

A Structural Empirical Analysis of Kicking Techniques in Modern Taekwondo Competition

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ABSTRACT

This study identified and validated key technical factors influencing the execution structure of kicking techniques (KT) in Modern Taekwondo Competition (MTC). Based on expert interviews, video analysis, and statistical modelling (PLS-SEM), the results demonstrate that the preparation stage and the direct take-off stage significantly affect subsequent execution phases ($p < 0.001$). By contrast, the preparation stage combined with an indirect take-off exhibits only limited effects ($p = 0.269$) and appears to be more advantageous for female athletes ($p < 0.05$). In particular, the knee-lift is strongly associated with strike direction, whereas foot usage plays a pivotal role in determining the target area ($p < 0.05$). Athletes preferred rapid, stable, linear-internal trajectories coupled with linear-horizontal strike directions, using instep-sole strikes aimed at the trunk area, delivering a sudden single strike at each stage of the KT-MTC structure. The findings recommend integrated, stage-specific training for improved competitive performance and highlight the shift from power-oriented techniques toward precision-based, interconnected tactical approaches in modern Taekwondo.

Keywords: Electric scoring system, kicking techniques, kicking techniques structure, Taekwondo competition.

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1. INTRODUCTION

Kicking techniques (KT) form the cornerstone of Taekwondo (TKD) competition, supplying the primary means of generating scoring opportunities, shaping match strategy, and ultimately securing victory (Kim, 1993; Chun, 2001; Park & Suh, 2019). Each KT unfolds through a multi-stage chain of movements, commonly classified as Initiation, Take-off, Knee-lift, Strike, and Retraction-Return (Yang, 2021; Sousa *et al.*, 2022; Guanglei & Yang, 2023). Executing this chain requires the precise orchestration of translational shifts in the body's centre of mass to maximise biomechanical efficiency, generating speed and power coalesce into a single, complete kick (Cho, 2006; Liu, 2022).

Traditional KT such as roundhouse, axe, side, push, hook, and the various rotational kicks (back, spinning, spinning-hook, etc.) follow prescribed structural principles that make their trajectories and impact directions readily recognisable from name alone (Jun & Kim, 2002). For example, the roundhouse kick transitions from a preparatory stance, lifts the knee on a diagonal, and strikes the opponent's trunk or head horizontally with the instep (Yang, 2021).

However, TKD's inclusion in the Olympic Games and the advent of electronic scoring systems have fundamentally altered KT execution (Ahn, 2010; Sejin, 2014). World Taekwondo (WT) rules (World Taekwondo, 2023) stipulate that any kick delivered with the foot area below the ankle is valid if it exceeds the impact threshold detected by electronic protectors (Yang, 2023; Liu, 2022). This has stimulated an explosion of technical variety in Modern Taekwondo Competition (MTC), shifting practice beyond the confines of traditional KT forms (Kim *et al.*, 2022; Choi *et al.*, 2021; Kim & Kim, 2014).



Seeking to capture these changes, Royuela *et al.* (2017) grouped KT into linear, circular, and spin categories, while Liu (2022) proposed a framework tailored to electronic scoring, emphasising foot-contact area (“foot-feel”) and striking direction. Athletes now exploit scoring windows by retracting the leg, chaining techniques, and generating diverse trajectories such as arcs, straight lines, curves, rotations, by integrating downward, upward, lateral, diagonal, and continuous aerial kicks. Consequently, KT in MTC have evolved into continuous, unpredictable actions that transcend the rigid protocols of earlier eras (Yang, 2023; Liu, 2022; Yang, 2021; Royuela *et al.*, 2017).

Most existing research, however, still analyses KT within traditional structural frameworks, yielding findings that overlook the breadth of modern variations. While conserving KT principles remains essential (Yang, 2023; Yang, 2021), there is a clear need for a ‘technical factor–based’ analytical tool that reflects KT-MTC characteristics, so one that can keep pace with athletes’ evolving tactics and preserve empirical validity (Morales-Sánchez & Falcó, 2022; Barrientos *et al.*, 2021).

Accordingly, this study aims to (1) Identify the technical factors and indicators that constitute the KT execution structure specific to MTC; (2) Verify the key techniques within each factor and examine their usage patterns in male and female athletes; (3) Validate these indicators and factors with empirical KT-MTC data, clarifying both inter-factor relationships and their interactions across the full execution sequence.

Ultimately, the goal is to move beyond the limitations of traditional KT analyses by developing an updated measurement framework that integrates foundational KT principles with the distinct demands of MTC. Using match footage from world-class athletes, the study seeks to deliver practical insights that enhance KT training and performance in MTC.

1.1. Research Hypothesis

The hypotheses of this study are as follows: (1) For both male and female athletes, the mean frequency with which each technical indicator is attempted differs significantly across the factors that constitute the KT execution process. (2) In the male, female, and overall groups, every direct path linking adjacent factors in the KT execution process exerts a statistically significant positive effect. (3) In the male, female, and overall groups, the specified indirect paths among the KT execution factors exert statistically significant positive effects.

2. METHODS

2.1. Literature Review

To ground the study on a firm theoretical footing, we conducted an integrative literature review that scrutinised the practical application of KT-MTC. We searched CNKI, RISS, Google Scholar, and PubMed in Chinese, English, and Korean using the terms ‘Taekwondo,’ ‘Taekwondo kicking techniques,’ ‘Taekwondo competition,’ and ‘electronic protector.’ This multilingual strategy yielded a wide spectrum of scholarly perspectives.

All retrieved sources were screened and then subjected to an in-depth thematic analysis, in which we coded, categorised, and conceptualised their key insights. Components most relevant to our research aims were retained, producing a concise evidence base comprising seven studies on TKD KT, four on KT process structures, and six on the distinctive characteristics of KT-MTC (Tables I and II). Together, these works clarify how KT-MTC are currently executed and understood, providing the conceptual scaffold for the present investigation.

Across decades of research, certain techniques, most notably the roundhouse, axe, back, and spin-based kicks recur consistently.

Although individual authors segment the kicking action differently, most acknowledge a core sequence of Preparation, Take-off, Knee-lift, Strike, Recovery/Return. In MTC, this sequence is enriched by multiple attack angles, deceptive set-ups, and electronic scoring sensors that reward precise foot-contact zones. As a result, athletes now employ highly refined and varied kicking methods: elaborate preparation and feint motions, multi-trajectories targeting head and trunk using single, combination, or airborne attacks.

2.2. Expert Interview

To align with the study’s objectives, semi-structured interviews were conducted based on prior research (Bouncken *et al.*, 2021). Four field experts: a world champion, an Asia champion, an official from the Asian TKD Union (ATU), and a coach with Olympic experience, participated after receiving a comprehensive briefing on the study’s aims and providing informed consent.

The initial interviews were held individually via online video conferencing throughout May 2024, with supplementary data collected through messenger communications as needed. During these

TABLE I: TRADITIONAL KT

Source	Techniques	Number of KT
Kim (1987)	Roundhouse Kick, Turning Kick, Axe Kick, Front Axe Kick, Side Kick, Double Flying Front Kick	6
Ahn et al. (1994)	Roundhouse Kick, Back Kick, Axe Kick, Front Hook Kick, Spinning Hook Kick	5
Choi et al. (1997)	Roundhouse Kick, Side Kick, Axe Kick, Back Kick, Front Hook Kick, Back Spinning Kick, Axe Kick, Push Kick	8
Kang and Ryew (2002)	Roundhouse Kick, Axe Kick, Back Spinning Kick, Back Kick, Side Kick, Double Flying Kick, Front Kick, Tornado Kick, Jump Roundhouse Kick, Push Kick	10
Choi et al. (2009)	Mid-Level Roundhouse Kick, High-Level Roundhouse Kick, Axe Kick, Mid-Level Back Kick, High-Level Back Kick, Back Spinning Kick, Mid-Level Jump Roundhouse Kick, High-Level Jump Roundhouse Kick, Jump Axe Kick, Mid-Level Tornado Kick, High-Level Tornado Kick, Mid-Level Double Flying Kick, High-Level Double Flying Kick	13
Jin (2019)	Push Kick, Front Roundhouse Kick, Back Roundhouse Kick, Hook Kick, Axe Kick, Back Kick, Back Spinning Kick, Double Flying Kick, Tornado Kick	9
Han (2024)	Horizontal-Line Kick, Side Kick, Axe Kick, Turning Techniques, Hook Kick, Tornado Kick, Single Technique, Combination Technique	8

TABLE II: KT STRUCTURE AND CHARACTERISTICS OF KT-MTC

Source	KT structure	Source	Characteristics of KT-MTC
Guanglei and Yang (2023)	Initiation, Knee lift, Strike, Return	Yang (2023)	Preparation: Footwork, posture, feint
Sousa et al. (2022)	Take off, Knee lift, leg extension, Contact momalet, leg flexion, Thigh extension	Liu (2022)	Technique intention: Direct or indirect KT deciding initiation attacks
Lu and Lin (2022)	Ready momalet, Momalet of flexion, Momalet of strike, Momalet of recovery	Sousa et al. (2022)	Technique trajectory: Straight, curved, medial, lateral, etc. irregular trajectories
Yang (2021)	Knee lift, Raising the leg, Swinging the leg (from outside to inside and from inside to outside)	Yang (2021)	Striking direction: Straight, diagonal, horizontal, upward, downward, etc. multi-directional kicks
		Barrientos et al. (2021)	Foot usage: Sole, heel, instep, inside of the foot, and the foot sensation area using the electronic sensor
		Royuela et al. (2017)	Striking target: Trunk and head of the electronic protective area
			Technique finishing: Single, continuous attack, aerial attacks

sessions, relevant information and keywords were transcribed using Word processor. Data were analyzed inductively using Grounded Theory, progressing through Open Coding (concept extraction), Axial Coding (integration of subcategories), and Selective Coding (establishment of core categories) to group similar keywords and refine central themes (Given, 2008).

This analytical process resulted in a systematic categorization and conceptualization of the stage-specific technical factors, indicators, and execution structure of KT-MTC. The findings informed the development of additional interview questions targeting: (i) the technical factors and execution structure of KT-MTC, (ii) the technical indicators of the preparation stage, (iii) the take-off stage, (iv) the knee-lift stage, (v) the strike stage, and (vi) the return stage.

A follow-up interview was conducted using the same methods, and the developed questions were posed. The outcomes, including all items detailed in Table III and the KT structure illustrated in Fig. 1, were subsequently shared among the researchers for triangulation, ultimately elucidating the core contents relate to the study's objectives (Patton, 2015; Choi et al., 2009).

2.3. Content Validity

To validate the items, experts meeting the strict Committee of Experts' Criteria (CEC) were selected. These criteria required that experts possess substantial professional knowledge and experience in TKD, specifically: (i) holding a Ph.D. or having served as a university professor in sports science; (ii) having coached at continental or World Championships (note that the original criterion of European competitions was broadened to continental competitions); (iii) possessing an international coach certification; (iv) possessing a national-level coach certification; and (v) having over 10 years of competitive experience. Experts who met at least four of these five criteria were re-invited (Sousa et al., 2022). Finally new six experts who qualified for the CEC were re-invited for the content validity.

A four-point Likert scale questionnaire was used to evaluate the Item-Content Validity Index (I-CVI) and the Scale-level Content Validity Index/Average (S-CVI/Ave). For each item, a rating of 3 or

TABLE III: TECHNICAL FACTORS AND INDICATORS OF KT EXECUTION STRUCTURE IN MTC

Stages		Indicators	Description
Preparation	Preparation	Stable Stance (SS)	Assume a right or left stance while maintaining body stability, using pressure or occupying advantageous positions to prepare for attack or counterattack opportunities
		Moving Technique (MT)	Use footwork to move forward, backward, left, or right, or adjust in place with varying speed and amplitude to create opportunities for attack or counterattack
		Faking Technique (FT)	Employ deceptive movements (e.g., fake kicks, fake steps) to confuse the opponent, creating optimal opportunities for offense or defense
Take off	Direct take-off	Direct Take-off Front leg (DTF)	Without any preliminary movements, the front leg is lifted directly from the ground
		Direct Take-off Skip (DTS)	Both feet leave the ground simultaneously, for the front leg initiating an attack while the hind leg slightly jumps
		Rear leg used: Direct Take-off Front leg (RDTF)	The hind foot first moves to a position near the front foot, and then the front foot lifts off the ground, forming an attack motion
		Direct Take-off Rear leg (DTR)	The hind leg is lifted directly from the ground to initiate an attack
		Direct Take-off Spin Technique (DTST)	When spinning, the hind leg is lifted directly to form an attack
	Indirect take-off	Indirect Take-off Front leg after Moving (IT-FM)	After moving through footwork, the front leg is lifted to attack
		Indirect Take-off Front leg after Kicking (IT-FK)	After using other kicking techniques, the front leg is lifted for a secondary attack
		Indirect Take-off Rear leg after Moving (IT-RM)	After moving through footwork, the rear-leg is lifted to attack
		Indirect Take-off Rear leg after Kicking (IT-RK)	After using other kicking techniques, the rear-leg is lifted for a secondary attack
		Indirect Take-off Spin after Moving (IT-SM)	After moving through footwork, a spinning technique is initiated to form an attack
		Indirect Take-off Spin after Kicking (IT-SK)	After using other kicking techniques, a spinning technique is then employed to attack
Knee-lift	Knee-lift	Linear (L)	The knee is lifted upward in a straight line
		Internal (I)	Lift the knee in a curved path inward
		External (E)	Lift the knee in a curved path outward
		Spin (S)	The knee-lift is executed with rotating the body with the head
		Switch Trajectory (ST)	The knee's motion trajectory switches suddenly from one path to another, such as changing from a straight line to an inside or outside line to kick
Strike	Direction	Upward (UW)	The foot moves upward and strike the target
		Downward (DW)	The foot is raised and then strikes downward in changing angle of kicks
		Horizontal Direction (HD)	The foot moves horizontally from one side to the other
		Diagonal Direction (DD)	The kicks at a diagonal angle to add variety to the attack angles
	Foot usage	Linear Direction (LD)	The kicks directly towards the target in a straight line
		Foot of Instep (FI)	The instep is used for striking, targeting the opponent's head or trunk
		Foot of Sole (FS)	The sole of the foot is used for striking, aimed at the opponent's head or trunk
		Inside of Foot (IF)	The inside of the foot is used for striking, often targeting the opponent's side of body or head in short distance
		Foot of Heel (FH)	The heel is used for striking, typically in changing angle of kicks to strike targets
	Target	Trunk Area (TA)	The target is the upper body area protected by armor, including the abdomale, sides, and back parts of the body
		Head Area (HA)	The target is the whole head including the face

Continued

TABLE III: CONTINUED

Stages		Indicators	Description
Return	Return	Single Landing Technique (SLT)	After one kick, the foot lands accurately to return to the ready position after the attack is completed.
		Combination Landing Technique (CLT)	After a kick, the next kick is quickly executed, maintaining offensive continuity
		Aerial Technique (AT)	kicks are executed consecutively in the air, maintaining the rhythm and continuity of the attack

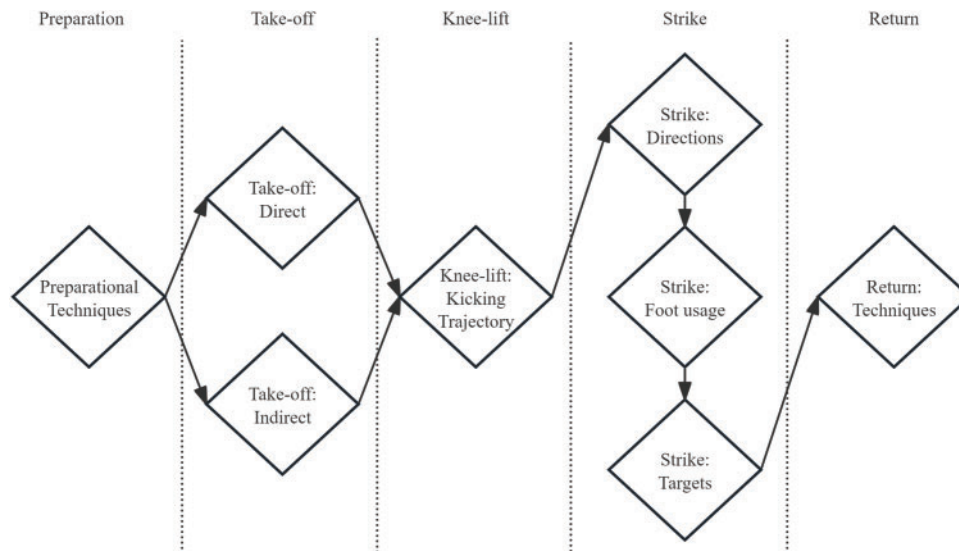


Fig. 1. Conceptual framework.

4 ('appropriate but requires modification' or 'appropriate') was assigned 1 point, while a rating of 1 or 2 ('does not meet criteria' or 'inappropriate') was assigned 0 points across all factors, indicators, and the overall structure. I-CVI was calculated by dividing the number of experts who rated a given item as 3 or 4 by the total number of experts, and S-CVI/Ave was obtained by averaging the I-CVI values for all items. When six experts participated in the evaluation, I-CVI of 0.83 or higher and S-CVI/Ave of 1.00 were deemed indicative of high content validity (Oh *et al.*, 2022). I-CVI was 1.00 and S-CVI/Ave was 1.00, confirming the overall validity.

2.4. Video Analysis

Given the rapid nature of movements in TKD games, video analysis is an essential in analyzing technical execution and achieving the study objectives (Bartlett, 2007; Barrientos *et al.*, 2021).

The subjects of this study were 14,537 kicking technical actions collected from each round in the male's 58 kg, 68 kg, 80 kg, +80 kg, and the female's 49 kg, 57 kg, 67 kg, +67 kg Olympic weight divisions at the final matches of the 2023 World TKD Championships, and the 2024 Paris Olympic Games, totaling 34 rounds in the male's division and 38 rounds in the female's division.

Video footage was downloaded from public media, and they were no ethical reporting issues (American Psychological Association, 2017). Data collection was conducted using an iPad Pro (2024) and CapCut software, adjusting quality of footage (1080 p full HD, 30 fps) and where the slow-motion function allowed for playback speed adjustments ($0.1\times - 1\times$) with both the Normal and Curve modes were employed appropriately, enabling either an overall observation of rapid movements or a targeted application of speed ramping at critical moment, permitting a more precise analysis of detailed motions.

Building upon predetermined KT structure, Operational Criteria for identifying the overall items were: (i) preparatory motion prior to the foot leaving the ground, (ii) the technique at the exact moment the foot leaves the ground, (iii) the trajectory involved in raising the knee, (iv) the direction in which the foot is aimed toward its target, (v) the specific part of the foot used, (iv) the area of impact, and (vii) the concluding stage encompassing single, consecutive, or aerial techniques. To record these observations, eight TKD specialists with over five years of athlete experience were organized into four teams of two. Each team focused on either the blue or red competitor in both male's and female's divisions, systematically classifying and logging each kicking motion on record sheets and in Excel coding.

Prior to initiating the primary data collection, the recorders received training in the operational criteria and analytical methodology, followed by a preliminary session in which they jointly reviewed

sample videos. To ensure the reliability of the collected data, a re-test analysis was conducted two days after the initial analysis using same methods (Cicchetti, 1994), and the Intraclass Correlation Coefficient (ICC) with the ICC (2.1) model and the corresponding 95% Confidence Interval was used to validate them. The ICC results for all items exceeded 0.75, indicating high reliability (Barrientos et al., 2021).

2.5. Statistical Analysis

SPSS 23 was utilized to analyze the hypotheses 1st. Based on the central limit theorem, the data were assumed to follow a normal distribution when the sample size exceeded 30 ($n > 30$). Levene's test for equality of variances was conducted ($p < 0.05$), indicating that equal variances were not assumed. Therefore, Welch's ANOVA and Welch's t-test (for two independent groups) were employed, and Games–Howell post hoc tests were performed.

Partial least squares structural equation modeling (PLS-SEM) was used to verify the hypotheses 2nd and 3rd, because PLS-SEM is particularly suitable when high correlations among indicators are not assumed, and each technical factor, composed of major KT indicators, independently contributes to the overall KT execution process structure, justifying the use of a formative model in this study. Furthermore, when content validity has been verified and the structure comprises multiple components, PLS-SEM enables evaluation of the relative importance of each component. This approach facilitates a more precise understanding of the structure and offers valuable insights for strategic decision-making. (Hair et al., 2013).

SmartPLS 4 software and bootstrapping with 5,000 resamples was conducted. When a formative measurement scale is used, there is no need to report indicator reliability, internal consistency reliability, or discriminant validity because outer loadings, composite reliability, and the square root of average variance extracted (AVE) are not meaningful for a latent variable composed of uncorrelated measures (Haenlein & Kaplan, 2004).

To validate the structure, Variance inflation factors (VIF) were calculated to examine multicollinearity, and VIF values of 5 or below indicated no multicollinearity issues. Next, the statistical significance ($p < 0.05$) of the outer weights, T-statistics (greater than 1.96), and 95% confidence intervals (not including 0) was evaluated, and any indicator that failed to meet the validity criteria was incrementally removed from the model (Hair et al., 2021; Sarstedt et al., 2019). Finally, path coefficients were analyzed.

3. RESULTS

Given evidence that KT performance in TKD competitions varies by gender (Lim, 2024; Manescardi et al., 2020; Jin, 2019), this study adopts a gender-stratified approach. We analyzed the structural technical factors and indicators of KT separately for male and female athletes, reporting the results for each group.

3.1. ANOVA and T-test (Male)

Preparation: Significant differences were found in the technical indicators of SS, MT, and FT (F-value = 36.78, $p < 0.001$). Post-hoc test results show that the average frequency of SS (17.36 attempts) is significantly higher than that of MT (6.97 attempts), with FT recording the lowest average (1.56 attempts).

Direct Take-off: Significant differences were found in the technical indicators of DTF, DTS, RDTF, DTR, and DTST (F-value = 30.72, $p < 0.001$). Post-hoc test results show that the average frequency of DTF (14.68 attempts) and DTR (2.85 attempts) is significantly higher than that of RDTF (1.00 attempt), DTS (0.91 attempts), and DTST (0.68 attempts).

Indirect Take-off: Significant differences were found in the technical indicators of IT-FM, IT-FK, IT-RM, IT-RK, IT-SM, and IT-SK (F-value = 15.39, $p < 0.001$). Post-hoc test results show that the average frequency of IT-FK (3.24 attempts) and IT-RK (2.00 attempts) is significantly higher than that of IT-FM (1.94 attempts), IT-RM (0.97 attempts), IT-SM (0.21 attempts), and IT-SK (0.06 attempts).

Knee-Lift: Significant differences were found in the technical indicators of L, I, E, S, and ST (F-value = 45.34, $p < 0.001$). Post-hoc test results show that the average frequency of L (11.15 attempts) and I (8.24 attempts) is significantly higher than that of E (2.76 attempts), S (0.68 attempts), and ST (0.59 attempts).

Striking Direction: Significant differences were found in the technical indicators of UW, DW, HD, DD, and LD (F-value = 47.46, $p < 0.001$). Post-hoc test results show that the average frequency of HD (10.56 attempts) and LD (8.82 attempts) is significantly higher than that of UW (1.76 attempts), DW (1.47 attempts), and DD (0.38 attempts).

TABLE IV: ANOVA ANALYSIS (MALE'S)

Techniques		Average of Techniques trials/Rounds		F value (Welch's test)	p-value	Post-hoc Test (GamesHowell)
		Mean	SD			
Preparation	SS ^a	17.35	8.35	36.78	0.001***	a > b > c
	MT ^b	6.97	7.42			
	FT ^c	1.56	2.67			
Take-off (Direct)	DTF ^a	14.68	7.67	30.72	0.001***	a > b, c, d, e d > b, e
	DTS ^b	0.91	1.40			
	RDTF ^c	1.00	1.61			
	DTR ^d	2.85	2.54			
	DTST ^e	0.68	1.38			
Take-off (Indirect)	IT-FM ^a	1.94	2.42	15.39	0.001***	a > e, f
	IT-FK ^b	3.24	3.63			b > c, e, f
	IT-RM ^c	0.97	1.44			c > e
	IT-RK ^d	2.00	2.42			d > e, f
	IT-SM ^e	0.21	.41			
	IT-SK ^f	0.06	.23			
Knee-lift	L ^a	11.15	5.87	45.34	0.001***	a > b > c > d, e
	I ^b	8.24	5.09			
	E ^c	2.76	3.36			
	S ^d	0.68	1.47			
	ST ^e	0.59	0.98			
Strike directions	UW ^a	1.76	2.16	47.45	0.001***	a > d
	DW ^b	1.47	2.04			b > d
	HD ^c	10.56	5.08			c > a, b, d
	DD ^d	0.38	0.73			e > a, b, d
	LD ^e	8.82	6.69			
Foot usages	FI ^a	10.26	4.94	69.09	0.001***	a > c, d
	FS ^b	10.82	6.33			b > c, d
	IF ^c	0.56	0.78			
	FH ^d	0.88	1.96			
Strike targets	TA	19.03	7.99	10.86 ⁺	0.001***	-
	HA	3.47	2.39			
Return	SLT ^a	17.03	6.94	45.34	0.001***	a > b, c
	CLT ^b	4.56	3.49			
	AT ^c	2.62	3.27			

Note: *p < 0.05, **p < 0.01, ***p < 0.001, ⁺Welch's t-test: t-value.

Foot Usage: Significant differences were found in the technical indicators of FI, FS, IF, and FH (F-value = 69.09, p < 0.001). Post-hoc test results show that the average frequency of FS (10.82 attempts) and FI (10.26 attempts) is significantly higher than that of FH (0.88 attempts) and IF (0.56 attempts).

Striking Target: Significant differences were found in the technical indicator of strike targets on the TA and HA (T-value = 10.86, p < 0.001). The average frequency of strikes to TA (19.03 attempts) is significantly higher than that of strikes to HA (3.47 attempts).

Return: Significant differences were found in the technical indicators of SLT, CLT, and AT (F-value = 59.64, p < 0.001). Post-hoc test results show that the average frequency of SLT (17.03 attempts) is significantly higher than that of CLT (4.56 attempts) and AT (2.32 attempts) (Table IV).

3.2. ANOVA and T-test (Female)

Preparation: Significant differences were found in the technical indicators of SS, MT, and FT (F-value = 55.93, p < 0.001). Post-hoc test results show that the average frequency of FT (23.32 attempts) and SS (22.95 attempts) is significantly higher than that of MT (6.11 attempts). Male athletes primarily favor the SS technique, while female athletes use FT and SS at similarly high rates, both showing significantly lower MT attempts.

Direct Take-off: Significant differences were found in the technical indicators of DTF, DTS, RDTF, DTR, and DTST (F-value = 34.15, p < 0.001). Post-hoc test results show that the average frequency of DTF (17.58 attempts) is the highest, followed by DTR (2.58 attempts), while RDTF (0.82 attempts),

TABLE V: ANOVA ANALYSIS (FEMALE'S)

Techniques		Average of Techniques trials/Rounds		F value (Welch's test)	p-value	Post-hoc Test (Games-Howell)
		Mean	SD			
Preparation	SS ^a	22.95	10.39	55.93	0.001***	a > b
	MT ^b	6.11	5.87			c > b
	FT ^c	23.32	16.33			
Take-off (Direct)	DTF ^a	17.58	9.52	34.15	0.001***	a > b, c, d, e
	DTS ^b	0.42	1.05			d > b, c, e
	RDTF ^c	0.82	1.13			
	DTR ^d	2.58	3.43			
	DTST ^e	0.32	0.90			
Take-off (Indirect)	IT-FM ^a	2.08	2.69	14.76	0.001***	a > e, f
	IT-FK ^b	3.16	3.86			b > e, f
	IT-RM ^c	1.61	2.85			c > f
	IT-RK ^d	1.42	1.58			d > e, f
	IT-SM ^e	0.26	0.68			
	IT-SK ^f	0.11	0.31			
Knee-lift	L ^a	13.42	10.73	31.985	0.001***	a > c, d, e
	I ^b	14.21	10.06			b > c, d, e
	E ^c	0.34	0.78			
	S ^d	0.52	1.00			
	ST ^e	0.97	1.34			
Strike directions	UW ^a	1.18	1.76	29.97	0.001***	b > d
	DW ^b	1.76	2.21			c > a, b, d
	HD ^c	13.37	10.31			e > a, b, d
	DD ^d	0.47	0.89			
	LD ^e	13.26	10.58			
Foot usages	FI ^a	13.58	7.57	66.97	0.001***	a > c, d
	FS ^b	14.45	9.94			b > c, d
	IF ^c	0.13	0.41			d > c
	FH ^d	1.16	2.11			
Strike targets	TA	25.05	10.80	127.73 ⁺	0.001***	—
	HA	4.50	2.99			
Return	SLT ^a	20.63	7.83	91.33	0.001***	a > b > c
	CLT ^b	5.89	5.61			
	AT ^c	2.62	3.27			

Note. *p < 0.05, **p < 0.01, ***p < 0.001, ⁺Welch's t-test: t-value.

DTS (0.42 attempts), and DTST (0.32 attempts) recorded lower frequencies. DTF is dominant in both male and female groups, with female slightly exceeding male.

Indirect Take-off: Significant differences were found in the technical indicators of IT-FM, IT-FK, IT-RM, IT-RK, IT-SM, and IT-SK (F-value = 14.76, $p < 0.001$). Post-hoc test results show that the average frequency of IT-FK (3.16 attempts) is the highest, followed by IT-FM (2.08 attempts); IT-RM (1.61 attempts), IT-RK (1.42 attempts), IT-SM (0.26 attempts), and IT-SK (0.11 attempts) followed in descending order. IT-FK is the most frequently attempted in both male and female, while male show a higher IT-RK and female a higher IT-FM.

Knee-Lift: Significant differences were found in the technical indicators of L, I, E, S, and ST (F-value = 31.98, $p < 0.001$). Post-hoc test results show that the average frequency of I (14.21 attempts) and L (13.42 attempts) is significantly higher than that of ST (0.97 attempts), S (0.53 attempts), and E (0.34 attempts), with E recording the lowest frequency. Male favor L over I, female use I and L nearly equally, with I slightly higher.

Strike Direction: Significant differences were found in the technical indicators of UW, DW, HD, DD, and LD (F-value = 29.97, $p < 0.001$). Post-hoc test results show that the average frequency of HD (13.37 attempts) and LD (13.26 attempts) is the highest, while DW (1.76 attempts), UW (1.18 attempts), and DD (0.47 attempts) are significantly lower. Both male and female groups prioritize HD and LD, but female's frequencies are higher.

Foot Usage: Significant differences were found in the technical indicators of FI, FS, IF, and FH (F-value = 66.97, $p < 0.001$). Post-hoc test results show that the average frequency of FS (14.45 attempts) and FI (13.58 attempts) is significantly higher than that of FH (1.16 attempts) and IF (0.13 attempts). Foot usage patterns are similar in male and female groups, with FS and FI being most common.

Strike Target: Significant differences were found in the technical indicator of strike targets on the TA and HA (T-value = 127.73, $p < 0.001$), the average frequency of strikes to the TA (25.05 attempts) is significantly higher than that of the HA (4.50 attempts). Target TA significantly more than HA in both male and female groups.

Return: Significant differences were found in the technical indicators of SLT, CLT, and AT (F-value = 91.33, $p < 0.001$). Post-hoc test results show that the average frequency of SLT (20.63 attempts) is significantly higher than that of CLT (5.89 attempts) and AT (2.79 attempts). SLT is the preferred choice over CLT and AT in both male and female groups (Table V).

3.3. Structure Validation

The execution process of KT was structured from the collected data, with the major technical indicators forming each factors, such as Preparation: SS, Direct take-off: DTF, Indirect take-off: IT-FK, Knee lift: I and L, Strike direction: HD and LD, Foot usage: FI and FS, Target area: TA and HA, and Return: SLT, CLT, and AT of male, female, and overall groups (Table VI), VIF values were found less than 5, multi-collinearity was not issue, and upon evaluating the statistical significance and relevance of the outer weights, they were found to be significant ($p < 0.05$), the T-statistics was greater than 1.96, and the confidence interval (CI) did not include 0, confirming the validity of the structure (Table VI).

3.4. Path Coefficients

Direct relationships in all groups, the paths Preparation → Direct take-off, Direct Take-off → Knee lift, Knee lift → Strike direction, Strike direction → Foot usage, Foot usage → Target area, and Target area → Return stage were statistically significant ($p < 0.05$). In contrast, Indirect Take-off → Knee lift was insignificant in the male group ($\beta = 0.007$, $t = 0.069$, $p = 0.472$), but was significant in both the female and the overall group ($p < 0.05$). Preparation → Indirect take-off was insignificant in any of the groups (male: $\beta = -0.096$, $t = 0.812$, $p = 0.208$; female: $\beta = 0.181$, $t = 1.399$, $p = 0.081$; overall: $\beta = 0.060$, $t = 0.616$, $p = 0.269$) (Table VII).

In the specific indirect relationships, Preparation → Direct Take-off → Knee lift → Strike direction → Foot usage → Target area → Return stage was statistically significant for all groups (male: $\beta = 0.314$, $T = 3.628$, $p = 0.000$; female: $\beta = 0.406$, $T = 5.057$, $p = 0.000$; overall: $\beta = 0.392$, $T = 6.862$, $p = 0.000$). In contrast, Preparation → Indirect Take-off → Knee lift → Strike direction → Foot usage → Target area → Return stage was insignificant in any of the groups (male: $\beta = 0.000$, $T = 0.041$, $p = 0.484$; female: $\beta = 0.057$, $T = 1.309$, $p = 0.095$; overall: $\beta = 0.010$, $T = 0.511$, $p = 0.305$) (Table VIII).

This confirms a sequential progression in KT execution, where earlier phases such as preparation and take-off directly impact final execution and return, validating the proposed structural model.

TABLE VI: STRUCTURE VALIDATION

Formative structures			Formative indicators			Male			Female			Complete		
			VIF	Outer weights	Tstatistics	Pvalues	CI (Bias cor- rected) 5%–5%		VIF	Outer weights	Tstatistics	Pvalues	CI (Bias cor- rected) 5%– 95%	
Preparation	SS		1	1	–	–	1	1	1	1	–	–	1	1
	Direct Take-off		1	1	–	–	1	1	1	1	–	–	1	1
	Indirect Take-off		1	1	–	–	1	1	1	1	–	–	1	1
Knee lift	I		1.059	0.384	2.156	0.016*	0.117	0.703	1.263	0.791	5.35	0.000*	0.546	1.033
	L		1.059	1.019	12.164	0.000*	0.903	1.178	1.263	1.072	9.538	0.000*	0.881	1.251
	LD		1.007	0.952	11.901	0.000*	0.826	1.09	1.24	0.992	8.92	0.000*	0.799	1.165
Strike direction	HD		1.007	0.397	2.568	0.005*	0.147	0.657	1.24	0.890	5.202	0.000*	0.613	1.176
	FI		1.031	0.409	4.504	0.000*	0.266	0.564	1.045	0.657	5.379	0.000*	0.465	0.867
	FS		1.031	0.844	13.11	0.000*	0.734	0.946	1.045	0.902	9.796	0.000*	0.744	1.047
Foot sage	TA		1.011	0.998	29.392	0.000*	0.942	1.053	1.025	1.005	23.853	0.000*	0.932	1.071
	HA		1.011	0.225	3.74	0.000*	0.121	0.319	1.025	0.281	3.78	0.000*	0.157	0.401
	SLT		1.107	0.890	10.842	0.000*	0.761	1.032	1.052	0.783	12.885	0.000*	0.677	0.877
Strike target	CLT		1.022	0.385	4.349	0.000*	0.246	0.537	1.132	0.630	6.482	0.000*	0.467	0.787
	AT		1.088	0.210	2.776	0.003*	0.085	0.333	1.177	0.195	3.067	0.001*	0.091	0.3

Note: VIF: Variance Inflation Factor; CI: Confidence Intervals (bias corrected), *Significance: P < 0.05.

TABLE VII: DIRECT RELATIONSHIPS

Direct relationships	Male				Female				Complete			
	β	T	P	Results	β	T	P	Results	β	T	P	Results
Preparation -> Direct take-off	0.610	5.312	0.000	Supported*	0.804	17.230	0.000	Supported*	0.740	16.085	0.000	Supported*
Preparation-> Indirect take-off	-0.096	0.812	0.208	Not Supported	0.181	1.399	0.081	Not Supported	0.060	0.616	0.269	Not Supported
Direct take-off -> Knee lift	0.795	12.619	0.000	Supported*	0.623	7.359	0.000	Supported*	0.700	12.237	0.000	Supported*
Indirect take-off -> Knee lift	0.007	0.069	0.472	Not Supported	0.391	3.802	0.000	Supported*	0.226	2.272	0.012	Supported*
Knee lift -> Strike direction	0.823	20.478	0.000	Supported*	0.924	38.751	0.000	Supported*	0.894	36.938	0.000	Supported*
Strike direction -> Foot usage	0.892	24.568	0.000	Supported*	0.947	58.019	0.000	Supported*	0.926	48.483	0.000	Supported*
Foot usage -> Target area	0.927	32.396	0.000	Supported*	0.952	68.314	0.000	Supported*	0.950	86.998	0.000	Supported*
Target area -> Return stage	0.951	77.719	0.000	Supported*	0.973	94.000	0.000	Supported*	0.962	113.893	0.000	Supported*

Note. * Relationships are significant at $P < 0.05$, B = Beta Coefficient, T = t – Statistics, P = Probability (P) value.

TABLE VIII: SPECIFIC INDIRECT RELATIONSHIPS

Specific indirect relationships	Male				Female				Complete			
	β	T	P	Results	β	T	P	Results	β	T	P	Results
Preparation -> Direct take-off -> Knee lift -> Strike direction -> Foot usage -> Target area -> Return stage	0.314	3.628	0.000	Supported*	0.406	5.057	0.000	Supported*	0.392	6.862	0.000	Supported*
Preparation -> Indirect take-off -> Knee lift -> Strike direction -> Foot usage -> Target area -> Return stage	0.000	0.041	0.484	Not Supported	0.057	1.309	0.095	Not Supported	0.010	0.511	0.305	Not Supported

Note: * Relationships are significant at $P < 0.05$, B = Beta Coefficient, T = t – Statistics, P = Probability (P) value.

4. DISCUSSION

According to the results, Preparation stage had a significant effect on Direct take-off, which in turn stably facilitated the entire process from Knee lift $\rightarrow$ Strike direction $\rightarrow$ Foot usage $\rightarrow$ Target area $\rightarrow$ Return stage. In contrast, although Indirect take-off yielded some effects in specific situations, it did not exhibit meaningful influence over the long-term overall pathway of complete KT (Preparation–Return). the Knee lift substantially affects the determination of the Strike direction, which directly shapes Foot usage patterns, while Target area plays a pivotal role in stabilizing the Return stage.

These findings underscore the importance of focusing training on Preparation and Direct take-off to reinforce the organic connectivity of Knee lift $\rightarrow$ Strike direction $\rightarrow$ Foot usage $\rightarrow$ Target area $\rightarrow$ Return stage, enhancing overall technical efficiency in KT-MTC.

Although Indirect take-off may serve as a supportive tactical choice, it is worth noting that it can be relatively advantageous for female athletes, because the strategy that allow them to capitalize on crucial technical resources such as feint technique prior to kicking, thereby enabling more effective engagement with their opponents compared to the directly surprise attacks usually employed by male athletes (Manescardi et al., 2020). Each stage of the KT sequence, from preparation through return should be instructed as an integrated flow by meticulously examining stage-specific technical factors (knee-lift, strike direction, foot usage, and target area) enables targeted training that maximises KT execution efficiency.

MTC now exhibits stable posture affords athletes more scoring opportunities while lowering the risk of conceding points, because it allows abrupt technical changes that expose an opponent's weaknesses (Sousa et al., 2022). Female athletes, in particular, often pair a stable stance with faking actions to mislead defenders and create openings (Manescardi et al., 2020). A marked preference for front-leg kicks: rapid and direct attacks permit either immediate impact or seamless follow-ups (Manescardi et al., 2020), but for spinning techniques, although tactically diverse, are used less often because their complexity reduces scoring reliability under pressure (Del Vecchio et al., 2011).

The data also show increased use of linear-internal trajectories and linear-horizontal strike directions, indicating a demand for fast and direct attacks that maintain centre-of-gravity control and maximise electronic-protector activation (Del Vecchio et al., 2011; Liu, 2022). Contact is most

commonly made with the instep-sole, which optimises accuracy and sensor triggering as well (Kim & Kim, 2014; Liu, 2022), athletes favour trunk targets over head kicks because the larger sensor area improves scoring probability, yet they still exploit head shots when the tactical situation allows (Sousa et al., 2022). Finally, sudden single attacks, precisely timed KT dominate over consecutive or aerial sequences, reflecting a strategy aimed at maximising hit success. Therefore, mastery of the electronic scoring system is fundamental to effective point acquisition in MTC (An, 2019).

Recent trends in MTC show that athletes are moving away from power-dominant kicking techniques and prioritising speed, efficiency, and precision instead (Lu & Lin, 2022; Manescardi et al., 2020). Responding to this shift, the present study offers an updated theoretical and empirical framework that traces how each stage of KT links to the next within MTC. Unlike prior studies, this research explicitly examines relationships between technical indicators across stages, highlighting gender specific tactical advantages. The detailed structural validation using advanced methods (PLS-SEM) further distinguishes it from previous work, offering practical insights to enhance targeted training methods. Thus, it advances current understanding of technical execution, emphasizing precision and interconnectedness over traditional, power-oriented methods.

Nonetheless, questions remain regarding the specific tactical roles of these techniques and analysis methods across diverse competitive environment, the ways in which athletes promptly adjust their technique choices in response to opponents' actions (Cicchetti, 1994). Future research should investigate how KT-MTC identified in this study are influenced by other factors such as opponent height, score gaps, fighting distance, timing, rule changes (Barrientos et al., 2021), and etc., offering specific insights to further advance KT. One limitation of this study is its focus on elite-level matches, which may not generalize to lower-tier competitions. Additionally, reliance on video footage limits access to technical variables such as force output.

5. CONCLUSION

Based on theoretical and empirical approaches of KT-MTC, this study provides key techniques throughout the KT execution process structure.

First, the preparation and direct take-off stages emerged as a pivotal determinant of the entire execution process of KT sequence, as it directly influences subsequent stages such as knee-lift, strike direction, foot usage, and target selection. Second, although indirect take-off proved tactically advantageous for female athletes, its overall impact on complete KT was limited, suggesting that targeted training is needed to maximize its potential. Third, a preference for stable, direct, linear-internal trajectories, and linear-horizontal directions indicated that directly faster and more efficient KT strategies are favored within MTC. Fourth, the use of the instep-sole is efficient for activation of the electronic system. Fifth, there is a strong tendency to favor trunk strikes and single techniques making unexpected attacks in MTC.

These findings underscore the value of a detailed breakdown of KT-MTC into distinct analyses that fine-tune the interplay among each stage of KT. This nuanced approach offers valuable clarity on how different factors interact to influence KT during MTC. Consequently, coaches and athletes should implement integrated training programs that accurately reflect the KT execution process structure, with a comprehensive focus on the unique characteristics of MTC.

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No potential conflict of interest was reported by the author(s).

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DATA DEPOSITION

Ko, Junho (2025), “Kicking Techniques in Modern Taekwondo Competition”, Mendeley Data, V4, doi: [10.17632/d9zhn2z57v.4](https://doi.org/10.17632/d9zhn2z57v.4).

CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

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