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Examining the relationship between response inhibition and Taekwondo performance: The importance of ecological validity

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ABSTRACT

The present study aimed to investigate the relationship between lab- and field-based response inhibition tasks and their associations with taekwondo athletes' on-field performance. Twenty-eight senior high-school taekwondo athletes were recruited to participate in this study. Athletes' on-field performances were evaluated by three experts (i.e., national-level coaches) using a 5-point Likert scale based on the observations of regular training and competitive performances. Further, all athletes completed a series of physical fitness and skill tests, as well as response inhibition tasks measured in the lab (i.e., the go/no-go task) and the field (i.e., the go/no-go task designed using BlazePod™ technology). The results revealed that, although a significant correlation was found between lab- and field-based response inhibition measures, only the field-based go/no-go decision-making performance correlated with expert-rated on-field performance. Specifically, this measure was found to be a stronger predictor of on-field performance than anthropometry, physical fitness and taekwondo-specific skill performance. In sum, our findings suggest that using field-based measures for assessing response inhibition offers a greater predictive power for real-life performance, which may be more beneficial for other practical applications.

1. Introduction

Martial arts combat involves intricate action strategies, such as interpreting an opponent's moves, planning attacks, anticipating actions, following the coach's instructions, tuning out the crowd, evaluating combat dynamics, and making critical decisions—all of which place significant demands on cognitive resources (Faro et al., 2020; Pujari, 2024). Specifically, taekwondo, a widely practiced form of martial arts, requires a range of higher-order cognitive functions during gameplay, particularly inhibitory control, which refers to the ability to suppress inappropriate actions and thoughts before reacting (Logan & Cowan, 1984; Muggleton et al., 2010; Wang, Chang, Liang, Chiu, et al., 2013). For example, in taekwondo, athletes must inhibit their reactions to an opponent's feints or deceptive moves to avoid making incorrect responses.

Notably, inhibitory control is composed of two main components (Kao et al., 2022; Yao et al., 2024). The first is response inhibition, which involves suppressing a dominant response tendency, such as refraining from reacting to less probable stimuli during a task. The second is perceptual conflict suppression, which involves managing stimulus-induced conflicts and ignoring irrelevant distractions during decision-making processes. Both components of inhibitory control have been investigated in taekwondo. For instance, taekwondo athletes have been shown to outperform non-athletes in response inhibition (Brevers et al., 2018). Additionally, intervention studies have demonstrated that taekwondo training may enhance perceptual conflict performance in children (Cho et al., 2017; Kim, 2015). In taekwondo competitions, athletes must frequently inhibit ongoing, unwanted responses to an opponent's feints, particularly motor responses such as kicks, a skill that may be linked to superior motor inhibition (Brevers et al., 2018). Therefore, our study focuses on the response inhibition component and explores its potential correlation with sports performance.

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Despite the potential of laboratory-based response inhibition measures for investigating the cognitive abilities in support of taekwondo skills and successful performance, athletes' cognitive performance in laboratory settings may not precisely reflect their cognitive functioning concurrently with skill execution in real-world sporting situations (Kalén et al., 2021). The limited ecological validity of lab-based cognitive measures may hinder the development of performance enhancement strategies targeting sport-specific cognitive domains, such as response inhibition in taekwondo. Therefore, it is crucial to develop cognitive assessments that can be effectively administered in real-world sporting environments (Moreau, Kao, & Wang, 2024; Wang et al., 2019) in order to more accurately evaluate cognitive abilities that are closely linked to sports performance during gameplay (Hernández-Mendo et al., 2019). This approach may enhance the predictive power of measurements for competitive performance and optimize the effectiveness of athletic training.

To overcome the limitations of laboratory-based cognitive measures in taekwondo, this study aims to develop a novel field-based measure using light-emitting diode (LED) equipment (i.e., BlazePod™ technology). This equipment offers visual stimuli with customizable settings for light-up color, duration, and inter-stimulus interval as well as records response time, allowing for the design of a more ecologically valid assessment of targeted cognitive functions (e.g., response inhibition). It is worth noting that LED equipment has been shown to provide reliable performance data and has been widely used in sports science applications to test various abilities, such as speed reactive agility (Hoffman, 2020; Zakharova et al., 2019), visuo-motor and attention (Florkiewicz et al., 2014), coordination motor ability (Gierczuk & Bujak, 2014), and hand-eye coordination (Örs et al., 2019). In particular, LED equipment can simulate field-specific perceptual stimuli in a flexible manner, improving its ecological validity (Hoffman, 2020; Zakharova et al., 2019). For example, LED equipment can be mounted on walls to provide 3D space information, allowing for the assessment of coordination abilities in football athletes in a way that is more ecologically valid compared with traditional training methods (e.g., using an agility ladder). Additionally, LED equipment can be programmed to simulate sport-specific contexts during competition, allowing for the customization of the assessment according to the trainer's needs and the type of sport (Gierczuk & Bujak, 2014; Örs et al., 2019). As such, LED equipment may be able to accurately characterize the cognitive skills required for skill performance in taekwondo.

While LED equipment has been shown to be useful for measuring physical fitness in sports, to the best of our knowledge, its use in designing sport-specific cognitive tests has been limited. Given that previous research on the cognitive abilities of taekwondo athletes has primarily been conducted in controlled laboratory settings, where athletes respond using devices like a mouse or keyboard, as in traditional lab-based cognitive tasks (Travassos et al., 2013), there is a need to account for response demands that may differ in real-field scenarios. To address this gap, we utilized BlazePod™ technology to design a field-based cognitive measure that incorporates essential taekwondo-specific skills, allowing for a more realistic assessment of cognitive performance in the context of sport-specific decision-making. To this end, we designed a novel test that combined a response inhibition task (i.e., a go/no-go paradigm) with a taekwondo skill test (i.e., roundhouse kick) using BlazePod™ technology in order to enhance our understanding of the role of response inhibition in taekwondo performance.

The primary aim of this study was to investigate the factors contributing to on-field performance in taekwondo athletes by examining the relationships among anthropometry, physical fitness, taekwondo-specific skills, and response inhibition. Specifically, this study sought to determine the extent to which field-based and lab-based cognitive measures correlate with each other and how they, along with other variables, predict expert-rated on-field performance. While the study included an assessment of cross-validation between lab-based and field-based cognitive tasks, the main focus was to evaluate the predictive power of specific parameters, such as field-based response inhibition, for competitive performance. This approach emphasizes identifying actionable factors for enhancing training and performance outcomes rather than solely comparing the validity of cognitive measures across settings. We hypothesized that the athletes would exhibit similar response inhibition effects in the taekwondo-specific response inhibition task compared with computerized tasks administered in the laboratory setting. In addition, it was hypothesized that the sport-specific design of the task, incorporating a taekwondo-specific context, would prove to be a more sensitive measure in reflecting the on-field performance of taekwondo athletes.

2. Method

2.1. Participants

We recruited 30 taekwondo athletes for this study from a senior high school taekwondo team in Taichung, Taiwan. All participants were active team members who engaged in regular training for at least 4 h per day, three or more days per week. Two participants have been excluded for failing to complete the experiment, resulting in a final sample size of 28. This sample size was chosen because it allowed the detection of a large positive effect between cognitive function and sport-specific skills with 27 volleyball athletes ($\eta_p^2 = 0.17$)](Montuori et al., 2019) as well as a significant correlation between coordination motor abilities and an LED test in a study of 20 male Greco-Roman wrestlers (Gierczuk & Bujak, 2014). The weight division of the participants was distributed as follows: Flyweight (n = 10), Featherweight (n = 12), Welterweight (n = 5), and Heavyweight (n = 1) according to Olympic game rules. All of them were without any injuries or neurological problems and had not taken any medication affecting cognitive function for the past six months. Informed consent was obtained from all participants, and the study was approved by the Human Research Ethics Committee (HREC) of National Cheng Kung University. In accordance with the guidelines of the HREC, the data acquired in the present study cannot be shared with the researcher without the written re-consent of the participants.

2.2. Experimental design

In this study, written informed consent was obtained from all participants and they were given the opportunity to ask questions about the testing procedures before the experiment. The experiment was conducted over a three-day period. To prevent injury, all participants, except for the laboratory-based response inhibition task, were instructed to perform a warm-up routine of at least 30 min of static stretching, dynamic stretching, and taekwondo-specific skills exercises. On the first day, the participants completed laboratory- and field-based response inhibition tasks, the Y-balance test, and a motor coordination task (i.e., Körperkoordinations test für Kinder). On the second day, they performed a standing long jump, a 20-m sprint, and the T-agility test. On the final day, they were given taekwondo-specific tests and the Progressive Aerobic Cardiovascular Endurance Run (PACER). To avoid the acute effects of physical exercise on cognitive function (Kao et al., 2022; Wang et al., 2023), the response inhibition tasks were administered before all other fitness tests. Moreover, taekwondo experts (e.g., national-level coaches) evaluated the on-field taekwondo performance of the participants. All tests were administered by research assistants under the supervision and guidance of coaches and experts.

2.3. Measurements

2.3.1. Expert-rated on-field performance

This study used a modified version of the expert-rated on-field performance assessment from previous studies (Hagyard et al., 2021; Vallerand et al., 2008). We initially sought the opinions of three experts holding World Taekwondo Headquarters-certified black belts (Table 1) to assess the suitability of evaluating taekwondo athletes' performance during matches, following the completion of the Likert scale design. These experts assessed the athletes' performance during county and national high school competition based on six criteria, using a 5-point Likert scale. These criteria were: "attack distance control," "attack time control," "ability to focus," "tactical execution," "top kicking ability," and "defensive ability." Each of these criteria was rated on a Likert scale ranging from 1 (worst) to 5 (best), yielding a total score out of 30.

2.3.2. Aerobic fitness assessment

Participants' aerobic capacity were evaluated using the PACER test, which has the capacity to reliably evaluate fitness level of elite athletes (Wang et al., 2017, 2020). The following calculation formula was used to estimate their maximal oxygen consumption (VO_{2max}) value (Boiarskaia et al., 2011).

$$VO_{2\,max} = 41.77 + 0.49 \times laps - 0.0029 \times laps^2 - 0.62 \times BMI + 0.35 \times gender \times age;\ where\ gender = 0\ for\ girls,\ 1\ for\ boys$$

2.3.3. Standing long jump

The standing long jump was utilized in this study to assess the lower limb muscle power of the participants (Chaabene et al., 2018). The best records from the three trials were selected for analysis. The unit of measurement used was centimeters (cm).

2.3.4. Y-balance test

The Y-balance test was used in this study to assess the participants' dynamic balance (Plisky et al., 2009). A composite score (CS) was calculated as: CS = ([maximum anterior reach distance + maximum posterior medial reach distance + maximum posterior-lateral reach distance]/[leg-length*3]) *100 (Schwiertz et al., 2019).

2.3.5. 20m sprint test

The 20m sprint test was conducted to evaluate the speed capabilities of the participants (Chaabene et al., 2018). The best records from the two trials were chosen for further analysis. The unit of measurement used for this test was seconds (s).

2.3.6. Agility t-test

The T-test was adopted to test participants' planned agility (Chaabene et al., 2018; Monks et al., 2017). Moreover, we used Blaze-Pod™ technology to set up the test (Fig. 1). The best records from the two trials were chosen for further analysis. The unit of measurement used for this test was milliseconds (ms).

2.3.7. Motor coordination task

This study employed the *Körperkoordinations test für Kinder* (KTK) to assess the coordination ability of taekwondo athletes (Coppens et al., 2021). The test consists of four parts: (a) Walking backward along balance beams of decreasing widths (6 cm, 4.5 cm, and 3 cm, respectively). Participants earned one point per step, with a maximum of eight points. Each balance beam was performed three times, and the total number of points was recorded. (b) Lateral jumping, where the number of jumps was tallied over two trials. (c) Hopping on one leg over foam obstacles with varying heights (ranging from 0 to 15 layers). Participants had three attempts per layer, with scores ranging from 3 points for passing on the first try, 2 points for passing on the second try, and so on. The maximum achievable score was 78. (d) Sideways movement, where the number of relocations was summed over two trials (Pion et al., 2014).

Table 1
Experts' information.

Experts	World Taekwondo Federation	National coach certificate	National referee certificate
Coach WHC	7th Dan grade	A-level	A-level
Coach WYC	7th Dan grade	A-level	A-level
Coach YWH	4th Dan grade	C-level	C-level

2.3.8. Taekwondo-specific skill test

We measured the participants' planned agility during kick context and speed during taekwondo-specific skills (roundhouse kick) by using a frequency speed of kick test (FSKT) (da Silva Santos et al., 2015) and taekwondo-specific agility test (TSAT) (Chaabene et al., 2018).

2.3.9. Response inhibition measures

This study employed two go/no-go tasks to measure response inhibition in both lab and field settings. Participants were instructed to perform the lab-based go/no-go task first, followed by the field-based task, in order to avoid the acute effects of physical exercise that could potentially influence the results of interest (Kao et al., 2020, 2021).

Lab-based go/no-go task. The lab-based go/no-go tasks used in this study were programmed and executed using E-Prime 2.0 (Psychology Software Tools, Sharpsburg, PA). The tasks consisted of two parts: a simple go and a go/no-go condition. The task required participants to monitor two boxes (height: 3 cm, width: 3 cm) of stimuli presented in the center of a computer screen (Fig. 2). The dot stimuli had a radius of 2.8 cm, and the participant-to-screen distance was 60 cm. The space between the two boxes was 12 cm, and the visual angle was set to 2°. Participants were instructed to respond as quickly and accurately as possible by stepping on the corresponding pedal (Label: AUSPICIOUS, Model: FS-1/2M) when presented with target stimuli while withholding responses to non-target stimuli. The purpose of using the lower limb to make the response was to align with the field-based cognitive test, and it has been shown to provide a valid measure of individual differences in cognitive performance (Wang et al., 2015). Previous research suggests that go/no-go tasks should use fast-paced designs, with trial durations under 4 s, and include rare no-go trials (no-go probability = 0.2) to reliably trigger prepotent motor activity during no-go trials (Wessel, 2018). Thus, the simple go condition in this study consisted of 100 stimuli in cyan and yellow, requiring participants to respond to each cue by stepping on the pedal. The go/no-go condition also included 100 stimuli, comprising 80 go cues and 20 no-go cues (Bezdjian et al., 2014; Nieuwenhuis et al., 2003). The two colors (i.e., cyan and yellow) were counterbalanced across conditions and participants. The inter-trial interval (ITI) ranged from 1500 to 2000 ms to discourage anticipatory responses. A fixation cross was displayed in the center of the screen during the ITI. Instructions were displayed on the computer screen at the beginning of the task, and participants stepped on the corresponding pedal to begin the task.

Field-based go/no-go task. This study designed a go/no-go task conducted in the field using BlazePod™ technology (Fig. 3). This LED equipment has been widely employed to measure athletes' performance in the field such as response time (RT) in young adults (ICC = 0.82) (de-Oliveira et al., 2021), reactive agility drills in football players (ICC = 0.88) (Hoffman, 2020), and sector reactive agility in Touch-rugby players (ICC = 0.97) (Chow et al., 2022). The excellent reliability demonstrated in previous studies suggests that BlazePod is a dependable tool for measuring response performance in field settings. Furthermore, its millisecond-level precision indicates that it offers sensitivity comparable to E-Prime.

In this task, the participants were instructed to stand and face a sandbag (height 185 cm, diameter 28 cm), and their responses were recorded by kicking the BlazePod™ technology. Four pieces of BlazePod were attached to the sandbag on each scoring side (left and right) and position (middle and head). The choice of head and middle scoring

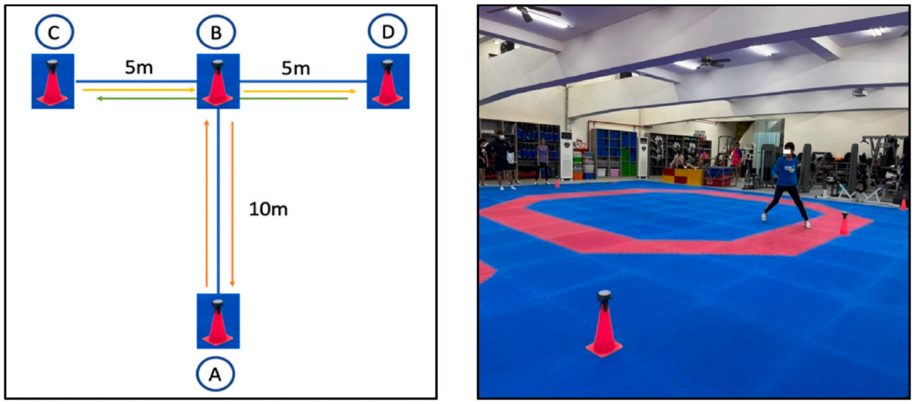

Fig. 1. Schematic representation of the agility *t*-test.

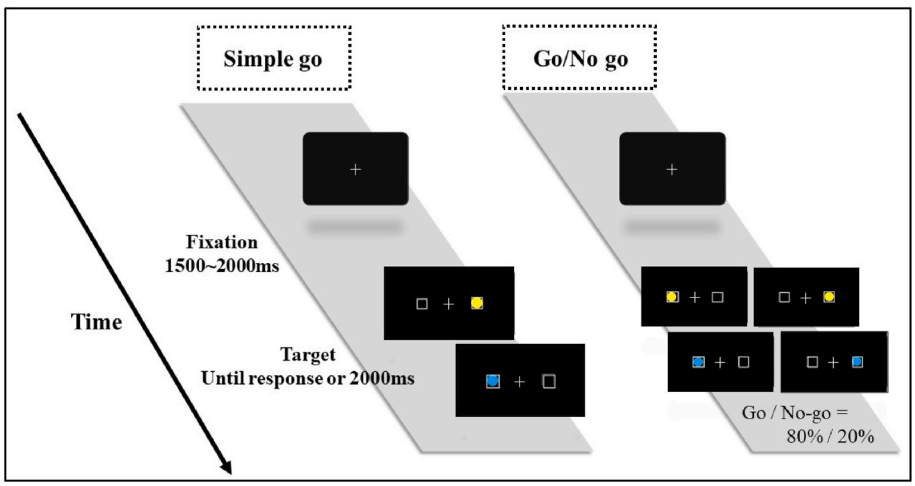

Fig. 2. Illustration of the experimental procedure of the go/no-go task.

Fig. 3. Schematic representation of the field-based response inhibition task.

positions were based on the individual heights of each participant's sternum and chin (Estevan & Falco, 2013). This test consisted of two parts. In the simple go condition, when the pod was lit, participants were instructed to respond as quickly and accurately as possible using a roundhouse kick. The pod's light-out setting (the duration the pod remained lit) was 2000 ms or until a response was made, and the pod light delay time (the interval between one pod's light turning off and the next one turning on) ranged randomly from 500 ms to 1000 ms, designed to replicate the response inhibition task protocol used in the lab. In the go/no-go condition, the pod's light-out setting was similar to that of the simple go condition. Participants were divided into two groups to counterbalance the task design. One group assigned yellow stimuli as the "go" cue and cyan stimuli as the "no-go" cue, while the other group reversed this, assigning yellow stimuli as the "no-go" cue and cyan stimuli as the "go" cue. Each participant completed five blocks, with each block consisting of 20 trials. The trial settings were pseudorandomized and evenly distributed across four positions.

To further reflect the go/nogo decision-making performance in the lab and the field, the decision-making measurement was defined as [lab/field-based go/nogo RTs] - [lab/field-based simple go RTs], indicating the time needed for making a go/nogo decision (Wang, Chang, Liang, Shih, et al., 2013). We only performed this measure on RTs due to the ceiling effect in accuracy rates and the lack of significant correlations between lab-based and field-based measures for the coefficient of variation (CV) of RT.

2.4. Statistics analysis

The cognitive measures, including accuracy rates, RTs, and CV of RT from the go/no-go tasks conducted in both lab and field settings were collected for further analysis. Accuracy was defined as the percentage of correct responses. However, due to its relatively high value, accuracy was excluded from further analysis. Mean RTs were calculated as the average time for correct responses, excluding error trials, non-response trials, and RTs deviating by more than three standard deviations (SDs). The CV of RT was calculated by dividing the SD of RT by the mean RT. The interrater reliability of the expert-rated on-field performance was evaluated using intraclass correlation. As per the qualitative assessment, ICC values of less than 0.7 represent low reliability, values between 0.7 and 0.9 indicate high reliability and values greater than 0.9 indicate very high reliability. The correlation between lab- and field-based response inhibition measures, as well as the association among participants' physical fitness, taekwondo-specific skills, and response inhibition, were analyzed using Pearson's correlation method. Hierarchical linear regression was used to determine the most predictive factors related to on-field performance, including skill-related fitness, taekwondo skills, and response inhibition (see results for details). Significance level was set at $p < .05$. All analysis was performed using JASP Team (2021)Software System.

3. Results

3.1. The descriptive statistics for the examined variables

The descriptive statistics for demographic information, anthropometry, physical fitness, Taekwondo skill performance, response inhibition, and expert-rated on-field performance are presented in Table 2.

3.2. Interrater reliability of expert-rated on-field performance

Table 3 displays the results of the interrater reliability assessment performed on 28 subjects by three raters. The analysis demonstrated high reliability across all tests. To assess reliability, the intra-class correlation coefficient (ICC) model (2,1) was used. ICC is commonly employed in research settings to evaluate the consistency of measurements made by different raters or observers on the same set of subjects or items. In this study, the ICC was found to be 0.89, with a 95% confidence interval (CI) ranging from 0.474 to 0.965.

Table 2
Descriptive statistics of participants' health- and skill-related fitness, Taekwondo-specific skill tests, and expert-rated on-field performance (Mean ± Standard Deviation).

Variables	N = 28 (Male = 16)	Minimum	Maximum
Age (year)	16.29 ± 1.20	14.00	18.00
Experience (year)	7.96 ± 2.91	2.60	13.40
Height (cm)	170.96 ± 7.28	155.00	184.00
Weight (kg)	59.51 ± 8.33	42.00	49.00
BMI (kg/m^2)	20.32 ± 2.26	16.18	25.28
Waist-hip ratio (waist/hip)	0.74 ± 0.05	0.67	0.84
Standing long jump (cm)	214.73 ± 28.59	159.00	280.00
T-test (sec)	12.47 ± 0.99	10.97	15.49
20m sprint (sec)	3.90 ± 0.31	3.13	4.56
Lower limb length (cm)	89.14 ± 4.80	78.00	97.00
Y-balance Left (cm)	105.46 ± 10.94	78.35	122.35
Y-balance Right (cm)	106.95 ± 10.60	86.94	125.49
KTK	244.50 ± 19.47	208.00	283.00
TSAT (sec)	1.91 ± 0.31	1.39	2.59
FSKT (reps)	42.36 ± 4.00	36.00	51.00
PACER (lap)	71.32 ± 17.50	50.00	107.00
VO_{2max} (ml/kg/min)	51.77 ± 3.81	43.34	57.43
Expert-rated on-field performance	21.43 ± 3.48	13.00	27.00

Table 3
Expert-rated on-field performance.

Intraclass Correlation			
Type	Point Estimate	Lower 95% CI	Upper 95% CI
ICC 2,1	0.892	0.474	0.965

Note. 28 subjects and 3 raters/measurements. ICC type as referenced by Shrout & Fleiss (1979).

3.3. The relationships across, physical fitness, taekwondo skill performance, response inhibition, and expert-rated on-field performance

Tables 4 and 5 present the descriptive statistics and correlation analyses for the go/no-go tasks conducted in both lab-based and field-based settings. The accuracy rates for the simple go and go/no-go tasks in both lab and field conditions exhibited a ceiling effect and thus were not included in further analyses. Significant correlations were found between RTs in both the lab-based and field-based simple go conditions ($r = 0.488$, $p = .008$) and go/no-go conditions ($r = 0.690$, $p < .001$). However, no significant correlations were found for the CV of RT in both the simple go ($r = -0.038$, $p = .850$) and go/no-go conditions ($r = 0.183$, $p = .351$). Pearson's correlation analysis indicates a significant correlation between skill-related fitness and taekwondo-specific skills (appendix 1). However, no significant correlations were found with response inhibition (appendix 1).

Table 4
Behavior performance description.

Conditions		Lab-based	Field-based
Simple go	Accuracy (%)	99.9 (0.003)	100
	RTs (ms)	422.54 (50.10)	866.21 (61.05)
	RTs of CV	0.19 (0.06)	0.15 (0.07)
Go/no-go	Accuracy (%)	99.5 (0.006)	99.9 (0.004)
	RTs (ms)	509.88 (69.32)	856.97 (64.43)
	RTs of CV	0.23 (0.10)	0.14 (0.04)

Note. RTs: response times; CV: coefficient of variation.

Table 5
The correlation between lab- and field-based response inhibition.

Variable		Simple go (Lab) RT	Go/No-go (Lab) RT	Simple go (Lab)CV	Go/No-go (Lab) CV	Simple go (Field) RT	Go/No-go (Field) RT	Simple go (Field)CV	Go/No-go (Field)CV	Expert-rated
Simple go (Lab) RT	Pearson's r	–								
	p-value	–								
Go/No-go (Lab) RT	Pearson's r	0.812 ***	–							
	p-value	<0.001	–							
Simple go (Lab)CV	Pearson's r	0.187	0.494 **	–						
	p-value	0.342	0.008	–						
Go/No-go (Lab) CV	Pearson's r	0.093	0.227	0.591 ***	–					
	p-value	0.638	0.245	<0.001	–					
Simple go (Field) RT	Pearson's r	0.488 **	0.569 **	0.113	−0.094	–				
	p-value	0.008	0.002	0.566	0.632	–				
Go/No-go (Field) RT	Pearson's r	0.524 **	0.690 ***	0.436 *	0.141	0.767 ***	–			
	p-value	0.004	<0.001	0.020	0.476	<0.001	–			
Simple go (Field)CV	Pearson's r	−0.091	−0.060	−0.038	0.165	−0.115	−0.328	–		
	p-value	0.646	0.763	0.850	0.400	0.560	0.088	–		
Go/No-go (Field)CV	Pearson's r	0.258	0.218	−0.089	−0.022	0.424 *	0.278	0.183	–	
	p-value	0.185	0.265	0.653	0.910	0.025	0.152	0.351	–	
Expert-rated	Pearson's r	−0.082	−0.128	−0.421 *	−0.254	0.160	−0.118	0.309	0.362	–
	p-value	0.677	0.516	0.026	0.192	0.415	0.549	0.109	0.058	–

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

3.4. *Multiple regression of the predictive factor for on-field performance*

According to the correlation results (appendix 1), waist-hip ratio, the laps of PACER, VO_{2max}, TSAT and field-based go/no-go decision were found to relate to on-field performance, we performed an enter multiple regression analysis including these factors to examine the predictive factor of on-field performance. The results revealed that the model had moderate predictive capacity ($r = 0.70$, $R^2 = 0.49$, *adjusted* $R^2 = 0.37$) and that the field-based go/no-go decision ability had the most significant correlation ($p = .044$) as compared to other factors (Table 6).

4. Discussion

This study investigates the correlation between laboratory- and field-based go/no-go performance in other's relationships with expert-rated on-field performance. The main findings are as follows: (1) the positive relationship between classic laboratory-based behavioral measures of response inhibition and the measure using LED equipment (i.e., BlazePod™ technology) in the field; (2) more significant correlation of field-based response inhibition measure for expert-rated performance than other factors. These findings indicate that LED equipment may be a valid intermediary to connect lab-based response inhibition tasks to the taekwondo field, and we seek to provide evidence for potential practical applications of cognitive measures and offer future directions for talent identification and neurocognitive training in taekwondo.

To the best of our knowledge, our study is the first to examine the correlation between the response inhibition performance of taekwondo athletes in both laboratory and field settings. Here we utilized BlazePod™ technology to a novel and innovative go/no-go task specifically tailored for examining response inhibition of taekwondo athletes during field performance, which enabled us to investigate the relationship between go/no-go task performance in controlled laboratory settings and real-world field conditions. Although task performance in labortory and field-based settings was correlated, only the field-based cognitive measure was associated with expert-related performance. This finding highlights the need to increase the ecological validity of research conducted in labs (Kalén et al., 2021).

In addition, we explore the correlations among response inhibition, physical fitness, taekwondo-specific skills, and expert-rated on-field performance in taekwondo athletes to gain a better understanding of which factor may more effectively explain taekwondo performance. Our correlation analysis found significant correlations between expert-rated on-field performance and aerobic fitness, waist-hip ratio, TSAT, and field-based go/no-go decision-making performance. Furthermore, our multiple regression analysis demonstrated that these variables collectively accounted for 37% of the variance in expert-rated on-field performance. Notably, field-based go/no-go decision-making performance emerged as particularly significant in predicting expert-rated on-field performance.

This study did not find a significant association between sports performance and response inhibition performance in the laboratory, implying the inherent limitations of traditional cognitive tasks conducted in controlled laboratory settings in predicting real-world sports performance. Despite the critical correlation between laboratory measures of inhibitory control and real-world sports performance has been demonstrated in many studies (Albuquerque et al., 2019; Verburgh et al., 2014) and suggests that athletes with superior inhibitory control

Table 6
Enter multiple regression analysis.

	Expert-rated on-field performance		
	B	*SE B*	*β*
Waist-hip ratio	−17.192	18.637	−0.236
The laps of PACER	0.038	0.058	0.190
VO2max	−0.397	0.233	−0.435
Field-based go/no-go decision	−0.028	0.013	−0.344*
TSAT	3.554	2.070	0.316
R^2	0.49		
Adj R^2	0.37		
F	4.233*		
df	(5, 22)		

*$p < .05$ **$p <. 01$ ***$p < .001$.

also have higher expertise level in the field (Kalén et al., 2021), consistent findings in this regard have yet to be presented (Elferink-Gemser et al., 2018). One possible explanation is that cognitive tasks conducted in a lab setting have limitations in inferring genuine sports performance. Moreover, previous research has suggested that despite using stimuli in laboratory tasks that resemble sport-specific contexts, the results may not always align with expectations (Pfister et al., 2023). Taken together, the relationship between cognitive function measured in laboratory settings and actual sports performance in real-world scenarios remains uncertain.

Interestingly, our study utilized a field-based go/no-go task designed with LED equipment and observed that expert-rated sports performance might be better explained by field-based response inhibition performance compared to other factors such as TSAT, aerobic fitness and waist-hip ratios. These findings potentially support the argument emphasizing the significance of employing specific perceptual skills in real-world scenarios (Simonet et al., 2022). Specifically, athletes with higher performance in taekwondo may demonstrate a higher level of response inhibition in taekwondo-related scenarios. Our results further confirm previous research showing that experts who engage in task-specific activities exhibit superior behavioral accuracies and faster RTs in specific design tasks (Muraskin et al., 2015), suggesting a link between neural differences and enhanced performance in task-specific contexts. As a result, our study demonstrated that designing cognitive tasks that closely resemble real-world scenarios (e.g., sport-specific responses) may provide a more accurate assessment of decision-making abilities. This may also support the need to design novel measures that combine both cognitive and physical skills, in order to more accurately reflect true cognitive ability during real-world physical activity (Kao et al., 2024).

According to Simonet et al. (2022), who advocate for research that extends beyond the laboratory, our findings have significant implications for athlete training, as well as the development of more effective assessment tools for measuring on-field performance. To achieve this, future research could prioritize the design of ecologically valid measures instead of traditional laboratory tests by incorporating sports technology equipment such as LED sensors (Lucia et al., 2023; Molinaro et al., 2023) and augmented reality. This approach would facilitate the transition from controlled laboratory environments to real-world settings, allowing for more accurate and efficient assessments of cognitive characteristics in specific populations and contexts. These populations include military personnel, police officers, firefighters, athletes, and others. By harnessing such technology, researchers can gain a deeper understanding of how cognitive function influences expert performance in real-world scenarios and tailor interventions accordingly.

Although our study employs an innovative approach and reveals promising findings, there are several limitations that must be considered. Firstly, we only employed one type of executive function task, while several other measurements are available such as the stop-signal reaction task, flanker task, Stroop task, and so on (Moreau & Wiebels, 2021). However, a limitation lies in the unavailability of BlazePod™ for flexibly designing complex stimulus presentations for certain cognitive tasks. In future research, more advanced technological settings are warranted to accommodate a variety of cognitive task designs. Secondly, it is worth noting that our sample across taekwondo weight divisions exhibits uneven distribution, following the Olympic game rules, with 10 participants in the Flyweight category, 12 participants in the Featherweight category, 5 participants in the Welterweight category, and 1 participant in the Heavyweight category. This variance in sample representation may limit the generalizability of our findings, particularly in relation to heavyweight division taekwondo athletes. Despite this limitation, we wished to ensure that all our participants belonged to the same training group, adhered to identical training plans, and engaged in training sessions of the same duration. By doing so, we mitigated concerns pertaining to potential training differences among them. However, future research could benefit from recruiting a greater number of participants from different weight divisions to obtain stronger evidence for the research question. In this regard, future research with larger sample sizes would also be beneficial for investigating the complex relationships among variables, for example using structural equation modeling or network analysis. These approaches would allow for a more comprehensive modeling of multicollinearity among the predictor variables (e.g., PACER and VO_{2max}; lab- and field-based cognitive measures) and provide a more robust understanding of their impact on on-field performance. Third, all participants were instructed to complete the laboratory task before engaging in the field-based response inhibition task that may induce the known acute exercise effect on cognition. Thus, the completion of the laboratory task prior to the field-based task may introduce a learning effect. Fourth, despite following the recommendations from previous studies by designing the task with a low frequency of no-go stimuli in order to induce a high demand for response inhibition (Wessel, 2018), we still observed relatively high accuracy in the go/no-go tasks. This may, in part, be attributed to the simplicity of the stimulus design. To better induce higher levels of response inhibition demand, we recommend that future research increase the difficulty and complexity of the stimuli (e.g., sport-specific stimuli), which may enhance the predictive value of the task. Fifth, while the field-based go/no-go task incorporated taekwondo-specific response actions (e.g., kicks), the lab-based go/no-go task required participants to respond by stepping on a corresponding pedal. This difference in experimental setting may have influenced participant motivation, which could have contributed to the findings observed in this study. Additionally, variations in movement range and input types between the lab-based and field-based tasks likely contributed to differences in performance. These discrepancies are more likely attributable to the complexity of the movements rather than the cognitive processing of go and no-go trials. Future studies should examine these possibilities. Lastly, it is crucial to acknowledge that this study utilized a cross-sectional design, which may restrict the generalizability of the findings compared to longitudinal research designs. Therefore, it is recommended that future research explores whether field-based cognitive tasks can provide enhanced predictive capabilities for athletic development.

5. Conclusion

In conclusion, our findings are important to refine our understanding of how experimentally constrained results might translate to ecological contexts. The present research shows that field-based response inhibition task may be a more sensitive measure to reflect the real-world performance of taekwondo and could provide a new framework for taekwondo training and talent identification.

CRediT authorship contribution statement

Wei-Li Hsieh: Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Shih-Chun Kao:** Writing – review & editing, Supervision, Methodology. **David Moreau:** Writing – review & editing, Supervision. **Chien-Ting Wu:** Writing – review & editing, Supervision, Methodology. **Chun-Hao Wang:** Writing – review & editing, Supervision, Resources, Methodology, Funding acquisition, Conceptualization.

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Not applicable.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2025.102817.

Data availability

In accordance with the guidelines of the HREC, the data acquired in the present study cannot be shared with the researcher without the written re-consent of the participants.

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