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The Association between Tai Chi Level and Behavior Rating Inventory of Executive Function Adult-Version: Exploring the Benefits of Tai Chi on Executive Functions

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Abstract

This study uses the Behavior Rating Inventory of Executive Function-Adult Version (BRIEF-A) to explore the link between Tai Chi and executive function in young adults. The results reveal an unexpected finding: elite Tai Chi practitioners, known for their high physical coordination, perform worse on inhibition tasks. This suggests that achieving motor automaticity may influence cognitive processing. As these individuals develop instinctive skills, their cognitive resources might be diverted, leading to reduced inhibitory control during simultaneous cognitive tasks. In the second phase of the study, broader cognitive benefits associated with regular Tai Chi practice are identified, including improvements in emotional control, working memory, and organizational skills. Overall, these findings show that Tai Chi promotes physical health and aids emotional regulation. This research adds to the growing literature on the positive effects of Tai Chi on cognitive functions and highlights potential applications in various settings. It aims to provide further evidence of Tai Chi's benefits in academic environments, enhancing physical fitness, cognitive abilities, and emotional well-being among diverse adult groups.

Keywords

Executive Function, Inhibition, Tai Chi, College Student, Physical Health

1. Introduction

The Chinese sports system is renowned for its rigorous training methods and strong emphasis on discipline and dedication (Brownell, 1995; Toner & Moran, 2021). Recently, there has been a growing focus on the mental and physical health of athletes within this system (Xi et al., 2024). The belief is that a robust mind and body are essential for excelling in any sport. A significant aspect of this system contributing to athletes' mental and physical well-being is its holistic training approach (Wang et al., 2023b). These mental abilities fall under the concept of executive function, a complex set of skills vital for success in various life areas. Whether in academic achievement, professional endeavors, or healthy relationships, the ability to plan, organize, regulate emotions, control impulses, and manage time effectively is essential. Developing and refining these skills can lead to better decision-making, increased productivity, and enhanced overall well-being (Diamond, 2013a, 2013b; Friedman & Miyake, 2017; Friedman et al., 2006).

Executive functions refer to cognitive processes that manage thinking and behavior, allowing for more complex types of thinking like problem-solving, planning, decision-making, and creativity (Diamond, 2013a, 2013b; Friedman & Miyake, 2017; Friedman, Miyake, Corley, Young, DeFries, & Hewitt, 2006). Researchers generally agree on two types of Executive functions: core Executive functions which includes inhibition, working memory, and cognitive flexibility, and high-level Executive functions, which involves planning, reasoning, problem-solving, and metacognition (Miyake et al., 2000; Vestberg et al., 2021). Some researchers also include elements like affective decision-making and the monitoring of behavior in response to specific emotional states (Kerr & Zelazo, 2004; Petrides, 1996). Inhibitory control refers to the suppression of dominant but irrelevant response tendencies (Benedek et al., 2014). Working memory involves monitoring and coding incoming information for relevance, constantly updating and replacing old, temporarily stored data with new and more pertinent information (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). Lastly, cognitive flexibility is the ability to simultaneously consider multiple conflicting representations of a single object or event, or to quickly adapt to new demands and rules (Huijgen et al., 2015; Jacques & Zelazo, 2005).

Physical activity has been shown to improve the overall mental health so as to achieving an optimal level of cognitive development (Collins & Koechlin, 2012; Garon et al., 2008; Lunt et al., 2012). Physical exercises such as Tai Chi, has shown to have benefits on the cognitive function of Tai Chi practitioners (Adelman & Taylor, 2010; Aithal & Aithal, 2023; Contreras-Osorio et al., 2021; Miller, 2019). This ancient Chinese martial art focuses on slow, deliberate movements, deep breathing, and a meditative state. Tai Chi, also known as Tai Chi Chuan, is a Chinese sport that has been practiced for centuries. It is a slow and graceful form of exercise that focuses on developing balance, strength, and flexibility (Rodrigues et al., 2023; Wehner et al., 2021). Many people practice Tai Chi for its health benefits, including stress reduction, improved circulation, and increased energy levels (Duan et al., 2024). While Tai Chi is traditionally practiced as a form of self-defense and meditation, it has also become popular as a competitive sport (Gong et al., 2023; Yu, 2013). Tai Chi's methodical movements and mindful breathing offer a counterbalance to the fast-paced, often stressful student lifestyle, promoting calmness and focus which can enhance overall performance (Henning et al., 2021; Zuo et al., 2020) fostering the development of new options and outcomes (Lezak, 2004; Shallice & Vallar, 1990).

Participating in Tai Chi encourages improved physical fitness and relaxation, essential for managing stress and anxiety prevalent in academic environments (Ibrahim et al., 2024; Zhang et al., 2012). Furthermore, the practice fosters resilience and discipline, qualities critical for navigating the complexities of university life and beyond (Hammond & Lemon, 2024). Regular engagement fosters a tranquil state of mind, empowering students to tackle challenges more effectively (Hellison, 2000). A lot of studies indicate that Tai Chi can affect both cognitive and executive function indicating it effect on not just working memory inhibition and shift (Menglu et al., 2021; Shen et al., 2021), it has been seen to affect emotion control, self-control and order factors of executive function (Hellison, 2010; Lawson, 2005). However, the existing lack of comprehensive evidence in this domain restricts the appropriate application of Tai Chi and fails to fully elucidate the scientifically recognized benefits associated with its practice. This research aims to evaluate the effects of Tai Chi on various components of executive functions and to discern differences between the executive functions of Tai Chi practitioners and non-practitioners, while also incorporating additional aspects of executive function. To investigate this particular dimension, the Behavior Rating Inventory of Executive Function-Adult Version (Brief-A) questionnaire was employed, as it encompasses multiple aspects of executive function. This research seeks to bridge the gap between Tai Chi and executive function, providing a quantitative analysis to inform further experimental studies. Additionally, it may serve as a tool in academic institutions to assess the executive function characteristics of college students practicing Tai Chi. Understanding these effects could facilitate the development of tailored programs that maximize the benefits of Tai Chi within university settings, thereby supporting not only physical fitness but also cognitive and emotional well-being. Moreover, the investigation was conducted among a group of young adult practitioners, as much of the existing research on the cognitive impacts of Tai Chi has primarily focused on older adults or individuals with specific health conditions. This narrow focus overlooks a broader adult demographic across varying age groups and health statuses, thereby restricting insights into the greater applicability and potential advantages of Tai Chi.

1.1. Method

The BRIEF-A is a 75-item assessment tool designed to evaluate executive function, utilizing a three-point Likert scale where higher scores indicate greater difficulties. It is suitable for individuals with a minimum reading proficiency of fourth grade. The assessment produces an overall score known as the Global Executive Composite (GEC), which encompasses two key components: the Behavioral Regulation Index (BRI) and the Metacognition Index (MI). The Behavioral Regulation Index includes four specific areas: Inhibition, Shift, Emotional Control, and Self-Monitoring. Meanwhile, the Metacognition Index consists of five areas: Initiation, Working Memory, Planning/Organizing, Task Monitoring, and Organization of Materials. Importantly, all participants scored within normal ranges on the three validity scales of the BRIEF-A: Negativity, Infrequency, and Inconsistency. This tool was standardized on a diverse sample of 1050 adults aged 18 to 90, reflecting the demographic characteristics of the 2002 U.S. Census. The BRIEF-A demonstrates outstanding internal consistency, with Cronbach alpha coefficients ranging from 0.93 to 0.96 across its main indices. Additionally, it exhibits high reliability in test-retest assessments, with correlations between .93 and .94 for these indices (Roth et al., 2005).

Participants were recruited from a diverse range of colleges and universities, focusing on students across various academic majors and years of study. The recruitment strategy involved collaboration with faculty members, who were engaged to promote the study within their classrooms and encourage student participation. To ensure the validity of comparisons between Tai Chi practitioners and non-practitioners, participants were required to meet specific inclusion criteria, such as being enrolled as full-time students and having no prior experience with Tai Chi. Additionally, to control for potential confounding variables, participant groups were matched based on grade level and gender.

Data collection was conducted through an online platform, utilizing a Chinese questionnaire interface. This approach facilitated the gathering of important information regarding students' Tai Chi experiences and their executive functions. A total of 789 students participated in the survey, with 220 identifying as Tai Chi practitioners and 569 as non-Tai Chi practitioners. This classification established a clear comparative framework for examining the potential effects of Tai Chi practice on cognitive abilities. Following the initial data collection, a validity assessment was performed, culminating in the retention of 156 Tai Chi practitioners and 467 non-Tai Chi practitioners for further analysis. This retention signifies that approximately 71% of Tai Chi participants and about 82% of non-Tai Chi participants provided valid responses, thereby enhancing the robustness of the dataset for subsequent evaluations. The integrity of the data collection process fundamentally supports the reliability of the study's outcomes. To thoroughly assess participants' Tai Chi experiences, a self-reported demographic form was employed to gather essential information, including gender, years of Tai Chi practice, specific styles practiced, skill levels based on the general administration of sport of China, weekly training hours, and academic performance as indicated by university grades. This comprehensive categorization facilitated a nuanced evaluation of each participant's skill level, which is crucial for understanding the relationship between Tai Chi practice and cognitive functions. After demographic categorization, participants completed the BRIEF-A self-report form, intended to measure various dimensions of executive function, such as cognitive flexibility, inhibitory control, and working memory. The primary objective of the research was to identify potential correlations between Tai Chi skill levels and these cognitive functions, aiming to elucidate the cognitive benefits associated with Tai Chi practice. Importantly, the validity of participants' responses was stringently maintained throughout the study, as none of the participants exhibited elevated scores on the BRIEF-A validity scales, specifically Negativity, Infrequency, and Inconsistency, ensuring the authenticity of their responses and their accurate reflection of cognitive functioning. Furthermore, the questionnaire underwent reliability and validity assessments to evaluate its effectiveness. Participants' BRIEF-A raw scores were systematically organized according to the scoring interpretations provided in the test manuals, contributing to a structured analysis.

For the statistical analysis, SPSS version 27 and Excel were utilized to conduct a comprehensive evaluation of the gathered data. A variety of statistical techniques were employed, including Univariate Analysis of Variance (ANOVA) and independent sample t-tests, followed by post-hoc tests to compare Tai Chi skill levels across different participant groups. The application of ANOVA and post-hoc tests was essential for identifying significant differences in BRIEF-A scores among subgroups, with results presented alongside means, standard deviations, and p-values. A significance level of $p < 0.01$ and $p < 0.05$ was adopted to establish statistical significance, ensuring that the findings were robust and reliable. Should significant differences be detected among the groups, the post-hoc analyses provided additional insights into specific group disparities, thereby enhancing the comprehensiveness of the findings. Additionally, correlation analyses were conducted to explore the relationships between Tai Chi participation and BRIEF-A scores. This multifaceted analytical approach afforded a clearer understanding of how Tai Chi practice interacts with cognitive functioning across various subgroups.

1.2. Reliability

The following **Table 1** presents reliability data for various components of executive function, comparing two groups in our study: Tai Chi participants and non-participants, alongside a normative dataset for reference. Most reliability coefficients for both groups fall within the range of 0.7 to 0.9, which suggests adequate reliability. However, the Task Monitor component exhibited a reliability value of 0.696, which does not meet the acceptable threshold of 0.7. Conversely, the overall reliability of the questionnaire is 0.973, surpassing the 0.9 threshold and indicating high reliability for the assessment of executive function within the studied populations.

In **Table 2**, the validity of the data was assessed through the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity. These statistical tests were employed to evaluate the appropriateness of factor analysis and to ensure that the data structure was suitable for further analysis.

From the data presented in **Table 2**, it can be observed that the Kaiser-Meyer-Olkin (KMO) value for the Non-Tai Chi group was 0.957, indicating an excellent level of sampling adequacy. In contrast, the KMO value for the Tai Chi group was 0.863, suggesting a good level of sampling adequacy. Additionally, the results of

Bartlett's Test of Sphericity revealed a significant chi-square statistic of 19158.082 (df = 2775, $p < 0.001$) for the Non-Tai Chi group. Similarly, the Tai Chi group demonstrated a significant chi-square statistic of 9115.264 (df = 2775, $p < 0.001$). These results confirm the appropriateness of conducting factor analyses for both groups, thereby supporting the validity of the instrument used in assessing executive function.

Table 1. Reliability study of the questionnaire.

Variables	No. of test items	Tai Chi Cronbach's Alpha Based on Standardized Items (n = 156)	Non-Tai Chi Cronbach's Alpha Based on Standardized Items (n = 467)	Manual normative (n = 1050)
Inhibition	8	0.808	0.793	0.73
Shift	5	0.774	0.821	0.78
Emotional control	10	0.883	0.900	0.9
Self Monitor	6	0.793	0.799	0.78
Initiate	8	0.8	0.799	0.79
Working Memory	8	0.815	0.815	0.8
Plan/Organize	10	0.852	0.855	0.85
Task Monitor	6	0.722	0.696	0.74
Organization of Materials	8	0.79	0.814	0.84
BRI	30	0.944	0.944	0.93
MI	40	0.954	0.948	0.94
GEC	70	0.973	0.970	0.96

Table 2. Validity of the questionnaire.

validity		Non Tai Chi	Tai Chi
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.957	0.863
Bartlett's Test of Sphericity	Approx. Chi-Square	19158.082	9115.264
	df	2775	2775
	Sig.	0.000	0.000

2. Results and Analysis

2.1. Study 1: The Impact of Tai Chi Skill Level on Executive Functions in Professional Tai Chi Athletes

The practice of Tai Chi, a traditional Chinese martial art distinguished by its slow, mindful movements, has garnered international attention for its numerous health benefits, notably in enhancing physical fitness and mental well-being. As participation in this disciplined art form increases, researchers are focusing on its cognitive effects, particularly regarding executive functions. Executive functions include essential cognitive processes such as working memory, cognitive flexibility, and inhibitory control, which are critical for goal-directed behavior and complex decision-making. Although the relationship between physical activity and cognitive function has been extensively investigated, the specific effects of Tai Chi skill level on executive functions among professional athletes remain relatively underexplored.

For this section, the hypotheses outlined to explore the relationship between Tai Chi skill level and executive functions among professional athletes is: Higher levels of Tai Chi skills will be associated with improved executive function performance. This hypothesis posits that individuals with advanced Tai Chi training demonstrate enhanced working memory, cognitive flexibility, and inhibitory control compared lower-level skills. The rationale behind this hypothesis is that the intricate movements and mental focus required in advanced Tai Chi practice may stimulate cognitive processes, leading to better executive functioning. By investigating these hypotheses, this study aims to clarify the impact of Tai Chi practice at varying levels of skill on cognitive performance, providing a deeper understanding of how this ancient martial art contributes to cognitive health in athletes.

The demographic information for the Tai Chi group is presented below. This includes participant gender, duration of Tai Chi practice (measured in years), the specific style of Tai Chi practiced, skill levels, average weekly training hours, and academic performance as reflected in university grade.

An in-depth analysis of the data table reveals several key trends and patterns across various categories. The gender distribution shows a significant disparity, with 72% male and 28% female respondents, reflected by a mean gender value of 1.28 and a standard deviation of 0.45. In terms of academic grades, freshmen dominate at 60%, followed by sophomores (13%), juniors (14%), seniors (7%), and graduates (5%), resulting in a mean grade level of 1.83 and a standard deviation of 1.21. For Tai Chi skill levels, 46% are Level III National Athletes, 36% Level II, 10% Elite, and 8% Level I, with a mean skill level of 3.18 and a standard deviation of 0.96. Most respondents (85%) have practiced Tai Chi for 1 - 5 years, indicated by a mean practice duration of 1.22 years and a standard deviation of 0.62. Chen-Style Tai Chi is the most popular at 48%, followed by Sun-Style (21%), Yang-Style (20%), and Wu-Style (10%), with a mean preference score of 2.06 and a standard deviation of 1.29. Regarding weekly practice hours, 72% practice 5 - 10 hours, with variation up to 30 hours, resulting in a mean of 1.52 hours and a standard deviation of 0.95. This data offers valuable insights into the respondents' demographics, experience levels, preferences, and practice habits (See **Table 3**).

In order to investigate this hypothesis of this study, analysis was undertaken to examine the impact of Tai Chi skill level among Tai Chi students. A Chi-square analysis was utilized to assess how demographic factors may influence the skill level of Tai Chi practitioners. This statistical technique was employed to determine the presence of a significant association between two categorical variables, specifically Tai Chi level and demographic variables. Additionally, an independent t-tests and ANOVA analyses were conducted to further explore the relationship between gender, Tai Chi skill level and executive function.

Table 3. Tai Chi student demographic information.

Items	Categories	N (156)	Percent (%)	Mean	Std. Deviation
Gender	Male	113.00	72%	1.28	0.45
	Female	43.00	28%		
Your current grade	Freshman	94.00	60%	1.83	1.21
	Sophomore	21.00	13%		
	Junior	22.00	14%		
	Senior	11.00	7%		
	Graduate	8.00	5%		
Tai Chi skill level	Elite level National athlete	16.00	10%	3.18	0.96
	level I National of athletes	12.00	8%		
	Level II National Athlete	56.00	36%		
	Level III National Athlete	72.00	46%		
How long have you been practicing Tai Chi?	1 - 5 years	133.00	85%	1.22	0.62
	6 - 10 years	15.00	10%		
	11 - 15 years	4.00	3%		
	16 - 20 years	4.00	3%		
In the past month, which style do you practice the most?	Chen-Style Tai Chi	75.00	48%	2.06	1.29
	Yang Style Tai Chi	31.00	20%		
	Sun Style Tai Chi	32.00	21%		
	Wu Style Tai Chi	2.00	1%		
	Wu Style Tai Chi	16.00	10%		
How many hours do you practice Tai Chi per week in the past month?	5 - 10 hours	113.00	72%	1.52	0.95
	11 - 15 hours	16.00	10%		
	16 - 20 hours	18.00	12%		
	21 - 25 hours	7.00	4%		
	26 - 30 hours	2.00	1%		

Table 4 presents the results of the chi-square analysis conducted on the variables of gender, academic year, duration of Tai Chi practice, hours of Tai Chi training per week, and the style of Tai Chi practiced. The Chi-square statistic and *p*-values are provided for each variable, with the significance levels denoted as $^{*}p < 0.05$ and $^{**}p < 0.01$. The results of the chi-square analysis indicate that there is a significant association between the duration of Tai Chi practice and the style of Tai Chi practiced ($\chi^2 = 42.922$, $p = 0.000 < 0.01$). Specifically, individuals who have been practicing Tai Chi for 1 - 5 years are more likely to practice Chen-style Tai Chi, while those who have been practicing for 11 - 15 years are more likely to practice Yang-style Tai Chi. This finding suggests that the duration of practice is related to the choice of Tai Chi style.

Table 4. Chi-square analysis of the demographic factors with skill level of Tai Chi practitioners.

Items	Categories	Tai Chi skill level (%)				Total	χ^2	p
		Elites ($n = 16$)	Level1 ($n = 12$)	Level2 ($n = 56$)	Level 3 ($n = 72$)			
Gender	Male	12 (75.00)	6 (50.00)	37 (66.07)	58 (80.56)	113 (72.44)	6.592	0.086
	Female	4 (25.00)	6 (50.00)	19 (33.93)	14 (19.44)	43 (27.56)		
Your current grade	Freshman	9 (56.25)	6 (50.00)	32 (57.14)	47 (65.28)	94 (60.26)	20.074	0.066
	Sophomore	5 (31.25)	1 (8.33)	4 (7.14)	11 (15.28)	21 (13.46)		
	Junior	1 (6.25)	1 (8.33)	13 (23.21)	7 (9.72)	22 (14.10)		
	Senior	0 (0.00)	3 (25.00)	3 (5.36)	5 (6.94)	11 (7.05)		
	Graduate	1 (6.25)	1 (8.33)	4 (7.14)	2 (2.78)	8 (5.13)		
How long have you been practicing Tai Chi?	1 - 5 years	10 (62.50)	8 (66.67)	45 (80.36)	70 (97.22)	133 (85.26)	37.265	0.000**
	6 - 10 years	3 (18.75)	3 (25.00)	9 (16.07)	0 (0.00)	15 (9.62)		
	11 - 15 years	0 (0.00)	1 (8.33)	1 (1.79)	2 (2.78)	4 (2.56)		
	16 - 20 years	3 (18.75)	0 (0.00)	1 (1.79)	0 (0.00)	4 (2.56)		
In the past month, which style do you practice the most?	Chen-Style Tai Chi	12 (75.00)	7 (58.33)	43 (76.79)	51 (70.83)	113 (72.44)	9.690	0.643
	Yang Style Tai Chi	1 (6.25)	2 (16.67)	3 (5.36)	10 (13.89)	16 (10.26)		
	Sun Style Tai Chi	2 (12.50)	2 (16.67)	7 (12.50)	7 (9.72)	18 (11.54)		
	Wu Style Tai Chi	0 (0.00)	1 (8.33)	2 (3.57)	4 (5.56)	7 (4.49)		
	Wu Style Tai Chi	1 (6.25)	0 (0.00)	1 (1.79)	0 (0.00)	2 (1.28)		
How many hours do you practice Tai Chi per week in the past month?	5 - 10 hours	13 (81.25)	5 (41.67)	22 (39.29)	35 (48.61)	75 (48.08)	42.922	0.000**
	11 - 15 hours	1 (6.25)	3 (25.00)	9 (16.07)	18 (25.00)	31 (19.87)		
	16 - 20 hours	1 (6.25)	3 (25.00)	23 (41.07)	5 (6.94)	32 (20.51)		
	21 - 25 hours	0 (0.00)	0 (0.00)	2 (3.57)	0 (0.00)	2 (1.28)		
	26 - 30 hours	1 (6.25)	1 (8.33)	0 (0.00)	14 (19.44)	16 (10.26)		

*$p < 0.05$, **$p < 0.01$.

Additionally, the analysis reveals a significant association between academic year and the level of Tai Chi skill level ($\chi^2 = 20.074$, $p = 0.066$). Individuals in their first year of study are more likely to be at a higher level of Tai Chi skill level compared to individuals in their second, third, or fourth year. This finding indicates that academic year may play a role in the mastery of Tai Chi techniques. Interestingly, the analysis also shows a non-significant association between gender and the level of Tai Chi skill level ($\chi^2 = 6.592$, $p = 0.086$). While there is a trend towards higher skill levels among male participants, the difference is not statistically significant. This suggests that gender may not be a significant factor in determining the level of Tai Chi skill level.

Based on the Chi-square analysis, further investigation into the correlation data of Tai Chi levels was determined to assess the relationships between various demographic factors and the outcomes measured by the BRIEF-A. Specifically, the analysis aimed to identify whether increases in Tai Chi participation correlated with improvements or variations in cognitive and behavioral scores.

The Pearson correlation coefficients presented in **Table 4** provide a statistical foundation for the examination of these interrelationships. This analysis emphasizes significant insights derived from the correlation matrix, thereby facilitating an understanding of the interplay among inhibition, fluctuations in emotional regulation, self-monitoring, initiation, working memory, task planning and organization, task monitoring, material organization, the Behavioral Regulation Index (BRI), the Metacognition Index (MI), Global Executive Control (GEC), and Tai Chi skill level.

Table 5. Pearson correlation between executive function and Tai Chi skill level.

	1	2	3	4	5	6	7	8	9	10	11	12	13
Inhibition (1)	1												
Shift (2)	0.789**	1											
Emotional_control (3)	0.779**	0.643**	1										
Self_Monitor (4)	0.795**	0.758**	0.719**	1									
Initiate (5)	0.839**	0.797**	0.755**	0.820**	1								
Working_Memory (6)	0.845**	0.807**	0.736**	0.783**	0.860**	1							
Plan_Organize (7)	0.826**	0.782**	0.671**	0.746**	0.817**	0.852**	1						
Task_Monitor (8)	0.769**	0.721**	0.693**	0.803**	0.807**	0.817**	0.771**	1					
Organization_of_ Materials (9)	0.833**	0.724**	0.718**	0.794**	0.811**	0.779**	0.764**	0.752**	1				
BRI (10)	0.934**	0.859**	0.906**	0.892**	0.886**	0.874**	0.830**	0.822**	0.849**	1			
MI (11)	0.898**	0.837**	0.778**	0.856**	0.936**	0.940**	0.925**	0.889**	0.895**	0.928**	1		
GEC (12)	0.931**	0.862**	0.849**	0.888**	0.931**	0.927**	0.899**	0.875**	0.891**	0.977**	0.986**	1	
Tai Chi skill level (13)	−0.155	−0.069	−0.180*	−0.132	−0.122	−0.126	−0.087	−0.067	−0.132	−0.158*	−0.118	−0.138	1

*$p < 0.05$, **$p < 0.01$.

The correlation matrix in **Table 5** illustrates in varying degrees of interrelatedness among the components associated with executive functioning that were examined in the study. Notably, all identified correlations achieved statistical significance at levels below 0.01, with the majority of coefficients indicating substantial positive relationships. For instance, the correlation between inhibition and shift ($r = 0.789$, $p < 0.01$) implies that individuals exhibiting higher inhibition are likely to experience significant improvements in their capacity to alter cognitive perspectives. This substantial finding suggests that enhanced levels of inhibition may also confer a strong capacity for cognitive flexibility, which is crucial for adapting to changing circumstances. Moreover, the emotional control construct is significantly correlated with various other constructs, revealing its complex relationship with self-monitoring ($r = 0.643$, $p < 0.01$), initiation ($r = 0.755$, $p < 0.01$), and working memory ($r = 0.736$, $p < 0.01$). These results indicate that effective management of emotions can positively influence an individual's ability to self-regulate and perform tasks efficiently. The significant correlations further emphasize the critical role of emotional stability as a foundational element for enhancing other cognitive functions. In addition, the analysis uncovers strong interconnections among constructs pertaining to planning, organization, and monitoring. For example, the organization of materials demonstrates a close correlation with planning and organizing (r = 0.764, $p < 0.01$) as well as task monitoring (r = 0.752, $p < 0.01$). These findings underscore the essential role that organizational skills play in anticipating and successfully executing tasks, thereby establishing a direct link between cognitive strategies and operational performance. Furthermore, it is crucial to note that the behavioral regulation index (BRI), metacognition index (MI), and global executive control (GEC) exhibit substantial correlations with one another, suggesting that these constructs may work collectively to enhance cognitive and executive functions. The BRI's correlation with the MI (r = 0.898, $p < 0.01$) and GEC (r = 0.931, $p < 0.01$) indicates that individuals demonstrating superior behavioral regulation are likely to possess heightened metacognitive and executive control capabilities.

In contrast, the correlation between Tai Chi skill level and executive function presents a different trend. Specifically, Tai Chi skill is found to exhibit negative correlations with emotional control (r = −0.180, $p < 0.05$) and BRI (r = −0.158, $p < 0.05$), suggesting that higher skill levels in Tai Chi may be associated with diminished cognitive and emotional capabilities. These findings propose that greater skill in Tai Chi could correspond to lower levels of various executive function components, potentially reflecting a shift in emphasis from cognitive regulation to physical execution. The complexity of this relationship invites further exploration into the influence of physical practice on executive function components, particularly within the context of martial arts.

To enhance the understanding of the distinctions in executive functioning among Tai Chi athletes, an independent T-test was performed to evaluate cognitive functioning differences between male and female participants. The study examined multiple domains, including inhibition, shifting, emotional regulation, self-monitoring, initiative, working memory, planning and organization, task monitoring, material organization, behavior regulation index (BRI), metacognition index (MI), and global executive composite (GEC).

The findings of **Table 6** indicates that there was no statistically significant difference between males and females in emotional control ($t(154) = −0.120$, $p = 0.905$), self-monitoring ($t(154) = 1.286$, $p = 0.200$), initiation ($t(154) = 0.852$, $p = 0.396$), working memory ($t(154) = 0.601$, $p = 0.549$), task monitoring ($t(154) = 1.578$, $p = 0.117$), organization of materials ($F(154) = 1.695$, $p = 0.092$), Behavioral Regulation Index (BRI) ($t(154) = 1.131$, $p = 0.260$), Metacognitive Index (MI) ($t(154) = 1.529$, $p = 0.128$), and Global Executive Composite (GEC) ($F(154) = 1.377$, $p = 0.170$). Conversely, a significant difference was observed in planning and organizing skills between the genders ($t (154) = 2.235$, $p = 0.027$), suggesting that females may exhibit superior planning and organizing capabilities in comparison to males.

Table 6. Gender independent T-test for Tai Chi student.

variables	Gender (Mean ± Std. Deviation)		t	*p*
	Male (n = 113)	Female (n = 43)		
inhibition	13.04 ± 2.83	12.09 ± 2.68	1.888	0.061
shift	10.12 ± 2.10	9.51 ± 2.15	1.615	0.108
Emotional_control	15.29 ± 3.53	15.37 ± 4.24	−0.120	0.905
Self_Monitor	9.90 ± 2.22	9.40 ± 2.15	1.286	0.200
Initiate	13.33 ± 2.71	12.91 ± 2.86	0.852	0.396
Working_Memory	12.90 ± 2.74	12.60 ± 2.85	0.601	0.549
Plan_Organize	14.73 ± 3.16	13.47 ± 3.19	2.235	0.027*
Task_Monitor	10.06 ± 1.96	9.51 ± 1.92	1.578	0.117
Organization_of_Materials	12.89 ± 2.76	12.07 ± 2.59	1.695	0.092
BRI	48.35 ± 9.77	46.37 ± 9.81	1.131	0.260
MI	63.92 ± 12.40	60.56 ± 11.94	1.529	0.128
GEC	112.27 ± 21.83	106.93 ± 21.19	1.377	0.170

*$p < 0.05$ **$p < 0.01$.

Furthermore, an ANOVA test was conducted on the Tai Chi skill level to evaluate its effect on executive function. The data collected for each skill level group was analyzed using a Welch ANOVA to determine if there were significant differences in executive function performance. The mean scores and standard deviations for each executive function measure across different skill levels were reported, along with the Welch F statistic and associated p-values.

The results of **Table 7** revealed a significant difference in inhibition performance across the skill levels (t(3, 34.49) = 5.684, p = 0.003). Post-hoc tests indicated that the Elites group had significantly higher inhibition scores compared to the other skill levels. Additionally, the Plan Organize executive function also showed a significant difference among the skill levels (t(3, 29.98) = 3.384, p = 0.028), with the Elites group higher scores than the other groups. On the other hand, no significant differences were found for the shift, emotional control, self-monitoring, initiate, working memory, task monitor, organization of materials, and motivation indices across the skill levels.

Overall, the findings suggest that individuals with higher Tai Chi skill levels, particularly the Elites group, exhibit lower performance in certain executive functions compared to lower skill levels. These results have implications for the potential cognitive benefits of Tai Chi practice and the importance of skill level in determining these cognitive outcomes. These findings suggest that individuals with higher Tai Chi skill levels may face challenges in certain cognitive tasks that require extensive attention and cognitive control. It is possible that the advanced techniques and movements involved in Tai Chi practice may place a greater demand on these cognitive functions, leading to lower performance in specific tasks. Additionally, the Elites group may have developed automaticity in their Tai Chi movements, which could impact their performance in tasks that require greater cognitive flexibility and adaptability.

Table 7. The skill level ANOVA test for Tai Chi student.

variables	Tai Chi skill level (Mean ± Std. Deviation)				Welch t	P	Group Difference
	Elites (n = 16)	Level 1 (n = 12)	Level 2 (n = 56)	Level 3 (n = 72)			
inhibition	14.69 ± 2.09	11.67 ± 1.97	12.77 ± 2.97	12.54 ± 2.79	5.684	0.003**	$L_E > L_1$, $L_E > L_2$, $L_E > L_3$
shift	10.75 ± 1.65	9.25 ± 2.05	9.96 ± 2.23	9.89 ± 2.13	1.643	0.196	
Emotional_control	17.50 ± 3.31	15.42 ± 2.27	15.18 ± 3.96	14.92 ± 3.71	2.531	0.071	
Self_Monitor	10.63 ± 1.63	9.33 ± 2.06	9.98 ± 2.37	9.47 ± 2.18	2.151	0.110	
Initiate	14.25 ± 2.02	13.00 ± 2.59	13.30 ± 2.95	12.94 ± 2.75	1.582	0.210	
Working_Memory	14.13 ± 2.36	12.33 ± 2.64	12.84 ± 2.79	12.60 ± 2.81	1.830	0.159	
Plan_Organize	16.13 ± 2.31	13.50 ± 2.94	14.02 ± 3.34	14.43 ± 3.24	3.384	0.028*	$L_E > L_1$, $L_E > L_2$
Task_Monitor	10.31 ± 1.89	9.50 ± 1.88	10.09 ± 1.88	9.75 ± 2.05	0.719	0.547	
Organization_ of_Materials	13.88 ± 2.42	12.42 ± 2.31	12.70 ± 2.80	12.42 ± 2.78	1.513	0.227	
BRI	53.56 ± 6.73	45.67 ± 7.10	47.89 ± 10.19	46.82 ± 10.10	4.211	0.011*	$L_E > L_1$, $L_E > L_2$, $L_E > L_3$
MI	68.69 ± 10.27	60.75 ± 10.67	62.95 ± 12.67	62.14 ± 12.59	1.844	0.156	
GEC	122.25 ± 16.52	106.42 ± 17.20	110.84 ± 22.51	108.96 ± 22.30	2.835	0.051	

*$p < 0.05$ **$p < 0.01$ L_E = Elite level National athlete; L_1; L_2; L_3 = level I, II III National of athletes; respectively.

These results have important implications for understanding the cognitive benefits of Tai Chi practice and the role of skill level in determining these outcomes. While Tai Chi has been shown to have positive effects on cognitive function in general, this study highlights the potential limitations for individuals with advanced skill levels. It underscores the importance of considering individual differences in Tai Chi practice and the need for tailored cognitive training programs to address specific cognitive challenges that may arise at different skill levels. The results of these analyses supported the findings of the Chi-square analysis, further highlighting the influence of Tai Chi skill level and gender on executive function.

2.2. Study 2: Executive Functional Difference Between Tai Chi and Non-Tai Chi Students

Tai Chi, a traditional Chinese martial art known for its slow, intentional movements and meditative characteristics, has garnered significant attention for its potential cognitive advantages. The first study revealed a noteworthy correlation between the skill levels of Tai Chi practitioners and their executive functions.

Specifically, highly skilled professional Tai Chi athletes exhibited lower performance on executive function tasks compared to their less experienced counterparts. This counterintuitive finding warrants further investigation into the cognitive demands and mental processes inherent in advanced Tai Chi practice. To elucidate this phenomenon, a second study was conducted, aimed at comparing executive functions between Tai Chi practitioners and non-practitioners. This research sought to provide enhanced insight into the cognitive profiles associated with varying Tai Chi skill levels. By assessing the executive functions of these two groups, the study aimed to illuminate the distinct ways in which Tai Chi practice may impact executive function across different skill levels.

The hypothesis for this study posits that regular practice of Tai Chi is associated with enhancements in executive functions, including working memory, cognitive flexibility, and inhibitory control, among participants. This study aims to investigate whether engaging in Tai Chi consistently leads to measurable improvements in these cognitive processes based on the BRIEF-A questionnaire.

Below is the demographic information for the non-Tai Chi group. It includes participant gender, and university grade.

Based on the Table 8, a total of 467 individuals were surveyed, with the majority being female at 83.3% and males accounting for 16.7%. This data sheds light on the gender distribution among participants and can aid in comprehending any potential gender discrepancies or variations in the responses provided. Upon examination of the current academic standing of the participants, the data reveals that 82.44% were freshmen, 8.57% were sophomores, 6.21% were juniors, 0.43% were seniors, and 2.36% were graduate students. This breakdown offers valuable insights into the educational background of the participants and can assist in customizing any interventions or programs to cater to their specific requirements. Additionally, the mean and standard deviation values for each category provide an understanding of the distribution of responses within each group. For instance, the mean gender value for males is 1.833 with a standard deviation of 0.373, signifying a relatively narrow range of responses. Conversely, the mean grade values exhibit more variability, with freshmen presenting a mean value of 1.317 and a higher standard deviation of 0.806, indicating greater variability in responses within the freshman cohort.

Table 8. Non Tai Chi student demographic information.

Items	Categories	N (467)	Percent (%)	Mean	Std. Deviation
Gender	Male	78	16.7	1.833	0.373
	Female	389	83.3		
Your current grade	Freshman	385	82.44	1.317	0.806
	Sophomore	40	8.57		
	Junior	29	6.21		
	Senior	2	0.43		
	Graduate	11	2.36		

To examine the impact of gender differences within the non-Tai Chi group, an independent samples t-test was conducted, as detailed below.

Table 9. Gender Independent T-test for Non-Tai Chi student.

Variables	Gender (Mean ± Std. Deviation)		t	*p*
	Male ($n = 78$)	Female ($n = 389$)		
Inhibition	13.55 ± 2.76	13.24 ± 2.81	0.899	0.369
Shift	10.32 ± 2.33	10.41 ± 2.18	−0.331	0.741
Emotional_Control	15.76 ± 4.12	16.54 ± 3.90	−1.604	0.109
Self_Monitor	10.19 ± 2.08	9.98 ± 2.21	0.794	0.428
Initiate	14.33 ± 2.84	14.12 ± 2.82	0.621	0.535
Working_Memory	13.92 ± 2.83	14.21 ± 2.75	−0.825	0.410
Plan_Organize	17.55 ± 3.65	16.83 ± 3.57	1.629	0.104
Task_Monitor	10.55 ± 1.71	10.47 ± 1.77	0.359	0.720
Organization_Of_Materials	13.58 ± 3.03	13.61 ± 2.83	−0.106	0.916
BRI	49.82 ± 9.99	50.17 ± 9.83	−0.283	0.777
MI	69.94 ± 12.71	69.24 ± 12.10	0.462	0.644
GEC	119.76 ± 21.85	119.40 ± 21.10	0.134	0.893

$^*p < 0.05$, $^{**}p < 0.01$.

The data provided in Table 9 shows the means and standard deviations for each task for both males and females, as well as the t-value and *p*-value for each task. A *p*-value of less than 0.05 is typically considered statistically significant, meaning that there is a significant difference between the means of the two groups. Looking at the results, it is apparent that there are no statistically significant differences between males and females in any of the tasks. The *p*-values for all tasks are greater than 0.05, indicating that the differences in means are likely due to random chance and not to a true difference between genders.

Executive Functional Difference between Tai Chi and Non-Tai Chi Student

This section analyzes the executive function of the Tai Chi and non-Tai Chi groups using an independent t-test to evaluate significant differences between the two groups.

The results in Table 10 reveal significant differences in cognitive and emotional variables between female university students who practice Tai Chi (n = 43) and those who do not (n = 389), as assessed by an independent t-test. Specifically, there were significant differences observed in inhibition (t(430) = −2.550, $p = 0.011$) and cognitive shifting (t(430) = −2.566, $p = 0.011$), both indicating statistical significance. Conversely, no significant differences were found regarding emotional control and self-monitoring. However, several cognitive areas demonstrated significant differences, including initiation (t(430) = −2.659, $p = 0.008$), working memory (t(430) = −3.613, $p = 0.000$), planning and organization (t(430) = −5.923, $p = 0.000$), task monitoring (t(430) = −3.354, $p = 0.001$), and organization of materials (t(430) = −3.429, $p = 0.001$). Additionally, the Behavioral Regulation Index (BRI) showed a significant difference (t(430) = −2.403, $p = 0.017$), as did the Metacognition Index (MI) (t(430) = −4.468, $p = 0.000$) and the Global Executive Composite (GEC) (t(430) = −3.676, $p = 0.000$). These results indicate that female students who practice Tai Chi exhibit superior executive function compared to their non-practicing counterparts.

Table 10. Independent t-test for female student.

Variables	Female University student (Mean ± Std. Deviation)		t	*p*
	Tai Chi (n = 43)	Non Tai Chi (n = 389)		
Inhibition	12.09 ± 2.68	13.24 ± 2.81	−2.550	0.011*
Shift	9.51 ± 2.15	10.41 ± 2.18	−2.566	0.011*
Emotional_control	15.37 ± 4.24	16.54 ± 3.90	−1.847	0.065
Self_Monitor	9.40 ± 2.15	9.98 ± 2.21	−1.642	0.101
Initiate	12.91 ± 2.86	14.12 ± 2.82	−2.659	0.008**
Working_Memory	12.60 ± 2.85	14.21 ± 2.75	−3.613	0.000**
Plan_Organize	13.47 ± 3.19	16.83 ± 3.57	−5.923	0.000**
Task_Monitor	9.51 ± 1.92	10.47 ± 1.77	−3.354	0.001**
Organization_of_Materials	12.07 ± 2.59	13.61 ± 2.83	−3.429	0.001**
BRI	46.37 ± 9.81	50.17 ± 9.83	−2.403	0.017*
MI	60.56 ± 11.94	69.24 ± 12.10	−4.468	0.000**
GEC	106.93 ± 21.19	119.40 ± 21.10	−3.676	0.000**

*$p < 0.05$, **$p < 0.01$.

An independent t-test analysis was conducted to compare male university students engaged in Tai Chi with those not participating in the activity, evaluating various variables. The results indicate that participants in Tai Chi exhibited a mean score lower than that of non-participants in the categories of Inhibition (t = −1.253, $p = 0.212$), Shift (t = −0.608, $p = 0.544$), Emotional Control (t = −0.812, $p = 0.418$), Self-Monitoring (t = −0.909, $p = 0.365$), and Task Monitor (t = −1.787, $p = 0.076$), suggesting no statistically significant differences across these measures. In contrast, significant differences were observed in Initiate (t = −2.472, $p = 0.014$), Working Memory (t = −2.498, $p = 0.013$), Plan and Organize (t = −5.685, $p = 0.000$), Metacognitive Index (t = −3.263, $p = 0.001$), and Global Executive Composite (t = −2.327, $p = 0.021$), where Tai Chi participants demonstrated superior performance. Furthermore, no significant differences were noted in Organization of Materials (t = −1.616, $p = 0.108$) and Behavioral Regulation Index (t = −1.011, $p = 0.314$) (See Table 11).

Table 11. Independent t-test for male student.

Variables	Male University student (Mean ± Std. Deviation)		t	*p*
	Tai Chi (n = 113)	Non Tai Chi (n = 78)		
Inhibition	13.04 ± 2.83	13.55 ± 2.76	−1.253	0.212
Shift	10.12 ± 2.10	10.32 ± 2.33	−0.608	0.544
Emotional_control	15.29 ± 3.53	15.76 ± 4.12	−0.812	0.418
Self_Monitor	9.90 ± 2.22	10.19 ± 2.08	−0.909	0.365
Initiate	13.33 ± 2.71	14.33 ± 2.84	−2.472	0.014*
Working_Memory	12.90 ± 2.74	13.92 ± 2.83	−2.498	0.013*
Plan_Organize	14.73 ± 3.16	17.55 ± 3.65	−5.685	0.000**
Task_Monitor	10.06 ± 1.96	10.55 ± 1.71	−1.787	0.076
Organization_of_Materials	12.89 ± 2.76	13.58 ± 3.03	−1.616	0.108
BRI	48.35 ± 9.77	49.82 ± 9.99	−1.011	0.314
MI	63.92 ± 12.40	69.94 ± 12.71	−3.263	0.001**
GEC	112.27 ± 21.83	119.76 ± 21.85	−2.327	0.021*

*$p < 0.05$, **$p < 0.01$.

Table 12. Independent T-test between the Tai Chi and Non-Tai Chi student.

Variables	University student (Mean ± Std. Deviation)		*t*	*p*
	Tai Chi (*n* = 156)	Non Tai Chi (*n* = 467)		
Inhibition	12.78 ± 2.81	13.29 ± 2.80	−1.990	0.047*
Shift	9.96 ± 2.13	10.40 ± 2.21	−2.181	0.030*
Emotional_control	15.31 ± 3.72	16.41 ± 3.94	−3.044	0.002**
Self_Monitor	9.76 ± 2.21	10.01 ± 2.19	−1.233	0.218
Initiate	13.21 ± 2.75	14.15 ± 2.82	−3.623	0.000**
Working_Memory	12.82 ± 2.76	14.16 ± 2.76	−5.241	0.000**
Plan_Organize	14.38 ± 3.21	16.95 ± 3.59	−7.930	0.000**
Task_Monitor	9.91 ± 1.96	10.49 ± 1.76	−3.264	0.001**
Organization_of_Materials	12.67 ± 2.73	13.61 ± 2.86	−3.603	0.000**
BRI	47.81 ± 9.79	50.11 ± 9.85	−2.531	0.012*
MI	62.99 ± 12.33	69.35 ± 12.19	−5.624	0.000**
GEC	110.80 ± 21.72	119.46 ± 21.21	−4.390	0.000**

*$p < 0.05$, **$p < 0.01$.

Table 12 summarizes the results of the independent t-test comparing the means of various executive function component between the two groups: Tai Chi (n = 156) and non-Tai Chi (n = 467) student. The variables include measures of inhibition, shift, emotional control, self-monitoring, initiation, working memory, planning and organizing, task monitoring, and organization of materials. Additionally, summary indexes such as the Behavioral Regulation Index (BRI), Metacognition Index (MI), and the Global Executive Composite (GEC) are provided.

The results of Table 12 revealed some interesting findings that shed light on the potential benefits of Tai Chi on cognitive performance. And identify the potential use of the BRIEF-A for the measurement of executive function between students. It can be observed that: in the domain of inhibition, individuals who practiced Tai Chi showed a mean score of 12.78 (±2.81), while those who did not practice Tai Chi had a mean score of 13.29 (±2.80). The t-test results indicated a statistically significant difference between the two groups ($t = -1.990$, $p = 0.047$), with Tai Chi practitioners demonstrating better inhibition abilities. Similarly, in the shift domain, Tai Chi practitioners scored lower (9.96 ± 2.13) compared to non-Tai Chi practitioners (10.40 ± 2.21), with a significant difference noted ($t = -2.181$, $p = 0.030$). This suggests that individuals who practice Tai Chi may have improved cognitive flexibility and the ability to shift between tasks efficiently. Emotional control was another area where Tai Chi practitioners outperformed non-Tai Chi practitioners, with a mean score of (15.31 ± 3.72) versus (16.41 ± 3.94) respectively. The t-test revealed a highly significant difference ($t = -3.044$, $p = 0.002$), indicating that Tai Chi may have a positive impact on emotional regulation and control. Furthermore, Tai Chi practitioners demonstrated superior abilities in initiating tasks, working memory, planning/organizing, task monitoring, and organization of materials, as evidenced by the highly significant differences in these domains. These findings suggest that regular practice of Tai Chi may be associated with better executive functioning skills and overall cognitive performance. On the other hand, there was no significant difference between the two groups in self-monitoring abilities, as indicated by a non-significant *p*-value ($p = 0.218$). This implies that Tai Chi may not have a direct impact on self-monitoring skills compared to other cognitive functions assessed in this study. This result is greatly affected the proportion of female in of the two groups as it is showed in Table 10.

3. Discursion

The results suggest that individuals in the Elite Tai Chi group, despite their high skill levels, show lower performance in specific executive functions, especially inhibition. This finding prompts intriguing questions about the cognitive aspects of Tai Chi practice. One potential explanation for this phenomenon is that elite practitioners may have developed a level of automaticity in their Tai Chi movements, which could reduce the reliance on conscious executive control, specifically inhibition. Research by Fitts and Posner (Fitts, 1967) on the stages of motor skill acquisition suggests that advanced performers shift from a cognitive stage—where conscious control is significant—to an autonomous stage, where actions become more reflexive. Consequently, this may lead to a lower performance on tasks requiring inhibition, which rely on executive functions to suppress responses. The observed decline in inhibitory control among elite Tai Chi practitioners may suggest a potential over-reliance on automatic processes developed through extensive training (Toner & Moran, 2021). It is conceivable that as individuals attain higher levels of skill, their movements become more instinctive, thereby reducing the cognitive resources allocated to conscious control and inhibition (Bebko et al., 2005; Christensen et al., 2016). This phenomenon, often referred to as "motor automaticity," and can lead to diminished engagement of high-level cognitive processes when performing the task.

Unlike many studies investigating how conscious movement investment affects movement outcomes, there have been only two studies assessing its relationship with motor inhibition (Beilock & Gray, 2012; Park et al., 2020). Beilock & Gray (2005) in their study assumed that novices would naturally show higher levels of conscious movement investment compared to high-skilled golfers who would show much more automatic monitoring and control of movement. They found that the novices were faster in inhibiting the stroke than the high-skilled golfers, especially when the stop signal was present during the downswing. Park et al., 2020 showed that inhibition would allow performers to control the degree of conscious movement investment They thus expected that motor inhibition would negatively correlate with performers' inclination to consciously invest in movement monitoring and control (Beilock & Carr, 2005).

Additionally, the demands of higher-level practice may change the cognitive resources allocated during Tai Chi execution. Elite practitioners might focus heavily on fluidity and precision of movement rather than on cognitive control tasks. This aligns with findings from a study by Toner & Moran (2021) which indicated that experts in various sports often demonstrate diminished performance on tasks requiring inhibition due to their automatized actions. Furthermore, this finding could indicate that elite practitioners may have developed a different cognitive style or strategy. They might engage in a form of mindfulness that allows them to focus on their physical movements, potentially at the expense of other cognitive tasks. This raises the question of whether the intense focus required for mastering Tai Chi might inadvertently diminish the resources available for other cognitive processes, thereby impacting performance in inhibition and possibly other executive functions. In the research of Wang et al. (2023a), it was found that moderate practice of physical actively as the improve the executive function. The moderate-dose group and low-dose group improved in terms of EF. However, the improvement effect was different, and the improvement effect of the moderate-dose group EF was better than that of the low-dose group. The second measurement, EF was better for all exercise groups than for the control group. Low-dose high-intensity interval training (HIIT) and moderate-dose HIIT improved the EF in college students, but moderate-dose was better. This study suggests that moderate-dose HIIT should be adopted to improve the EF in college students.

Future studies should aim to investigate the intricate relationship between Tai Chi skill levels and executive function performance in various contexts. A mixed-methods approach, combining quantitative assessments with qualitative insights from elite practitioners, could yield a more comprehensive understanding of how skill levels influence cognitive processes. Overall, these findings underscore the complexity of the relationship between physical skill and cognitive function within the realm of Tai Chi, challenging traditional assumptions and suggesting potential areas for further exploration. Additionally, it opens up avenues for further research on the cognitive demands of Tai Chi practice across different skill levels. Exploring how elite practitioners differ in their cognitive approaches could provide valuable insights into how varying levels of skill level affect cognitive function and performance. Ultimately, these findings encourage a re-evaluation of the assumptions linking physical prowess and cognitive enhancement, suggesting that skill acquisition in disciplines like Tai Chi may engage the brain in unique and nuanced ways. It invites a broader discussion on how various forms of movement culture impact cognitive health and functioning across diverse populations.

On the other hand, when comparing the executive function of the Tai Chi group to that of the non-Tai Chi group, as observed in **Table 10**, it is evident that the Tai Chi group exhibited better executive function than the non-Tai Chi group. This finding aligns with numerous studies that have reported similar results. For instance, research by Wang & Lyu (2024) found that college student practicing Tai Chi showed significant improvements in executive inhibition functions, including aspects of executive function. Furthermore, a Systematic Review by Martin (2024) supports the notion that regular physical activity, such as Tai Chi, enhances cognitive performance among older adults. The improvement observed in executive function may be attributed to the combined effects of physical exercise, mindfulness, and social interaction inherent in Tai Chi practice (Leung et al., 2022). Thus, our results corroborate previous research indicating that physical activity has the potential to improve executive functions, contributing to better cognitive health in younger adults (Colcombe & Kramer, 2003).

In contrast, a comparison of executive function between the Tai Chi group and the non-Tai Chi group, as presented in **Table 12**, demonstrates that the Tai Chi group displayed superior executive function. Additionally, gender comparisons within both groups revealed that male Tai Chi participants exhibited enhanced executive function attributed to improved Metacognitive Insight (MI), while female participants showed better executive function due to advancements in both Behavioral Regulation Index (BRI) and MI. These findings suggest that Tai Chi practice positively impacts female performance on the BRI, a factor essential for self-control. These results suggest that long-term practice of Tai Chi can positively influence executive function, particularly highlighting its beneficial effects on the BRI for females, which is crucial for self-control. Overall, Tai Chi practice promotes executive function across both genders.

This finding is consistent with numerous studies that highlight the cognitive benefits of Tai Chi and similar physical activities. For instance, a review by (Wang et al., 2010) found significant improvements in executive function among older adults participating in Tai Chi compared to those engaging in sedentary activities.

Furthermore, this result aligns with previous research indicating that physical activity, in general, has the potential to enhance executive function. A meta-analysis by Xu et al. (2023) supports this notion, demonstrating that various forms of exercise contribute positively to cognitive outcomes, particularly executive function. The mechanisms behind these improvements may involve increased blood flow to the brain, neurogenesis, and enhanced mood states associated with regular physical activity (Golsteijn et al., 2021; Trudeau & Shephard, 2008).

4. Conclusion

The statistical framework established in this study fosters a comprehensive and nuanced analysis of the effects of Tai Chi on executive function outcomes as measured by the BRIEF-A. Notably, the findings concerning the performance of elite Tai Chi practitioners in various executive functions—particularly in the domain of inhibition—illustrate a profound and intriguing intersection between physical aptitude and cognitive processing. Interestingly, these high-level practitioners demonstrated lower performance in inhibition tasks, which provokes critical inquiries into the true nature of expertise within Tai Chi, along with the cognitive dynamics that underpin such mastery. As practitioners transition from the cognitive demands of motor skill acquisition to a more automatic level of execution, their movements may become instinctive, relying less on conscious deliberation. This shift towards motor automaticity could conceivably result in diminished capability to inhibit responses in concurrent cognitive tasks. In this context, the phenomenon of motor automaticity prompts the hypothesis that, while Tai Chi practitioners achieve exceptional fluidity and precision in their physical movements, they may face a consequential trade-off in higher-order cognitive functions such as inhibition.

Moreover, the prospect that these experts engage in a distinct cognitive strategy—one that emphasizes mindfulness and focused movement—adds another layer of complexity to our understanding of executive functions as they relate to physical skill. By intentionally honing their attention on their bodies and movements, Tai Chi practitioners may reallocate cognitive resources in a manner that enhances their physical performance but potentially detracts from their inhibitory control capabilities. This interplay between physical actions and cognitive engagement suggests a multi-dimensional relationship, one that calls for further investigation into how varying levels of expertise not only shape motor skills but also influence cognitive processes in Tai Chi and analogous complex motor tasks. As ongoing research delves into these intricate relationships, there remains a significant opportunity to enrich our comprehension of the interplay between physical training and cognitive function, ultimately leading to more informed methodologies for integrating physical practices, such as Tai Chi, into holistic cognitive enhancement routines.

In the second study, the data analysis provided further illumination on the potential cognitive benefits associated with regular Tai Chi practice, encompassing various domains such as inhibition, shifting, emotional control, initiation, working memory, planning and organizing, task monitoring, and material organization. These findings offer invaluable insights into the cognitive effects yielded by engaging in Tai Chi and reinforce the notion that the integration of this ancient martial art into daily routines could serve as a catalyst for enhancing cognitive abilities and promoting overall mental well-being. Collectively, this body of research underscores the importance of considering how the deliberate practice of Tai Chi not only facilitates physical health but also contributes to the maintenance and improvement of cognitive function across various spheres, highlighting the multifaceted benefits of physical activity in the context of cognitive health and resilience. Thus, this ongoing exploration not only underscores the rich, reciprocal relationship between physical movements and cognitive processes but also points to a paradigm shift in how we understand and apply these practices for holistic health and well-being.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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