-reach	-.120	.130	.247	.195
Side step	-.068	-.156	-.194	-.213
Standing long jump	-.026	-.103	-.473*	-.442

WD: weight division, TK1: Taekwondo kick 0-30 sec, TK2: Taekwondo kick 30-60 sec, TK3: Taekwondo kick 60-90 sec
*p<.05, **p<.01

Table 12. Correlations between kicking performance and Wingate test power variables

Filed test / Wingate test	WD	TK1	TK2	TK3
AP30S	-.453*	.514*	.184	.084
TW30S	-.454*	.515*	.185	.086
AP90S	-.702**	.711**	.481*	.471*
TW90S	-.701**	.711**	.481*	.471*

WD: weight division, TK1: Taekwondo kick 0-30 sec, TK2: Taekwondo kick 30-60 sec, TK3: Taekwondo kick 60-90 sec, AP30S: Wingate test 30 second average power, TW30S: Wingate test 30 second total work, AP90S: Wingate test 90 second average power, TW90S: Wingate test 90 second total work
*p<.05, **p<.01

Table 13. Correlations between kicking performance and isokinetic muscle function variables

Field test / Isokinetic test	WD	TK1	TK2	TK3
E60° PT	-.235	.400	.051	.128
F60° PT	-.133	.213	-.202	-.172
E180° AP	-.313	.469*	.219	.158
F180° AP	-.311	.366	-.018	-.069
E300° TW	-.612**	.529*	.327	.257
F300° TW	-.237	.320	.118	.000

WD: weight division, TK1: Taekwondo kick 0-30 sec, TK2: Taekwondo kick 30-60 sec, TK3: Taekwondo kick 60-90 sec, E60° PT: 60°/sec extension peak torque, F60° PT: 60°/sec flexion peak torque, E180° AP: 180°/sec extension average power, F180° AP: 180°/sec flexion average power, E300° TW: 300°/sec extension total work, F300° TW: 300°/sec flexion total work
*p<.05, **p<.01

Correlation between field performance and isokinetic muscle function tests

As shown in Table 14, the results of the correlations between the field performance tests and isokinetic muscle function variables showed back muscle strength had a significant positive correlation with 60°/sec extension peak torque (E60° PT), 60°/sec flexion peak torque (F60° PT), 180°/sec extension average power (E180° AP), 180°/sec flexion average power (F180° AP), E180°/F180° AP, and 300°/sec extension total work (E300° TW). As for grip strength, a significant positive significance was shown in E180°/ F180° AP and E300° TW.

Table 14. Correlations between field performance tests and isokinetic muscle function variables

Field test / Isokinetic test	30m	50m	BS/kg	HG/kg	SU	SR	ST	SJ
E60° PT	-.282	-.048	.681**	.427	.249	-.038	-.062	.436
F60° PT	.056	.370	.467*	.101	.186	-.262	.177	.244
E180° AP	-.166	-.046	.644**	.641**	.373	-.024	-.182	.323
F180° AP	-.151	-.003	.508*	.445*	.388	.068	.141	.218
E300° TW	-.151	-.349	.640**	.673**	.406	-.223	.090	.235
F300° TW	-.165	-.275	.294	.440	.250	-.113	.145	.064

E60° PT: 60°/sec extension peak torque, F60° PT: 60°/sec flexion peak torque, E180° AP: 180°/sec extension average power, F180° AP: 180°/sec flexion average power, E300° TW: 300°/sec extension total work, F300° TW: 300°/sec flexion total work, SU: sit-up, SR: sit-and-reach, ST: side step, SJ: standing long jump
*p<.05, **p<.01

Table 15. Correlations between Wingate anaerobic power variables and isokinetic muscle function variables

Field test / Wingate test	30m	50m	BS/kg	HG/kg	SU	SR	ST	SJ
AP30S	-.114	-.341	.483*	.509*	.126	.145	.122	.483*
TW30S	-.115	-.341	.483*	.508*	.123	.144	.121	.480*
AP90S	-.167	-.158	.501*	.427	.239	.038	.045	-.001
TW90S	-.168	-.158	.502*	.427	.239	.037	.045	-.001

AP30S: Wingate test 30 second average power, TW30S: Wingate test 30 second total work, AP90S: Wingate test 90 second average power, TW90S: Wingate test 90 second total work, SU: sit-up, SR: sit-and-reach, ST: side step, SJ: standing long jump
**p<.05*

Table 16. Correlations between Wingate anaerobic power variables and isokinetic muscle function variables

Wingate test / Isokinetic test	AP30S	TW30S	AP90S	TW90S
E60° PT	.219	.218	.298	.298
F60° PT	.302	.303	.088	.089
E180° AP	.332	.331	.375	.375
F180° AP	.567*	.567*	.341	.341
E300° TW	.629*	.628*	.778*	.779*
F300° TW	.669*	.669*	.421	.421

AP30S: Wingate test 30 second average power, TW30S: Wingate test 30 second total work, AP90S: Wingate test 90 second average power, TW90S: Wingate test 90 second total work, E60° PT: 60°/sec extension peak torque, F60° PT: 60°/sec flexion peak torque, E180° AP: 180°/sec extension average power, F180° AP: 180°/sec flexion average power, E300° TW: 300°/sec extension total work, F300° TW: 300°/sec flexion total work
**p<.01*

Correlation between field performance test variables and Wingate test power variables

As shown in Table 15, the results of the correlations between the field performance tests and the isokinetic muscular function measurement variables showed the back muscle strength test had a significant positive correlation with the anaerobic power variables for the 30- and 90-second Wingate tests. However, the grip strength and standing long jump tests showed a positive correlation only in the 30-second anaerobic power test.

Correlation between Wingate test power variable and isokinetic muscle function variables

Table 16 shows the results between the Wingate test power measurement variables and the isokinetic muscle function measurement variables. The 30-second anaerobic power measurement variables were significant to the F180° AP, E300° TW, and F300° TW isokinetic muscle function measurement variables. Additionally, there was a positive significant difference between the 90–second anaerobic power measurement and the F300° TW isokinetic muscle function measurement variables.

Multiple regression analytical results for anaerobic power prediction

An analysis of the field performance tests and the kicking field tests (90 second kicking with 5-second intervals) was conducted to design an anaerobic power model using the Wingate gate as the reference value with multiple regression for Taekwondo roundhouse kicks. The variance analysis and estimated regression coefficients are shown in Tables 17 and 18.

The variables manifested in the anaerobic power regression model from the field performance and kicking field tests measurement variables are shown in Table 19. The following constants used were: 0-5 seconds

Table 17. Variance analysis of regression model for anaerobic power estimation by field test variables

	SS	df	MS	F
Regression	3.785	4	.946	12.555*
Residual	1.131	15	.075	

*p<.05

Table 18. Anaerobic power estimation regression coefficient by field test variables

Variables	Unstandardized Coefficients		Standardized Coefficients	r	*t*
	b	S.E	*β*		
Constant	5.537	2.540			2.180*
X_1	.337	.071	.622	.652	4.756***
X_2	-1.042	.311	-.431	-.341	-3.351**
X_3	.235	.080	.379	.167	2.930**
X_4	.014	.006	.320	.483	2.401*
F=12555***, R^2=770					

X_1: 0-5 sec Taekwondo kick 1 (num), X_2: 50 m speed running (sec), X_3: 10-15 sec Taekwondo kick 1 (num), X_4: standing long jump (cm)

*p<.05, **p<.01, ***p<.001

Table 19. Multiple regression for estimating anaerobic power from field test measurement variables

	Variables	R^2	SE	P
X_1	0-5s TK1 (num)	77.0	.27	.030
X_2	50m Speed running(sec)			
X_3	10-15s TK1 (num)			
X_4	Standing long jump (cm)			

X_1: 0-5 sec Taekwondo kick 1 (num), X_2: 50 m speed running (sec),
X_3: 10-15 sec Taekwondo kick 1 (num), X_4: standing long jump (cm)
Multiple regression for estimation: $Y = 5.537 + 0.337X_1 - 1.042X_2 + 0.235X_3 + 0.014X_4$

Table 20. Difference between the measured values of Wingate and estimated model values determined by field performance test measurement variables

	WAP	EAP	Difference
Means±SD	8.64±0.51	8.73±0.45	-0.10±0.57

WAP: Wingate average power, EAP: estimated average power

Taekwondo kick 1 (num) (X_1), 50m speed (X_2), 10-15 seconds Taekwondo kick 1 (num) (X_3), and standing long jump (cm) (X_4). The anaerobic power estimation model designed by the estimated variables X1-X4 is shown in Table 19. The estimated model designed showed an explanatory power of 77% (R=87.8, R2=.770, SE=.27, p<.05) for anaerobic power.

The difference between the measured values of Wingate evaluation for anaerobic power and the estimated model values designed by the field performance and kicking tests was –0.10±0.57 watts, as shown in Table 20.

Validation of anaerobic power estimation model results

Based on the reference (actual) values for anaerobic power, an anaerobic power estimation model was designed using a multiple regression analysis that incorporated field performance and kicking field test variables. As a result of comparing the measured values for the anaerobic power with the estimated values, the residuals were –0.10±0.57 watts (r=.878), and there was no difference between the measured values and the estimated values. Therefore, the validity of the anaerobic power estimation model designed using the field performance and kicking field test measurement variables of an experimental group (n=20 people) was classified by computer randomization (experimental group: T-1, T-2, T-6, T-9, T-13, T-15, T-17, T-18, T-19, T-20). In order to verify the model's validity, the difference between the estimated values (X_1, X_2, X_3, and X_4) calculated by the field performance and the kicking field test measurement variables of the test group (n=10) for the validity test were compared and validated. The results of the anaerobic power estimation model validation are as follows.

In order to verify the anaerobic power estimation model, the difference between the measured and calculated values of the test group's (n=10) anaerobic power were calculated by Wingate test (Figure 4). The results were .10±0.25 watts and are shown in Table 21 and Fig-

Table 21. Difference between Wingate analytical value for anaerobic power and estimated value by estimation model

	WAP	EAP	Diff.
1	8.81	9.28	-0.47
2	8.91	9.05	-0.14
3	9.50	9.43	0.07
4	9.89	9.68	0.21
5	8.03	8.46	-0.43
6	9.05	8.99	0.06
7	8.67	8.78	-0.11
8	8.86	8.90	-0.04
9	8.76	9.13	-0.37
10	8.87	8.66	0.21
Mean±SD	8.94±0.49	9.04±0.36	-0.10±0.25

WAP: Wingate average power, EAP: estimated average power

Table 22. T-test between actually measured values of anaerobic power by Wingate and estimated values by estimation model

	N	Mean	SD	t	p
WAP	10	8.94	.49	.515	.613
EAP	10	9.04	.37		

WAP: Wingate average power, EAP: estimated average power

ure 3. As shown in Table 22, there was no statistically significant difference in the t-test results between the measured values of the test group and the estimated value (p>.05).

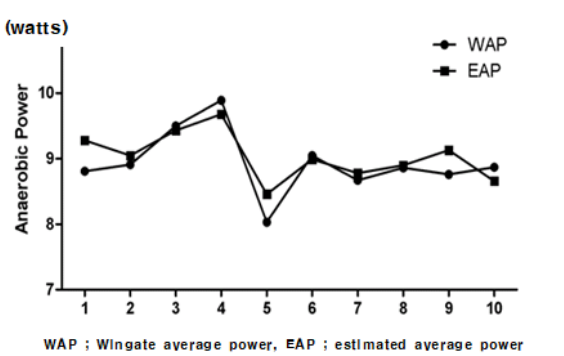

Figure 4. Comparison of measured Wingate test values with estimated value by estimation model

Discussion

Taekwondo players' anaerobic power by weight class

The isokinetic strength measurement of the lower limbs is considered one of the most objective and accurate evaluation methods [Cools *et al.* 2007]. Knee joint strength is critical to all lower limb movement; thus, when assessing lower limb muscle strength, evaluating the isokinetic muscle strength of the knee is important [Koh, Lee, Kong 2007]. In Taekwondo sparring competitors have been reported to possess superb lower limb muscle strength and movement because most points in the competition are awarded to kicks rather than punches [Kim, Lee 2010]. As a result of analyzing the difference in agility and muscle function between groups according to the kicking performance level, J.H. Jung [2011] reported no significant difference between peak torque and average power at 60˚/sec, 120˚/sec, 180˚/sec and 300˚/sec, but the group in his study with the highest kicking performance capability had significantly higher peak torque and average power during hip joint extension than other groups. In that study, there was no significant difference absolute isokinetic power, average power, and total exercise quantity between weight divisions, but the average power of the flexor of 180˚/sec (p<.05) and total exercise quantity of extensor of 300˚/sec in the -68kg weight division was significantly higher than other weight divisions (p<.05).

Such results suggest that it is reasonable to perform a comparative analysis with relative values divided by subjects' weight rather than the absolute value for a reasonable isokinetic muscle function evaluation. Kim, Eum, and Kim [2009] measured the isokinetic muscular function at 60˚/sec, 180˚/sec, and 300˚/sec between elite Taekwondo athletes and non- elite Taekwondo athletes. The results showed partial matches of right flexion in 180˚/sec. K.S. Kim [2004] analyzed factors such as body composition and basic field performance that correspond to physiological characteristics of Taekwondo athletes according to weight division. In that study, there was a significantly higher discrimination between body condition and composition between weight divisions. But the weight division of Taekwondo athletes by basic physical strength was low. Among the physical strength factors measured in the field in Kim's 2004 study, there was no significant difference in the physical strength factors excluding grip strength per body weight.

The present study shows a relative physical strength comparison by weight division is more appropriate than absolute results of the physical strength tests when determining anaerobic power. As a result of measuring the kicking performance capability in the study's field test, 1) kicking performance decreased as the kicking set progressed in time in all weight divisions, 2) the difference in weight divisions by kicking interval was classified as high in the sequence of -68kg, -80kg, +80kg divisions, yet 3) the -68kg division group proved significantly higher than the –80kg and +80kg groups (p<.05) in kicking performance. These results indicate the lower the weight division has a higher capability to perform kicks at peak speed.

J.J. Jung [2005] reported that when performing Taekwondo roundhouse kicks for 30, 60, and 90 seconds, there was a steep decline in the number of kicks after the 60 and 90 seconds, which was followed by a gradual decrease in amount of kicks. He concluded accordingly that performing Taekwondo roundhouse kicks at peak speed for 30 seconds would be a proper method to evaluate Taekwondo anaerobic power. In present study, the lightweight (-68kg) group's weight division was higher in the 30-second Taekwondo roundhouse kick test. While no significant difference was found between groups' lactate acid tests, the -68kg weight division had the highest 11.8±2.0mmol (Table 9). This indicates that rapid kicking is the product of high highest anaerobic exercise capability.

Field test and laboratory test relevance

In Taekwondo sparring competition, the explosive muscular strength and anaerobic exercising capability to attack and defend against a moving opponent is an important physical strength factor. Two methods can be used to measure the expression of this type of anaerobic power: the Wingate test to confirm the quantified value, and the isokinetic power test to measure the maximum acceleration energy. Moreover, previous studies have shown a high correlation between the two tests [Bulbulan, Wilcox, Darabos 1986; Gollnick, Armstrong, Sembrowich 1973].

Field tests have been conducted to take into account the actual exercise performance process [Kim J.H. *et al.* 2010; Kim K.J. 1997; Kim, Kwon 2005; Kim D.Y. *et al.* 2006; Jung, Shim 2000]. However, athletes and coaches have been skeptical in terms of their utilization in the field, because the Wingate test and isokinetic muscle function measurement methods used in the laboratory evaluated anaerobic exercise capability as a mechanical workload value by rotational motion and flexion/extension exercise ability of the lower limbs.

For this study, we analyzed the correlation between short–term, continuous kicking at peak speed while taking into consideration the characteristics of Taekwondo sparring competition as well as their anaerobic power and isokinetic muscular functions. There was a significant inverse correlation (p<.05) between the weight divisions and kicking performances as well an inverse correlation between all basic field performance test variables. In particular, back muscle strength per body weight showed a significant difference between weight divisions (p<.05). These results show that the lower the weight divisions have a higher kicking performance capability and better physical strength. This study also showed that Wingate anaerobic power and isokinetic muscle function were higher in the lightweight division, and that group also has a high inverse correlation with the kicking performance because it has a more outstanding anaerobic exercise capability than the higher weight classes. In relation to the kicking performance capability, back muscle strength was shown to have a significant correlation (p<.05) with the 0- to 30–second Taekwondo roundhouse kick test, and the standing long jump showed a significant inverse correlation (p<.05) with the 30- to 60-second kicking test.

The lumbar region, which includes the waist and abdominal region of the body's center, plays an important role in the performance of physical activities and sports [Cho Y.H. 2006]. In the case of Taekwondo, kicking frequency is high [Kim H.C. *et al.* 2007], and the Taekwondo roundhouse kick involves the trunk muscles such as rectus abdominis, abdomen, and backbone erector [Jung 2011].

In the current study, the high correlation of back muscle strength in the 0- to 30–second Taekwondo roundhouse kick test required stability of the trunk through movement of the spine and extension power of the lumbar. Our subjects' standing long jump tests revealed an inverse correlation with their kicking performances, because the muscles of their lower limbs were used in both tests but the muscles mobilized in the lower limbs were different. The inverse correlation can also be explained by the fact that the standing long jump is a whole body movement rather than an anaerobic energy system used for 30 seconds of kicking. As a result of identifying the correlation between the kicking performance capability and Wingate anaerobic power variables, there was a significantly inverse correlation (p<.05, p<.01) between weight division and average power, and total exercise quantity during the Wingate test. Furthermore, the average power and total exercise quantity gained during the Wingate test showed a positive correlation with the kicking performance capability for 30 seconds in the 0- to 30–second Taekwondo roundhouse kick test. However, the average power and total exercise quantity for the 90-seconds Wingate test showed a significant correlation (p<.05, p<.01) with the kicking of all Taekwondo kicking test.

These results indicate the lower the weight of the kicker, the higher their average power and total momentum on the Wingate test will be (30 sec: 0.075 kpm, 90 sec 0.05 kpm). It also suggests that the Wingate test method may produce different results than the kick performance test. That is, in general, the Wingate anaerobic test is used to evaluate the maximum muscle strength, muscle endurance, and muscle fatigue that can be demonstrated in a short period of time [Cho H.C., Kim J.K. 2004]. In the Wingate anaerobic power test, the energy metabolism system is transferred from anaerobic metabolism to aerobic metabolism when performed for more than 30 seconds, as argued by Carey and Richardson [2003] and Vandewalle, Peres, and Monod [1987]. Thus, it is necessary to consider the test time, especially for elite athletes. In current study, the 30-second kicking performance capability, 30-second Wingate average power, and total exercise quantity were shown to correlate with each other, so the 30-second kicking test may be applied in the field test as an evaluation index for anaerobic evaluation. Gastin and Lawson [1994] also reported that anaerobic power tests have contribute to anaerobic metabolism highly for up to 60 seconds; however, conducting these tests for more than 60 seconds uses a high level aerobic metabolism.

During Taekwondo matches, spontaneous kicking accompanied by short-term explosion of power is crucial, but the anaerobic endurance capability that enables continued and powerful kicking is also a crucial factor. Therefore, as shown in this study, we considered the ability to perform the Taekwondo roundhouse kick at peak speed for 30 seconds to be an objective evaluation of anaerobic exercise ability in the field. As a result of examining the relationship between kicking performance and isokinetic muscle function, the lower weight division (-68kg) had a higher average power and total exercise quantity and, as in the case of the Wingate test (0.075kpm), there was a significant ($p<.05$) correlation between the 30-second kicking performance in the 0- to 30–second Taekwondo roundhouse kick test, average power of the extensor muscle at 180˚/sec, and the total exercise quantity exerted at 300˚/sec. Such results suggest that the higher maximum kicking performance for 30 seconds, the higher the average power and the total exercise quantity of the isokinetic extensor muscle will be.

Anaerobic power prediction using field test

Anaerobic metabolism capability is related closely to any exercise that performs high intensity muscle contractions for a short period [Kim D.Y. *et al*. 2007]. Baker and Davies [2002] as well as Cho, Kim, and Kim [2007], used the Wingate test to measure peak power and average power, and developed equations for peak power and average power prediction using field tests, muscle mass, fat mass, and total weight without fat mass. In Kim E.Y. *et al.*'s [2010] mean power prediction equation, however, weight and vertical jump were the main variables and explanatory power was determined by multiple regression analysis (79.9%), while the mean power predictive equation was the main variable determined by multiple regression analysis (66.4%). In order to create the Wingate power estimation model in this study, Taekwondo athletes performed basic field performance tests and 3 sets of 30-second kicking, or a total of 90 seconds of kicking output, according to the weight divisions. Multiple regression analysis showed that the most influential factors on Wingate average power were 0-5 second kicking, 50m running, 10-15 second kicking, and vertical jump with 77.0% of explanatory power.

In this study, the Wingate average power prediction equation showed a high explanatory power at the beginning of 0-5 second kicking and at 50m running, which indicates the maximal capability of the muscle by the ATP-PC system within 5 seconds [Serresse *et al.* 1988], and accordingly, it seemed to be more affected by Wingate anaerobic power. Oh, Park, and Jung *et al.* [2006] showed 30m and 50m running produced higher explanatory power than Wingate maximum power tests when short running distances of 30m, 50m, 100m, and 200m were correlated with the Wingate test. It is likely that nervousness and technical factors were more influential than the mere mobilization of muscle in these short distance dashes, however.

Furthermore, exercises such as running utilize the whole body for mobilization of the lower limbs, whereas the cycle ergometer exercise is a type of movement in which only the muscles of the lower limbs (i.e., the flexor and extensor muscles of the hip joint and the dorsal and flexor muscles of the ankle) are mobilized [Brown, Whitehurst, Buchalter 1993]. The ability to maintain maximum speed as well as the ability to reach maximum speed in a short time, such as when performing a fast continuous kicking and running 30m and 50m, are therefore crucial. In the current study, a t-test was conducted to determine the mean difference between the calculated and the actual measured values through the multiple regression analysis using anaerobic power and basic physical strength and kicking performance in the field as the reference values. As a result, there was no statistically significant difference, so it is reasonable to claim that Taekwondo athletes can use this estimation model to predict anaerobic exercise capability in the field.

Conclusion

The current study analyzed the correlation among different variables in field and laboratory tests for the purpose of establishing a base to measure anaerobic power in Taekwondo sparring matches. The research subjects were selected among elite athletes from a Korean university who have five years or more experience as elite athletes. Anaerobic power was measured in the laboratory by using the Wingate test, and the isokinetic muscular function was measured by using Biodex. Field tests were also performed: physical strength was measured by having subjects execute 3 sets of Taekwondo roundhouse kicks at maximum speed for 30 sec. each set. To determine if a difference in anaerobic power between different weight Taekwondo classes exists, an ANOVA test was performed on isokinetic muscular function and physical strength, and a correlation analysis was performed to determine correlation among variables. To build a model to estimate anaerobic motor ability in the field, Wingate anaerobic power variables were inserted as dependent variables, while physical strength and kicking performance were used as independent variables to perform a stepwise multiple regression.

In terms of Wingate anaerobic power by weight division, the average power and total activity was significantly higher ($p<.05$) in the +80kg weight class than in the -80kg and +68kg class groups. The average power of isokinetic muscular function of 180˚/sec flexor muscle and total activity of 300˚/sec flexor muscle was significantly higher in the +80kg weight class. The 30-second kick and 3 set kicking performances were significantly higher in the +80kg weight class. The correlation between kicking performance and Wingate anaerobic power according to weight class was negative, and there was a significant positive correlation ($p<.05$) between a 30-second kicking performance and Wingate anaerobic power variables. In terms of the correlation between weight class and isokinetic muscular function, the total activity performed at 300˚/sec was significantly higher ($p<.05$) in the lower weight classes, and there was positive correlation among the 30-second kick performance with the average power performed at 180˚/sec and total activity performed at 300˚/sec.

Based on the anaerobic power calculated by the Wingate test, the 5-second kick, 50m run, 10-to-15-second kicking performance, and standing long jump were used as field test items to estimate anaerobic power. The designed estimation model was $Y= 5.537 +0.337X1 - 1.042X2 + 0.235X3 +0.014X4$ $R^2 = .770$ to explain 77% of the anaerobic power. In conclusion, the 30-second kick was correlated to Wingate power and isokinetic muscular function, and the field test items were correlated to estimate subjects' anaerobic power. More specifically, the 5-second kick, 50m run, 10-to-15-second kick, and standing long jump had a significant effect on Wingate anaerobic power. Therefore, our proposed model for estimating anaerobic power in Taekwondo sparring athletes can be useful in the field.

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Model szacunkowy dla wydolności beztlenowej zawodników Taekwondo na podstawie testów terenowych

Słowa kluczowe: ocena za pomocą pomiaru, badania terenowe, test Wingate'a, izokinetyczny test mięśni

Abstrakt

Tło. Siła beztlenowa mierzona w Taekwondo w trakcie krótkotrwałego szybkiego kopnięcia, oraz siły i wytrzymałości mięśni potrzebnych do popchnięcia przeciwnika, musi być niezwykle duża. We wcześniejszych badaniach opracowano beztlenowe testy wydajności, ale są one niewygodne i nieco niedostosowane dla zawodników Taekwondo.

Problem i cel. Aby zaprojektować model szacunkowy do mierzenia zmiennych w badaniach terenowych kopnięcia okrężnego w Taekwondo, zastosowano test siły beztlenowej Wingate'a do zmierzenia prędkości kopnięć 20 najlepszych zawodników

Taekwondo w testach laboratoryjnych i terenowych w okresie trzech tygodni.
Metody. Aby oszacować beztlenową wydajność zastosowane zostały testy laboratoryjne obejmujące 30- i 90-sekundowe testy Wingate, a testy terenowe uwzględniały standardowe testy sprawnościowe i wykonanie w rundzie Taekwondo jednego zestawu kopnięć z maksymalną prędkością w ciągu trzech kolejnych dni, przez odpowiednio 30, 60 i 90 sekund. Zmienne zostały poddane analizie średniej statystycznej, korelacji i analizy regresji wielokrotnej według klasy wagowej badanych. Test Wingate'a posłużył do oszacowania wydajności beztlenowej.
Wyniki. Siła beztlenowa mierzona testem Wingate'a znacząco wpłynęła na wydajność kopnięć w Taekwondo przez 0-5 sekund i 10-15 sekund, wyniki biegu na 50 metrów i testy w skoku w dal z miejsca.
Wnioski. Wyniki niniejszego badania sugerują, że wykorzystanie 30 sekund ciągu kopnięć przy maksymalnej prędkości, biegu na 50 m i skoku w dal z miejsca są dozwolonymi komponentami testów terenowych dla modelu szacunkowego potrzebnego do określania wydajności beztlenowej zawodników Taekwondo.