Original Article

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Comparison of Isokinetic Muscle Function and Anaerobic Exercise Capacity in the Knee According to Kukki Taekwondo Training Type

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Abstract

Introduction: This study's purpose was to measure and compare isokinetic muscle function and anaerobic exercise capacity of knee joints according to the three Kukki Taekwondo competition types. *Methods:* A total of 21 elite Korean male poomsae (forms), gyorugi (sparring), and demonstration athletes majoring in Taekwondo were selected as the subjects of the study. Subjects' physical fitness levels were measured using standardized strength, endurance, agility, balance, and flexibility tests. In particular, the isokinetic muscle function measurement system was used to measure the muscle function of subjects' knee joints, and the Wingate test was used to measure their anaerobic exercise ability. *Results*: Gyorugi athletes showed better results than their poomsae and demonstration counterparts in nearly all metrics, including body composition, physical fitness factors, isokinetic muscle function (60°/sec), muscle power (180°/sec), and anaerobic exercise capacity. Gyorugi athletes were also taller and showed higher muscle mass, strength, muscular endurance, and agility. However, poomsae athletes showed a higher level of flexibility. The results found isokinetic muscle function and anaerobic exercise capacity of the knee joint to be most important for gyorugi athletes and then for demonstration and poomsae athletes, in that order. *Conclusions*: This study provides useful information needed to identify the physical fitness factors of the different Kukki Taekwondo athletes, and, in turn, it is may serve as important fundamental data for developing future systematic Taekwondo training programs.

Keywords: poomsae (forms), gyorugi (sparring), Taekwondo demonstration, anaerobic capacity, Wingate test

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INTRODUCTION

Kukki Taekwondo was adopted as a demonstration sport at the 1988 Seoul Olympics, which laid the foundation for the combat sport's globalization [1], but it was not designated as an official sport until the 2000 Sydney Olympics. Today, it has developed into a world-class combat sport with more than 10 million practitioners and athletes in 210 countries who have adopted it as a tool for health and personality education [2,3]. Taekwondo competition today is divided into three types. Gyorugi (sparring) is now an official Olympic event and has played a significant role in the globalization of competitive Taekwondo. However, poomsae (forms) and Taekwondo demonstration competitions are growing in global popularity.

Poomsae are sets of prearranged offensive and defensive movements that simulate interactions with imaginary opponents [4]. They also "contain the fundamental techniques teachings of the martial art and combat sport of Taekwondo" [5] and are used to determine a practitioner's skill level. The Korea Taekwondo Association (KTA) started the Taekwondo Hanmadang Competition in 1992, but this Taekwondo poomsae and choreographed demonstration tournament was transferred to Kukkiwon (the educational headquarters for Kukki Taekwondo) in 2000. In 2003, the Kukkiwon changed the name of the event to the "World Taekwondo Hanmadang." Since 2006, World Taekwondo (WT, formerly the World Taekwondo Federation [WTF]) has also organized the World Taekwondo Poomsae Championships to promote that traditional martial arts skill. After poomsae competition began growing in popularity, it became an official event in the 2018 Jakarta Asian Games, indicating that with each passing year poomsae tournaments are quickly become an important aspect of international Taekwondo competition.

Taekwondo poomsae competition is characterized by athletes' being able to perform traditional martial arts exercises with "[a]ccuracy in basic movement" and "in individual movement of the Poomsae," "[b]alance," "[s]peed and power," "[r]hythm and tempo," and "[e]xpression of energy" [6]. Athletes compete either alone or in pairs in a synchronized poomsae demonstration in which no contact with an opponent is made. This type of competition shows Taekwondo skills and artistry that are not permitted in gyorugi competition. Similarly, Taekwondo demonstration athletes compete in choreographed, highly creative, and often acrobatic choreographed routines that include poomsae, board breaking, self-defense skills, and other aspects of traditional Taekwondo training not seen in other competitions.

Taekwondo is a full-body sport, but the muscle function of the lower extremities is very important due to the numerous kicking techniques utilized in competition [7-9]. Poomsae and demonstration competitions clearly possess unique characteristics. Previous studies in Korean have reported on the importance of isokinetic muscle function of the knee joint [10] and anaerobic exercise ability [11-12] in Taekwondo athletes and competitors. Gyorugi matches are three, two-minute rounds of high speed fighting characterized by fast stepping and strong, high kicking combinations. In poomsae competitions, athletes perform only two poomsae that are approximately one minute each and are more rhythmic; as such, they are more akin to dance competitions than to a combat sport. Demonstration competitions like the Kukkiwon's Hanmadang require teams to perform for several minutes during which competitors break boards and perform various other Taekwondo, gymnastic, and acrobatic skills.

Previous studies have examined maximal velocity of the kinematics and kinetics in Taekwondo kicks [13-14] as well as other physical characteristics of Taekwondo kicks [15-18]. The primary finding from these biomechanical researches that correlates to the present study is that power is influenced by the type of target or the absence of a target when performing Taekwondo kicks [19]. In Kukki Taekwondo competition, gyorugi players strike opponents with their hands and feet while in demonstration competitions players strike through boards, concrete bricks, and other targets. Taekwondo athletes thus create a different type of power when kicking or punching a moving opponent just hard enough to score a point versus striking through solid stationary targets. Poomsae athletes on the other hand do not strike any targets, indicating a third type of power is created in that competition type.

However, there are two areas of concern with correlating previous Taekwondo biomechanical studies to the current one. First, there are two styles of Taekwondo studied that are distinctly practiced within these studies [20-21]: the International Taekwon-Do Federation (ITF) and Kukki (Korean: "national") Taekwondo practitioners. Over time, Kukki Taekwondo practitioners have begun executing many, if not most, of their techniques differently from their ITF Taekwondo forbearers [21]. No studies were found to have distinguished between the isokinetic muscle function and anaerobic exercise capacity in Taekwondo athletes between these two styles. Therefore, it would be erroneous to compare previous studies on Taekwondo isokinetic muscle function and anaerobic exercise capacity to the present one due to this lack of distinction. As all subjects in this research practiced only Kukki Taekwondo, the findings and conclusions herein only pertain to that Taekwondo style, whereas many previous international studies focused on ITF Taekwondo [13,14,19]. Consequently, no correlation can be stated definitively to exist between many of the previous studies on Taekwondo kicking styles and the present study on isokinetic muscle function and anaerobic exercise capacity according to Kukki Taekwondo training type (i.e., gyorugi, poomsae, and demonstration). The present study is thus unique, especially in the English-language literature, within the general field of study on Kukki Taekwondo biomechanics. It may also be pertinent to note that international ITF competitions include tul (ITF's preferred word for poomsae), matsogi (the ITF's word for sparring), self-defense demonstrations, and breaking all in one event. ITF athletes are expected to be able to compete in all competition types and rarely train for just one competition type.

While each Kukki Taekwondo competition type requires the muscle function of lower extremities and explosive power in a relatively short time, there may be differences in physical fitness factors required for each. To date, no detailed analysis has been performed to confirm this hypothesis. There are four elements of physical fitness: aerobic fitness, muscular fitness, flexibility, and balance. Subjects' overall fitness was measured using several standardized fitness tests as advised by the Korean Institute for Sports Science. In particular, isokinetic muscle function tests were performed, since they are known to be objective and reliable tools to measure and evaluate muscle function [22]. Likewise, the Wingate test was used to measure and evaluate subjects' anaerobic motor capacity [23]. Therefore, this study aims to provide basic data needed to create optimal training programs for Taekwondo gyorugi, poomsae, and demonstration athletes by comparing and analyzing differences in their isokinetic muscle function and anaerobic exercise ability.

Note on Korean Terminology

All Korean terms are presented in the Romanized spellings preferred by their respective Taekwondo organizations. The Korean word □□□ (McCune-Reischauer Romanization: T'aegwŏndo) itself has numerous Romanized spellings, but Taekwondo was used herein for the sake of simplicity except in proper organizational names.

MATERIALS AND METHODS

Subjects and testing procedure

Subjects of this study were 21 elite male university Taekwondo gyorugi (n=7), poomsae (n=7), and demonstration (n=7) athletes. As above, practice of ITF and Kukki Taekwondo is distinct. Subjects were volunteers, and the researchers informed the subjects of the purposes and contents of the study. Subjects were informed of their right to leave the study at any time. Table 1 includes the subjects' physical characteristics. To avoid bias due to the somatic differences between this study's subjects, Table 1 also contains subjects' Taekwondo career and rank data. In Taekwondo, a practitioner's dan level provides some insight into their ability and years of training. This study's subjects all practiced Kukki Taekwondo and were evaluated by the Kukkiwon in Seoul, the educational and testing headquarters of that style of Taekwondo [24]. In Kukki Taekwondo, it takes approximately one year to earn a 1st dan (Korean: grade of black belt). Practitioners are typically eligible to promote to 2nd dan after another year of practice. They then can promote to 3rd dan after two more years of practice, to 4th dan with three years of practice after that, and so on. Therefore, a Kukki Taekwondo 3rd dan can expect to have between 2-4 years of Taekwondo practice and a 4th dan between 4-7 years of Taekwondo practice. This study's subjects had sufficient Taekwondo training period (gyorugi: 10.00±2.56 yrs., poomsae: 6.14±3.04 yrs., demonstration: 5.57±1.05 yrs.) and expertise (gyorugi: 4th dan, poomsae:

3.86±0.64 dan, demonstration: 3.86±0.35 dan) to exemplify the physical characteristics required for each training type (Table 1). However, a myriad of mitigating factors exist that could influence a Taekwondo practitioner's skill level. The results of the present study should be verified therefore in subject researches with different study populations.

The tests performed for this study were conducted over three days to avoid fatigue. Subjects performed cardiorespiratory, flexibility, muscle strength, endurance, power, and agility tests on the first day. On the second day, they performed the isokinetic muscle function test. Then, on the third day, they performed the anaerobic power test. Subjects were instructed to perform light stretching and warmup exercises five minutes prior to each test.

Muscle endurance tests

Two muscle endurance tests were conducted to determine the differences in fitness factors between the gyorugi, poomsae, and demonstration athlete groups. Subjects performed a sit up test on a sit-up measuring table (FAS-5370, Korea). They started the test by placing both hands behind their head while lying flat on the table with their knees bent at a right angle. Test examiners recorded a score each time a subject moved their upper body upward until both elbows touched the knees and returned to the lying position with their back flat on the table. The motion was repeated for 1 minute, and the number of completed sit-ups was recorded. A score was not counted if the subject removed their hands from the back of their head, failed to touch their knees with their elbows, and/or failed to place their back flat on the table. All measurements were performed twice with subjects performing the second test 30 minutes after the initial test to prevent fatigue. The better of the two results was recorded.

According to Patterson, Platzer, and Rascher [25], "The original version of the [repeated jump test] is reliable, and sensitive enough to detect adaptations in anaerobic power" (p. 129). As such, a repeated jump test was conducted to determine subjects' fitness level. The repeated jump test was performed by having subjects stand with their feet flat on the ground shoulder width apart with their arms raised directly above their heads. Keeping their arms straight, a measurement bar (FAS-5310, Korea) was placed 30cm above their outstretched hands. Subjects were instructed to jump vertically and touch the bar as many times as possible for 30 seconds. Each touch was recorded as a score. A jump was not recorded if the subject failed to touch the measurement bar. All measurements were performed twice with subjects performing the second test 30 minutes after the initial test to prevent fatigue. The better of the two results was recorded.

Muscle power test (standing long jump test)

The standing long jump test (SLJT) was conducted to determine muscle power differences between gyorugi, poomsae, and demonstration athlete groups. Subjects performed the SLJT using a digital standing long jump meter (FT-7700, Seedtech, Korea), which consists of a mat that lies on the floor that records subjects' jumps electronically to the nearest hundredth cm. Examiners instructed the subjects on how to perform the jump, then asked subjects to place their toes behind the starting line. Subjects performed the SLJT twice and performed the second test 30 minutes after the initial test to prevent fatigue.

Table 1. Physical characteristics of Taekwondo athletes (means±SD)

Athlete group	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m2)	%fat (%)	Taekwondo career (years)	Rank (dan)
Gyorugi	19.86±1.77	182.41±2.76	75.86±7.84	22.77±1.94	11.29±2.03	10.00±2.56	4.00±0.00
Poomsae	19.57±0.79	175.27±4.78	71.54±6.30	23.34±2.57	17.60±5.47	6.14±3.04	3.86±0.64
Demonstration	20.14±1.86	170.97±4.66	64.19±4.76	21.93±0.98	14.64±5.13	5.57±1.05	3.86±0.35

Gyorugi: sparring, poomsae: forms, dan: degree of black belt

Reaction time test

A reaction time test was performed to determine the differences in fitness factors between the gyorugi, poomsae, and demonstration athlete groups. Subjects' reaction times were measured using a systemic reaction time measurement tool (ST-140, Seedtech, Korea). Light and sound stimuli tests were formed. For both tests, subjects stood on the tool's mat with feet shoulder width apart. For the sound test, the tool provided a tone indicating when subjects were to jump their feet apart so they landed with their feet on either side of the mat. For the second test, the tool flashed a light indicating to the subject when to jump in the same manner. Reaction times were measured from the time the stimuli were provided to when the subjects' feet left the mat. Subjects performed each test three times, and the second test was performed 30 minutes after the initial test to prevent fatigue. The better of the two results was recorded.

Agility test

Subjects' agility was measured using a sidestep meter (ST-110, Seedtech, Korea) (Figure 1). Subjects began the test by standing with their feet shoulder width apart and equidistance from the centerline of the electronic meter with their knees bent and relaxed. The two beams of the electronic meter were placed 120 cm apart, and subjects sidestepped for 20 seconds. The sidestep meter marked the beginning and ending of the test. The number of times a subject's feet crossed the beam was recorded. After a 3-minute rest, the test was repeated, and the better of the two results was recorded.

Balance test

For the balance test, subjects stood barefoot on the floor with both hands on their waist. The test began when a subject raised one foot off the floor approximately 15 cm. Test examiners began recording the time using a stopwatch (model S141; SEIKO, Japan) as soon as the subject lifted their foot. The test was concluded if the subject replaced their foot on the ground, moved their stationary foot, or lifted their hands off /heir hips. Time was recorded to the tenth of a second. After a 3-minute rest, the test was repeated, and the better of the two results was recorded.

Flexibility test

Subjects' flexibility was measured using the trunk flexion test (Figure 2). Measurements were taken with a long-seat flexion meter (TKK-5403, Takei, Japan) and the trunk extension meter (TKK-5404, Takei, Japan). Subjects were instructed to stand upright with knees extended and hands behind them in a prone position. Subjects then bent forward at the waist as far as possible. Measurements were taken in a straight line from the subject's chin to the floor. All measurements were performed twice, and the second test was performed 30 minutes after the initial test to prevent fatigue. The better of the two results was recorded.

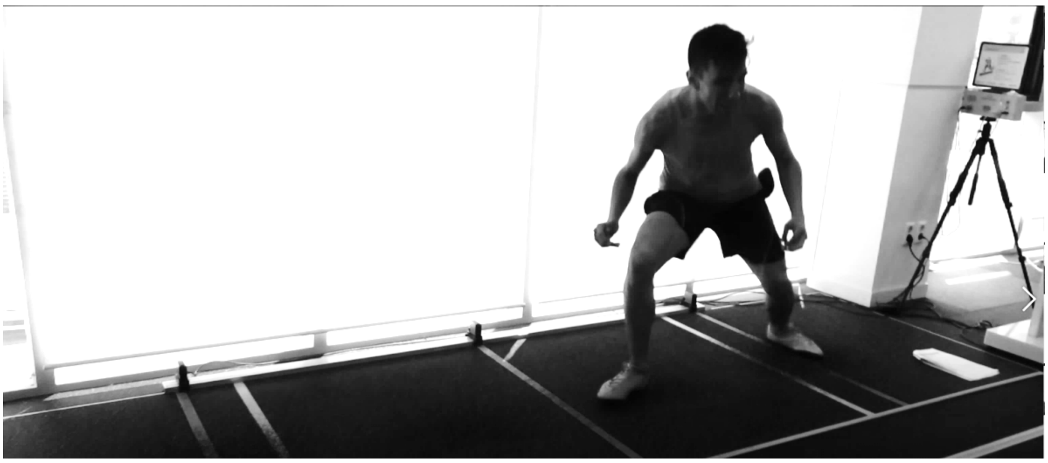

Figure 1. Example of the sidestep test (agility) used for the current study.

Figure 2. Example of the trunk flexion test (flexibility) used for the current study.

Isokinetic muscle function test of the knee joint

The isokinetic muscle function measurement system (CSMI, USA) was used to measure the muscle function of the knee joint according to the system's manual (Figure 3). The muscle strength was measured by performing flexion and extension movements of the knee joint three times at an angular velocity of 60°/sec and five times of the muscle power at 180°/sec. After performing three preliminary exercises for learning purposes, subjects performed the test again and measurements were taken. Peak torque, average power, total work, ratio of left and right (%) knee isokinetic muscle function, as well as the flexion and extensor ratios were recorded through the measurement results [26]. All measurements were performed twice, and the second test was performed 30 minutes after the initial test to prevent fatigue. The better of the two results was recorded.

Anaerobic exercise test (Wingate test)

Anaerobic exercise ability was measured with a Wingate test (Figure 4), a non-evasive and simple-to-conduct anaerobic test that measures leg muscle performance [27]. Subjects were measured for 30 seconds using a bicycle ergometer (Monark 818E, Sweden). Taking into account the characteristics of this measurement, prior training was conducted on the measurement procedures to reduce the decrease of will and power output in the second half of the test. During the tests, test examiners provided verbal encouragement to motivate subjects to achieve their best results. The values for peak power, average power, total energy, and peak drop were measured and recorded [28-29].

Figure 3. Example of the isokinetic muscle function test used for the current study.

Figure 4. Example of the anaerobic exercise test (Wingate test) used for the current study.

Statistics processing

For statistical processing, the average and standard deviation of each measurement were calculated using the SPSS (version 25.0) statistical program. One-way ANOVA was conducted to examine the differences between groups, and the Tukey method was used for the post-test. The significance level was p<0.05.

Table 2. Body composition analysis result

Items	Group	Means±SD	F	p	Post-hoc
Height (cm)	Gyorugi	182.41±2.76	13.434	0.000 0.013	a>c*** a>b*
	Poomsae	175.27±4.78			
	Demonstration	170.97±4.66			
Weight (kg)	Gyorugi	75.86±7.84	5.911	0.009 0.017	a>c**
	Poomsae	71.54±6.30			
	Demonstration	64.19±4.76			
Lean mass (kg)	Gyorugi	63.16±5.34	10.212	0.001 0.019	a>c** a>b*
	Poomsae	55.29±2.40			
	Demonstration	51.69±6.04			
Fat mass (kg)	Gyorugi	8.76±2.40	2.682	0.096	
	Poomsae	12.84±5.04			
	Demonstration	9.27±2.76			
BMI (kg/m2)	Gyorugi	22.77±1.94	0.938	0.409	
	Poomsae	23.34±2.57			
	Demonstration	21.93±0.98			
%fat (%)	Gyorugi	11.29±2.03	3.473	0.042	b>a*
	Poomsae	17.60±5.47			
	Demonstration	14.64±5.13			
BMR (Kcal)	Gyorugi	1819.43±124.58	10.264	0.001 0.018	a>c** a>b*
	Poomsae	1638.00±56.80			
	Demonstration	1556.00±135.77			
Abdominal %fat (%)	Gyorugi	0.78±0.01	8.479	0.003 0.012	b>a** b>c*
	Poomsae	0.84±0.04			
	Demonstration	0.79±0.02			

a - Gyorugi (sparring), b - Poomsae (forms), c - Demonstration, BMR - Basal metabolic rate, *: p<0.05, **: p<0.01, ***: p<0.001

RESULTS

Body composition

All subjects' height, weight, lean mass, fat mass, percentage of body fat, and Basal metabolic rate (BMR) were measured to determine their body composition. Table 2 contains the results of the analysis of body composition between the gyorugi, poomsae, and demonstration groups.

Physical fitness factors

Table 3 includes the results of the physical fitness tests (e.g., back strength, sit up, repeated jump, and SLJT) performed by the 21 male gyorugi, poomsae, and demonstration athletes.

Isokinetic muscle strength of the knee joint (60°/sec)

Table 4 contains the results of the knee joint isokinetic muscle strength tests (i.e., right and left extensor as well as flexor in bodyweight percentage and newton-metre) performed by the gyorugi, poomsae, and demonstration athletes.

Table 3. Physical fitness factors analysis results

Items	Group	Means±SD	F	p	post-hoc
Back strength (kg)	Gyorugi	152.07±21.51	10.204	0.003 0.003	a>c** a>b**
	Poomsae	117.94±12.89			
	Demonstration	118.29±12.74			
Sit ups (reps)	Gyorugi	54.57±6.83	4.505	0.035	a>b*
	Poomsae	45.14±5.27			
	Demonstration	53.57±7.11			
Repeated jump (reps)	Gyorugi	55.29±3.99	8.482	0.041 0.002	a>c* a>b**
	Poomsae	45.00±6.40			
	Demonstration	48.57±3.26			
SLJT (cm)	Gyorugi	249.57±8.08	3.290	0.061	
	Poomsae	231.63±15.92			
	Demonstration	243.50±14.59			
Response to sound stimulus (seconds)	Gyorugi	0.252±0.039	2.332	0.126	
	Poomsae	0.272±0.019			
	Demonstration	0.240±0.025			
Response to light stimulus (seconds)	Gyorugi	0.280±0.049	1.074	0.363	
	Poomsae	0.293±0.024			
	Demonstration	0.264±0.034			
Sidestep (reps)	Gyorugi	53.71±3.20	5.532	0.012	a>b*
	Poomsae	46.00±5.63			
	Demonstration	51.57±4.28			
Balance test (seconds)	Gyorugi	42.11±32.99	2.061	0.156	
	Poomsae	95.67±61.67			
	Demonstration	82.09±54.86			
Trunk flexion (cm)	Gyorugi	18.17±4.86	8.064	0.008 0.007	b>a** b>c**
	Poomsae	28.66±2.07			
	Demonstration	17.93±8.35			
Trunk extension (cm)	Gyorugi	62.43±7.62	1.876		
	Poomsae	60.03±8.88			
	Demonstration	55.06±4.62			

a - Gyorugi (sparring), b - Poomsae (forms), c - Demonstration, SLJT - standing long jump test, * p<0.05, **p<0.01

Table 4. Analysis result of knee joint isokinetic muscle strength (60°/sec)

Items	Group	Means±SD	F	p	post-hoc
Right extensor (%BW)	Gyorugi	316.43±32.38	1.887	0.180	
	Poomsae	272.43±40.91			
	Demonstration	299.43±52.51			
Left extensor (%BW)	Gyorugi	298.00±30.00	1.409	0.270	
	Poomsae	296.43±38.50			
	Demonstration	301.57±47.35			
Right extensor (Nm)	Gyorugi	238.86±23.48	9.166	0.005 0.004	a>c** a>b**
	Poomsae	192.86±13.32			
	Demonstration	194.86±28.64			
Left extensor (Nm)	Gyorugi	225.29±25.65	4.241	0.035	a>b*
	Poomsae	190.71±14.80			
	Demonstration	196.85±28.42			
Left/right extensor (deficit)	Gyorugi	5.75±3.63	1.775	0.035	
	Poomsae	4.96±3.18			
	Demonstration	9.72±7.33			
Right flexor (%BW)	Gyorugi	163.57±22.01	1.904	0.198	
	Poomsae	141.43±23.09			
	Demonstration	165.14±30.37			
Left flexor (%BW)	Gyorugi	162.71±20.41	2.515	0.178	
	Poomsae	133.00±30.32			
	Demonstration	156.57±26.80			
Right flexor (Nm)	Gyorugi	123.43±16.49	4.383	0.025	a>b*
	Poomsae	100.00±9.61			
	Demonstration	107.57±17.91			
Left flexor (Nm)	Gyorugi	123.00±16.96	5.533	0.012	a>b*
	Poomsae	93.86±16.19			
	Demonstration	102.43±17.37			
Left/right flexor (deficit)	Gyorugi	8.04±3.88	0.062	0.012	
	Poomsae	9.47±11.71			
	Demonstration	8.04±9.02			
Flexor/extensor left ratio (%)	Gyorugi	54.71±5.44	0.691	0.941	
	Poomsae	49.14±6.96			
	Demonstration	53.00±13.01			
Flexor/extensor right ratio (%)	Gyorugi	52.00±6.61	0.619	0.541	
	Poomsae	52.00±4.65			
	Demonstration	55.57±8.89			

a - Gyorugi (sparring), b - Poomsae (forms), c - Demonstration, %BW - body weight percentage, Nm - newton-metre, * $p<0.05$, ** $p<0.01$

Isokinetic muscle power of the knee joint (180°/sec)

Table 5 includes the results of the isokinetic muscle power test (i.e., right and left extensor as well as flexor in %BW and Nm).

Table 5. Analysis result of knee joint isokinetic muscle power (180°/sec)

Items	Group (n)	Means±SD	F	p	post-hoc
Right extensor (%BW)	Gyorugi	204.57±15.91	2.034	0.160	
	Poomsae	184.14±22.70			
	Demonstration	208.71±31.91			
Left extensor (%BW)	Gyorugi	200.86±16.77	4.182	0.031	c>b*
	Poomsae	179.00±17.32			
	Demonstration	208.71±24.68			
Right extensor (Nm)	Gyorugi	154.71±11.21	6.828	0.038 0.006	a>c* a>b**
	Poomsae	130.29±7.20			
	Demonstration	136.14±17.96			
Left extensor (Nm)	Gyorugi	151.86±17.99	6.240	0.007	a>b**
	Poomsae	127.57±6.02			
	Demonstration	136.14±12.28			
Left/right extensor (deficit)	Gyorugi	6.26±4.21	0.932	0.412	
	Poomsae	4.39±3.59			
	Demonstration	7.22±4.01			
Right flexor (%BW)	Gyorugi	133.57±25.72	2.475	0.112	
	Poomsae	109.14±14.87			
	Demonstration	125.43±20.74			
Left flexor (%BW)	Gyorugi	131.43±17.95	1.509	0.248	
	Poomsae	112.14±17.72			
	Demonstration	126.71±27.76			
Right flexor (Nm)	Gyorugi	100.43±17.57	5.711	0.013	a>b*
	Poomsae	77.43±6.16			
	Demonstration	82.14±14.01			
Left flexor (Nm)	Gyorugi	99.43±14.92	4.018	0.042	a>b*
	Poomsae	79.71±8.88			
	Demonstration	82.86±16.88			
Left/right flexor (deficit)	Gyorugi	7.70±7.06	1.135	0.343	
	Poomsae	4.50±5.41			
	Demonstration	8.92±4.15			
Flexor/extensor left ratio (%)	Gyorugi	65.71±8.92	0.500	0.614	
	Poomsae	62.43±5.68			
	Demonstration	61.00±11.55			
Flexor/extensor right ratio (%)	Gyorugi	64.71±8.30	0.772	0.477	
	Poomsae	59.43±2.88			
	Demonstration	61.00±11.11			

a - Gyorugi (sparring), b - Poomsae (forms), c - Demonstration, %BW - body weight percentage, Nm - newton-metre, * p<0.05, ** p<0.01

Anaerobic exercise capacity analysis result

Table 6 contains the analysis results of anaerobic exercise ability in the gyorugi, poomsae, and demonstration groups.

Table 6. Anaerobic exercise ability analysis result

Items	Group	Means±SD	F	p	post-hoc
Peak power (W)	Gyorugi	701.53±114.06	4.657	0.03	a>c*
	Poomsae	603.04±39.90			
	Demonstration	589.13±48.29			
Peak power (W/kg)	Gyorugi	9.18±0.67	2.14	0.147	
	Poomsae	8.45±0.49			
	Demonstration	9.03±0.87			
Average power (W)	Gyorugi	519.97±77.51	4.787	0.022	a>c*
	Poomsae	456.92±40.04			
	Demonstration	437.57±23.13			
Total energy (J)	Gyorugi	14425.71±2093.09	3.071	0.71	
	Poomsae	13164.71±1088.93			
	Demonstration	10508.04±4667.53			
Fatigue index (%)	Gyorugi	62.11±6.27	4.311	0.024	a>b*
	Poomsae	51.43±5.03			
	Demonstration	55.57±8.76			

a - Gyorugi (sparring), b - Poomsae (forms), c - Demonstration, W - watt, J – Jules, * p<0.05

DISCUSSION

The present study measured and compared isokinetic muscle function and anaerobic exercise capacity of the knee joint according to Taekwondo competition type (poomsae, gyorugi, and demonstration). Basic physical fitness factors as well as the characteristics of subjects' anaerobic athletic ability and knee joint isokinetic muscle function required for each competition type were measured. The results of this research could be used to create optimized training programs for athletes specializing in each competition type based on their individual needs. In body composition, this study found the height of the gyorugi athletes were significantly different compared to their poomsae (p<0.05) and demonstration counterparts (p<0.001).

The present study's results were consistent with the results of a prior study by Tak et al. [30], who reported tall gyorugi athletes had a tactical advantage during competition due to their longer legs. The results from the present study were unsurprising since gyorugi athletes' increased height can affect the athletes' performance due to recent rule changes that emphasized kicking to the head made by World Taekwondo (WT), the International Olympic Committee's (IOC) international federation for Taekwondo competition.

Muscle mass, fat mass, and BMR of the gyorugi athletes were significantly different from the poomsae (p<0.05) and demonstration athletes (p<0.01). For the body fat ratio, the gyorugi athletes were significantly lower than the poomsae athletes (p<0.05). Given the energy consumption and other gyorugi event characteristics, the results of this study can be explained again by recent WT gyorugi rule changes that include points being awarded when an opponent is pushed out of the ring. This act and the other physical demands placed on the body during gyorugi competition require a large amount of strength and energy. Since muscle mass, fat mass, and BMR are closely related to each other [31-32], the results of the current study on athletes' muscle mass, fat mass, and basal metabolic mass are equally unsurprising.

Gyorugi competitors' back muscle strength was significantly stronger than the poomsae and demonstration athletes (p<0.01). For sit-ups, the gyorugi athletes were significantly different compared to the poomsae athletes (p<0.05), but no significant difference was found between the gyorugi and demonstration athletes. These results can be attributed to the poomsae athletes' training that prioritizes stability and equilibrium, whereas gyorugi athletes require quick movements using various steps and demonstration athletes perform various types of rotational movements with high jumps and acrobatic movements. Two qualitative studies, Cha who reported the differences in lower limb muscle, trunk muscle, balance, and proprioceptive sensibility [33] and Rho who reported the differences in movements and the common physical fitness factors of poomsae, gyorugi, and demonstration athletes in a study designed to improve poomsae competition performance [34], support the present study's results.

In repeated jumps, the gyorugi athletes were significantly different compared to the poomsae ($p<0.01$) and demonstration athletes ($p<0.05$). For the sidestep test, gyorugi athletes were statistically significantly different compared to the poomsae athletes ($p<0.05$), but no significant difference was found between the gyorugi and demonstration athletes. These results are consistent with the results of prior studies [35-37].

During competition, gyorugi athletes must remain nimble to deliver attacks and counterattacks, which require very fast footwork that facilitate various fast kicking techniques. This study substantiated this in that the gyorugi athletes scores were significantly different compared to the poomsae and demonstration athletes in the repeated jump and sidestep tests that were used to determine athletes' muscle endurance and agility, respectfully. However, the isokinetic muscle function test showed poomsae athletes were significantly different in knee forward flexion as compared to the gyorugi and demonstration athletes ($p<0.01$). This was statistically consistent with the Kwon, Cho, and Eo's [38] results. These studies' results reflect the characteristics of the poomsae event, which demands athletes possess high levels of flexibility and stability. Tak et al. [30] reported that gyorugi athletes were more agile and muscular, while poomsae athletes had excellent balance and flexibility, which also supports the findings of the present study.

The knee joint isokinetic force strength test (angle speed 60°/sec) showed gyorugi athletes were significantly different in the case of right flexor ($p<0.01$) from their poomsae and demonstration counterparts. In the case of the left flexor, gyorugi athletes were significantly different as compared to poomsae athletes ($p<0.05$). In the case of left and right flexor, gyorugi athletes were significantly different to poomsae athletes ($p<0.05$). In the present study's knee isokinetic muscle power test (angle speed 180°/sec), gyorugi athletes were significantly different ($p<0.05$) in their left flexor strength per weight among poomsae and demonstration athletes. Gyorugi athletes' right flexor strength was also significantly different as compared to the poomsae ($p<0.01$) and demonstration athletes ($p<0.05$). Likewise, their left flexor was significantly different in respect compared to poomsae athletes ($p<0.01$), and their left and right flexor strength were significantly different compared to poomsae athletes ($p<0.05$). These results were consistent with Kim [39], who reported on the difference between cardiopulmonary and isokinetic muscle functions of Taekwondo athletes; Kim et al. [7], who reported on the isokinetic muscle strength of Taekwondo practitioners and athletes; as well as Kim and Park [40], who reported on the difference in knee and ankle strength of Taekwondo gyorugi and poomsae athletes.

For maximum knee joint strength (angular velocity 60°/sec) and flexion/extension strength at an angular velocity of 180°/sec, this study's gyorugi athletes' results were significantly different compared to poomsae athletes. These results were consistent with Kim and Park [40]. Moreover, the results of our subjects' isokinetic weight ratio flexion and extension muscle strength of the knee joint (measured at an angular velocity of 60°/sec) were consistent Kim, Oh, Cha, and Yun's results [9], who reported that there was no significant difference between gyorugi and poomsae athletes and general Taekwondo practitioners with 5 years Taekwondo training. However, the current research's demonstration athletes' left extensor strength (measured at an angular velocity of 60°/sec) was significantly different from that of the gyorugi athletes whereas Oh and Cha [41] reported that their gyorugi group's flexion strength was significantly different compared to that of Korean national gyorugi team athletes. Thus, there was a slight difference in left extensor strength results from the present study and previous researches. In addition, Oh and Cha [41] reported a significant difference between gyorugi athletes and demonstration athletes in the left flexion strength (measured at an angular velocity of 180°/sec), which is another difference to the current study's findings.

The present study's anaerobic exercise test results show that gyorugi athletes were significantly different comparted to demonstration athletes in peak power and average power ($p<0.05$). Kwon, Cho, and Eo [38] argued that Taekwondo demonstration athletes must continuously perform complex movements accompanied by translational and rotational movements, and poomsae athletes must perform highly accurate movements. In addition, Cha and Oh [41] also reported a significant difference in left flexural muscle (measured at the angular velocity of 180°/sec) between gyorugi athletes and demonstration athletes, which contradicts the results of the present study.

There was a significant difference ($p<0.05$) in fatigue index (FI) between gyorugi and poomsae athletes, but no significant difference between these groups and the demonstration athletes. During gyorugi competition, athletes can control the intensity of their sparring matches by deciding how aggressive to be. On the other hand, poomsae competitors must exert continuous maximum strength until the end of the match (i.e., they finish performing their poomsae) at a relatively moderate and rhythmic pace. Also different are demonstration athletes who must perform a variety of complex and rapid hand and foot movements continuously that require large amounts of strength, dexterity, and balance. Thus, the FI results reflect the physical strength and game characteristics required for the competitions of gyorugi, poomsae, and demonstration athletes. The fact that this study's FI results were dissimilar with those of previous studies may be a reflection of physical strength conditioning and training methods used in the subjects' region or university.

CONCLUSIONS

In the present study, male Kukki Taekwondo gyorugi athletes showed better results than their poomsae and demonstration counterparts in almost every metric, including body composition, physical fitness factors, isokinetic muscle function (60°/sec), muscle power (180°/sec), and anaerobic exercise capacity. Gyorugi athletes were taller and showed higher muscle mass, strength, muscular endurance, and agility. Poomsae athletes alternatively showed a higher level of flexibility, which is another important fitness factor.

This study furthermore found isokinetic muscle function and anaerobic exercise capacity of the knee joint to be most important to gyorugi athletes and then demonstration and poomsae athletes in that order. Today's gyorugi athletes execute numerous types of kicks during competition. Previous WT competition rules encouraged athletes to execute only a couple of types of kicks, which promoted repetitions of the same kicking techniques and thus less dynamic and exciting competition to watch. The newer competition rules, which award points for more jumping and spinning kicks to the head, encourage athletes to use a diversity array of kicks to attack their opponents. Similarly, Taekwondo demonstration athletes must perform a lot of flexion and extension of the knee, because they kick multiple targets at various heights. Finally, poomsae athletes utilize their knees differently from the other two style of Taekwondo competition. Kicks in most Taekwondo poomsae divisions are typically performed in a symmetrical sequence in combination with hand techniques in which the left and right sides of the body are used equally. Very rarely are two kicks performed consecutively (the only time the latter occurs frequently is during freestyle poomsae divisions), and the kicks are almost always performed at the extreme limits of human flexibility.

The results of this study can provide useful information for understanding the physical characteristics of Taekwondo gyorugi, poomsae, and demonstration athletes. As such, our findings are expected to provide important basic data for creating future specialized systematic training programs for the three types of Taekwondo competitions. The limitations of this research include the absence of female subjects, a small sample size, our subjects' limited age range, and that all subjects came from the same region of Korea. Moreover, the above results only pertain to Kukki Taekwondo athletes, since the subjects were trained on in that Taekwondo style. If ITF Taekwondo practitioners had been included in this study, different results may have been obtained since the two Taekwondo styles require basic techniques to be performed dissimilarly.

To confirm this study's conclusions, future studies should therefore include wider demographic ranges that include female subjects and a more diverse aged population, especially since WT poomsae competitions now have age categories ranging from cadet (12-14 years old) to an "Over 65 Division (66-years old and above) (WT, p. 9) [6]. In addition, comparative studies between Kukki and ITF Taekwondo styles could determine if the differences in kick executions in the two styles affect practitioners' isokinetic muscle function and anaerobic exercise capacity.

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