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# The impact of 24-forms Tai Chi on alpha band power and physical fitness in young adults: a randomized controlled trial

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**Regular physical activity is beneficial for health, but research on interventions for young people's physical and mental health remains limited. Tai Chi may have potential benefits, but its effects on young adults are not well - studied. 45 college students were randomly assigned to a Tai Chi (TC) group or a control group. The TC group underwent 45-minute sessions, three times a week for 12 weeks. Physical health performance and alpha-band power of resting-state electroencephalography were measured before and after the intervention. Both groups improved in long jump performance ($p$ < 0.05), but the TC group had a greater improvement (13.73 ± 15.54 vs. 4.91 ± 9.24 cm). The alpha-band power increased in the TC group and decreased in the control group. Tai Chi can enhance physical fitness and alpha-band power in college students, suggesting its potential as a health-promoting activity.**

**Keywords** Physical inactivity, Simplified Tai Chi, Resting-state electroencephalography, Long jump, Flexibility

Regular participation in physical activity has been linked to numerous health benefits, including a reduction in the risk of all-cause mortality, cardiovascular disease, metabolic syndrome, lung cancer, skeletal hip fracture, depression, and dementia by 13–68%[1,2]. It also enhances children's cognition, increasing bone density by 1–2%[2]. While adolescents should engage in at least 60 min of moderate-to-vigorous PA daily[3,4], only 81% of children and adolescents do not meet these guidelines[5]. However, exercise training comes in various forms, many are costly and have limitations. Interestingly, there is limited research on interventions that address both physical and mental health simultaneously among college students.

A meta-analysis study has demonstrated that exercise interventions effectively enhance physical fitness, including cardiovascular fitness, muscular strength and endurance in individuals with obesity, and improve global cognition[6]. Recent studies have further explored the effects of different types of exercise on young adults' health[7,8]. For instance, Brown et al. found that high-intensity interval training can be an effective means for improving cardiovascular and muscular fitness, increasing lean mass and bone mineral content, and thereby improving cardiometabolic, as well as musculoskeletal in healthy young adult females[9]. Guo also found that 4 weeks of high-intensity interval training significantly improved young adults' cardiovascular fitness, body composition, and $VO_2$max. These findings have broadened our understanding of how exercise impacts the well-being of this age group[10].

However, the impact of Tai Chi (TC) on young people's alpha-band power and comprehensive physical fitness remains under-investigated. TC, with its unique combination of slow movements, deep breathing, and meditation, is hypothesized to have distinct effects on both physical and neural aspects. While there is evidence suggesting its positive influence on the elderly and individuals with certain health conditions, the specific mechanisms and benefits for young people are still not well-defined. Understanding these effects could

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potentially provide new insights into promoting health and well-being among young populations, and thus, further research in this area is warranted.

TC, which combines martial arts and meditation, serves as a low-to-moderate aerobic exercise that enhances optimal physical performance[11]. Despite numerous confirmed health benefits associated with TC, such as improving cognitive function in older adults, enhancing balance to reduce the risk of falls, and improving flexibility and muscle strength[12]. While some studies have shown that TC can improve balance and flexibility in young adults[13,14], others have reported inconsistent results regarding its impact on muscle strength[15]. These discrepancies highlight the need for further research, such as this study, to clarify the effects of Tai Chi on different aspects of physical fitness in young populations.

Moreover, there is inconsistency regarding the specific type and duration of TC practice in existing studies. Moreover, previous studies tend to focus on single aspects such as psychology, physical fitness, or cognition, often relying on questionnaires, which may lack depth. While some neuroimaging studies have investigated TC's effects on cognitive function, such as one employing voxel-based morphometry which found significant functional increases in the frontal cortex and left superior parietal lobule following eight weeks of Ba Fa Wu Bu style TC training in college students[16], others have explored the impact of long-term alpha neurofeedback training using music stimuli[17], and EEG-based cross-sectional studies for anxiety and depression recognition[18].

TC, a traditional Chinese martial art practiced for both self-defense and health benefits, involves slow, deliberate movements combined with deep breathing and meditation. It is often described as "moving meditation" and has been associated with numerous health benefits, including improved balance, flexibility, strength, and overall well-being. One aspect of TC's impact on the body is its influence on brain wave activity. Alpha band are a type of neural oscillation that occurs in the frequency range of 8 to 12 Hz. They are associated with a calm, focused mind and are often present during meditation, relaxation, and creative activities[19]. The slow, rhythmic movements of TC, combined with focused attention on breathing and body awareness, are believed to promote the generation of alpha band[20]. This can result in a state of deep relaxation and mental clarity, which may contribute to the overall sense of well-being experienced by TC practitioners. Overall, while existing literature suggests that TC may indeed have beneficial effects on alpha band and physical performance, discrepancies in study designs, subjects, and the specific type and duration of TC practice highlight the need for further well-designed studies.

Therefore, this study aims to elucidate the neural mechanisms underlying attention and executive control through the utilization of alpha band power of rs-EEG. Additionally, it seeks to evaluate the impact of a 12-week TC practice on both physical and alpha band power among college students. This research would provide valuable insights for the development of TC programs geared towards enhancing student well-being. Therefore, we hypothesized that 12 weeks of TC practice can significantly improve the physical fitness and alpha-band performance of college students.

## Materials and methods

### Study design

This study was conducted as a randomized controlled trial, with received approval from the Center for Ethics in Human Research in Khon Kaen University (No. HE652012) and registration number ChiCTR2400081473 as of 01/03/2024 and it was accessible at https://www.chictr.org.cn/showproj.html?proj=213219. The study was in accordance with the Declaration of Helsinki and the national guidelines and regulations. Following baseline assessments, all participants were stratified based on gender, age, and BMI classifications, which included underweight, normal weight, overweight, and obesity[21], block followed by randomization to a TC group or a control group from the envelopes by assistants, with allocation concealed from researchers. Data were collected at baseline and after 12 weeks of TC training, see Fig. 1. All participants received instructions to keep their usual lifestyle practices during the study.

### Participants

A total of 45 eligible participants from a university in China participated in the study, they were assigned into 2 groups: the TC group ($n$ = 22) and the control group ($n$ = 23). All participants provided written informed consent to participate in the study. The sample size estimation was based on the results of a previous study, and calculations were conducted using G*Power software. With an overall sample size of 44 participants, The study achieved a significant effect of 0.8 at a significance level of $\alpha = 0.05$, with an effect size of 0.85. Accounting for potential drop-out rates in each group, the total anticipated sample size was set at 60 participants.

The participants underwent screening based on the following inclusion criteria: (1) aged between 18 and 22 years, (2) independent ambulation, (3) able to participate in low-to-moderate intensity movement, (4) no intake of antioxidant supplementation and no regular use of medication, (5) absence of musculoskeletal pain or conditions that limit exercise practice. The exclusion criteria were as follows: (1) reporting any history or risk of cardiopulmonary symptoms, (2) having experience in applying cognitive tasks.

All participants completed the International Physical Activity Questionnaire (IPAQ) and Physical Activity Readiness Questionnaire (PAR-Q) to provide information on their demographics, medical history, and health behaviors before the experiment.

### Intervention

TC training was conducted three times a week for 12 consecutive weeks. The first two sessions for the experimental group took place at the gym of the university under the guidance of well-trained instructors. Participants were instructed to follow the instructor's motions at the same rhythm, with the intensity monitored using Xiaomi sports bracelets to maintain approximately 55% of their maximum heart rate. Each TC session

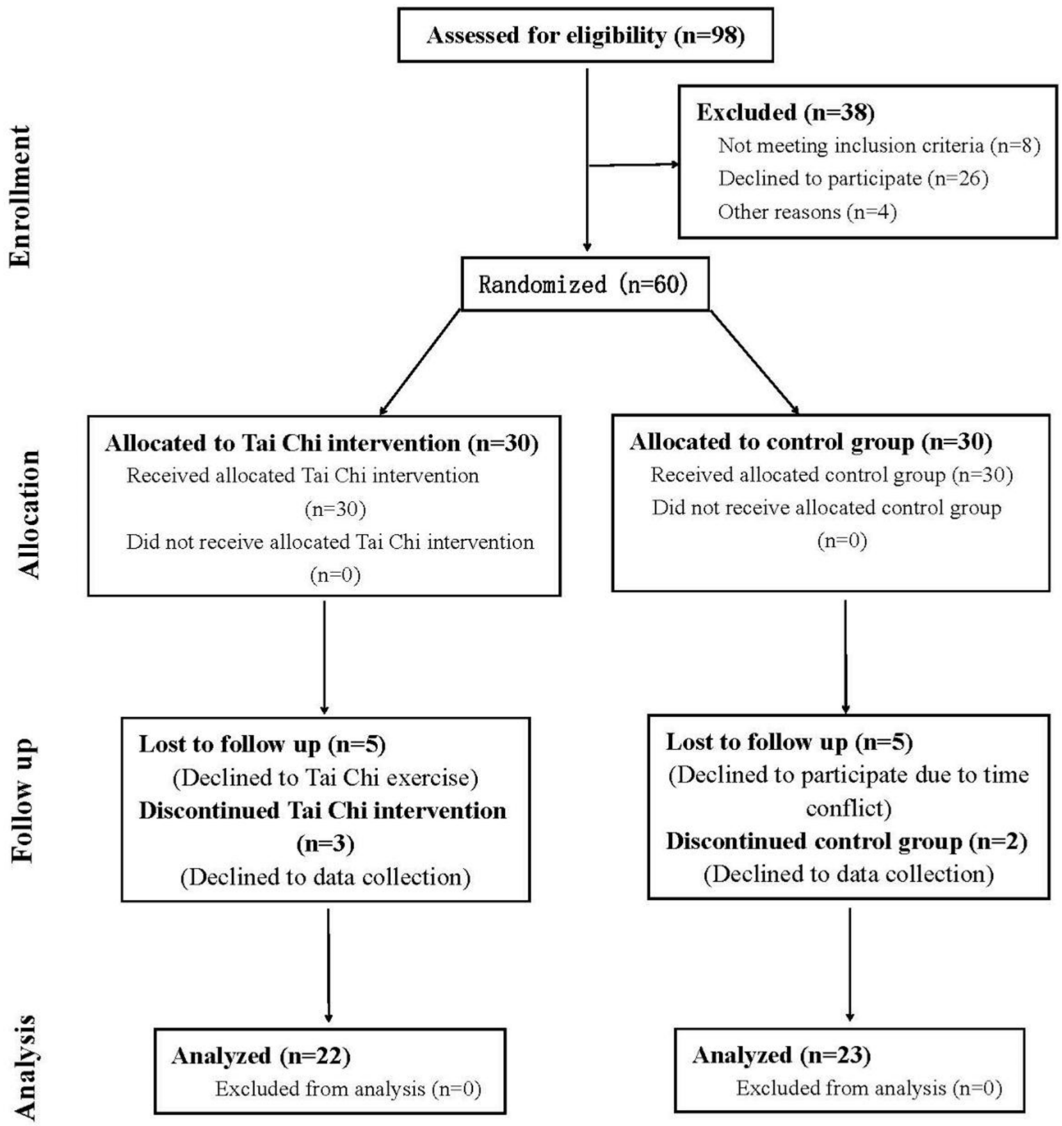


**Fig. 1**. Flowchart of the study protocol.

lasted approximately 45 min, consisting of 35 min of exercise, and 5 min for warming up/cooling down. Participants in the control group were asked to continue with their daily routines.

## Data collection
The outcomes were assessed at baseline one day before the experiment and again one day after the completion of the 12-week intervention. All physical performance outcomes were evaluated by three well-trained blinded investigators. The reliability of the measurements was assessed using the intra-class correlation coefficient (ICC) with 95% confidence intervals. Cronbach's alpha for reliability of height, flexibility, balance, and long jump were found to be 0.99, 0.99, 0.89, and 0.99, respectively.

## Anthropometry
Height measurements were taken using a height scale, while weight measurements were obtained using a smart scale (Huawei Smart Scale 3 Pro, Huawei, China, manufactured in 2021). Participants were asked to step onto the height and weight scales. Body Mass Index (BMI) was calculated using the weight (kg.)/height (m.)$^2$ ratio.

## Physical fitness performance
This study's protocol involved the random evaluation of participants' physical performance, known as secondary outcome, which included grip strength, standing long jump, balance, flexibility, and pulmonary function. Each assessment was performed twice, with a 1-minute rest period between trials, and the best value was used for the analysis[22].

Grip strength was assessed using a dynamometer (JH-1441 Mechanical flexion, Jiangsu Suhong Medical Equipment Co., Ltd., China, manufactured in 2013). Participants were instructed to squeeze the handle of the dynamometer as hard as possible for three seconds. Inter-rater and test-retest reliability yielded ICC coefficients ranging from 0.74 to 0.93[23].

For the standing long jump, participants jumped forward from a starting line, and the distance was measured to where their heels landed on the mat (Simple long jump mat, Jiangsu Suhong Medical Equipment Co., Ltd., China, manufactured in 2013). Inter-rater reliability was reported to be 0.96 and 0.99 among male and female raters[24].

Balance was assessed using the single-leg stance test, with participants standing on one leg with eyes open or closed, and the duration was timed using a stopwatch (RS-8060 Stopwatch, Shenzhen Resee Technology Co., Ltd., China, manufactured in 2015). The test's reliability was reported as ICC 0.89 with eyes open and 0.86 with eyes closed[25].

Flexibility was measured using the sit-and-reach test, with participants extending their legs and reaching forward while seated, utilizing a sit-and-reach flexion apparatus (JH-1441 Mechanical flexion, Jiangsu Suhong Medical Equipment Co., Ltd., China, manufactured in 2013). The test's reliability ranged from ICC 0.91 to 0.93[26].

Cardiorespiratory endurance was evaluated using a spirometer (JH-1662 Electronic Spirometer, Jiangsu Suhong Medical Equipment Co., Ltd., China, manufactured in 2013). Participants were instructed to breathe smoothly, and forced expiratory volume values were recorded. Inter-instrument reliability ranged from ICC 0.92 to 0.95[27].

### Alpha band of resting-state electroencephalography (rs-EEG)

As a primary outcome of this study, Rs-EEG offers insights into the functional connectivity between different brain regions and is utilized to identify patterns of brain activity associated with various mental states at rest, such as sleep, meditation, and cognitive processing. Participants wore a 64-channel EEG cap, and EEG signals were recorded using 8 electrodes positioned according to the International 10–20 System (F3, F4, C3, C4, P3, P4, T7, and T8). The ground electrode was positioned in the middle of the forehead, and the reference electrode was situated at the tip of the nose[28]. This setup allowed for the comprehensive assessment of neural activity across multiple brain regions, providing valuable insights into the effects of the intervention on brain function.

To minimize artifacts caused by postural changes and eye movements, participants were instructed to remain seated in a chair with their eyes closed for a duration of 8 min. During this time, EEG data were recorded at a sampling rate of 1000 Hz, and electrodes maintained an impedance of less than 50 kΩ throughout the recording period[29]. Subsequently, the power spectrum densities for each epoch were assessed in the alpha frequency band (8–12 Hz), which is particularly relevant to sensorimotor processes. This analysis allowed for the examination of neural activity patterns associated with the intervention and its effects on cognitive and physical performance[30].

All EEG data were preprocessed using Brain Vision Analyzer (Version 2.2.0; Brain Products GmbH, Munich, Germany, manufactured in 2008). The data were initially re-referenced to the average reference, and a notch filter (50 Hz) was applied to eliminate power-line noise. Subsequently, an IIR filter was applied to perform low-pass filtering (cutoff 40 Hz) and high-pass filtering (cutoff 0.5 Hz) of the data.

Raw data inspection was conducted using a semi-automatic inspection method, with any remaining artifacts automatically identified based on specified criteria. These criteria included the Gradient criteria (maximum permissible voltage step: 50 V/ms, marked as bad for 200 ms before and 200 ms after the event), maximum and minimum criteria (highest possible absolute difference: 100 V, 200 ms interval, marked as bad 200 ms before and 200 ms after the event), and amplitude criteria (maximum permissible amplitude: -200 V/ms, maximum permissible amplitude: 200 volts per millisecond at lowest permitted activity, from maximum to minimum).

The dataset was then segmented into 2-second epochs, and any bad intervals were skipped. Finally, the durations of 2-second artifact-free epochs were exported for microstate analysis[31]. A Fast Fourier Transform (FFT) was performed on the selected data for each segment after the signal was re-referenced to an average (using 8 chosen electrodes) reference. Power spectrum densities were then averaged for each participant to quantify resting-state EEG power. This rigorous preprocessing approach ensured the removal of artifacts and allowed for reliable analysis of resting-state EEG data.

### Statistical analysis

All statistical analyses were conducted using IBM SPSS Statistics software version 26.0 (IBM Corp., Armonk, NY). Normality of the data was assessed using the Shapiro-Wilk test. Data were presented as means and standard deviations. Within-group differences were analyzed using paired t-tests and nonparametric tests, between-group differences were performed using Independent t-tests and nonparametric tests, as appropriate. Effect sizes were calculated for significant changes within groups. The level of significance was set at $p < 0.05$.

## Results

### Participant baseline characteristics

Except for age and grip strength, there were no significant differences in baseline characteristics between the two groups (Table 1). This suggests that participants were well-matched in terms of demographic and baseline physical characteristics prior to the intervention.

From Table 2, there was an overall increase in alpha band power of rs-EEG across various brain regions in the TC group, conversely, almost all alpha band power in the control group significantly decreased after 12 weeks ($p < 0.05$). Specifically, significant decreases were observed in alpha power at C3-α, C4-, F3-α, F4-α, P3-α, P4-α, and T7-α.

### Changes in physical fitness performance

After 12 weeks of training in Fig. 2, both groups demonstrated significant increases in long jump performance (169.41 ± 38.86 to 183.14 ± 38.62 cm; 166.39 ± 30.99 to 171.3 ± 32.88 cm, respectively, $p < 0.05$). However, the

| Variables | Tai Chi group ($n$ = 22) M (± SD) | Control group ($n$ = 23) M (± SD) | $P$-value | Total ($n$ = 45) M (± SD) |
|---|---|---|---|---|
| Demographic | | | | |
| Age | 20.09 (0.29) | 20.70 (0.56) | 0.01** | 20.40 (0.54) |
| Gender (male/female) | 7, 15 | 3, 20 | 0.14;$\chi^2$ = 0.13 | 10, 35 |
| BMI (kg/m$^2$) | 22.33 (3.32) | 21.42 (3.83) | 0.40;$\chi^2$ = 0.39 | 21.86 (3.58) |
| Physical fitness performance | | | | |
| Long jump (cm) | 169.41 (38.86) | 166.39 (30.99) | 0.73 | 167.87 (34.68) |
| Grip strength (kg) | 32 (9.02) | 27.68 (9.39) | 0.04* | 29.79 (9.37) |
| Balance (s) | 47.32 (55.13) | 48.07 (32.92) | 0.17 | 47.70 (44.64) |
| Flexibility (cm) | 15.45 (8.72) | 18.88 (5.08) | 0.19 | 17.21 (7.22) |
| Vital capacity (ml) | 3463.59 (722.71) | 3247.52 (647.80) | 0.36 | 3353.16 (686.32) |
| Alpha band power | | | | |
| C3-α ($10^{-3}$ μV Hz) | 9.0 (14.3) | 6.9 (6.7) | 0.98 | 7.90 (10.97) |
| C4-α ($10^{-3}$ μV Hz) | 7.1 (10.5) | 8.4 (11.3) | 0.43 | 7.78 (10.77) |
| F3-α ($10^{-3}$ μV Hz) | 5.6 (6.1) | 5.6 (5.1) | 0.56 | 5.60 (5.58) |
| F4-α ($10^{-3}$ μV Hz) | 4.9 (5.5) | 6.1 (7.3) | 0.62 | 5.52 (6.42) |
| P3-α ($10^{-3}$ μV Hz) | 21.7 (50) | 12.0 (14.6) | 0.80 | 16.73 (36.35) |
| P4-α ($10^{-3}$ μV Hz) | 15.8 (28.1) | 13.8 (15.5) | 0.31 | 14.78 (22.28) |
| T7-α ($10^{-3}$ μV Hz) | 2.9 (2.6) | 4.0 (3.6) | 0.39 | 3.47 (3.15) |
| T8-α ($10^{-3}$ μV Hz) | 3.3 (3.9) | 3.2 (3.6) | 0.78 | 3.28 (3.71) |

**Table 1**. Demographic characteristics of participants ($n$ = 45). BMI = Body Mass Index. Use * for $p < 0.05$ and ** for $p < 0.01$.

| Variables ($10^{-3}$ μV Hz) | Tai Chi group M (± SD) | | | Control group M (± SD) | | | Differences before and after M (± SD) | | | The changed ratio before and after (% ) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before | After | $P$ | Before | After | $P$ | TC group | Control group | $P$ | TC group | Control group |
| C3-α | 9.0 (14.3) | 9.6 (13.4) | 0.83 | 6.9 (6.7) | 3.5 (2.7) | 0.01** | 0.6 (13.2) | -3.4 (5.5) | 0.05* | 6.67 | -49.28 |
| C4-α | 7.1 (10.5) | 6.8 (7.4) | 0.86 | 8.4 (11.3) | 3.4 (2.5) | 0.03* | -0.3 (7.0) | -5.0 (10.0) | 0.02* | -4.23 | -59.52 |
| F3-α | 5.6 (6.1) | 5.9 (7.0) | 0.83 | 5.6 (5.1) | 2.7 (2.2) | 0.01** | 0.3 (7.2) | -2.9 (4.2) | 0.07 | 5.36 | -51.79 |
| F4-α | 4.9 (5.5) | 6.4 (6.9) | 0.18 | 6.1 (7.3) | 2.4 (1.9) | 0.02* | 1.5 (5) | -3.7 (6.7) | 0.01** | 30.61 | -60.66 |
| P3-α | 21.7 (50) | 22.7 (33.6) | 0.87 | 12.0 (14.6) | 5.5 (5.6) | 0.04* | 1.0 (30.9) | -6.6 (14.3) | 0.06 | 4.61 | -55.00 |
| P4-α | 15.8 (28.1) | 23.7 (41.8) | 0.26 | 13.8 (15.5) | 6.2 (4.4) | 0.02* | 7.9 (32.5) | -7.6 (14.7) | 0.01** | 50.00 | -55.07 |
| T7-α | 2.9 (2.6) | 8.2 (13.8) | 0.05 | 4.0 (3.6) | 2.1 (1.7) | 0.01** | 5.2 (11.9) | -1.9 (2.7) | 0.03* | 179.31 | -47.50 |
| T8-α | 3.3 (3.9) | 5.8 (9.9) | 0.09 | 3.2 (3.6) | 2.2 (1.6) | 0.12 | 2.5 (6.5) | -1.1 (3.2) | 0.01** | 75.76 | -34.38 |

**Table 2**. Effects on alpha band power after 12 weeks of TC intervention. *For $p < 0.05$ and **for $p < 0.01$.

TC group exhibited a significantly greater improvement in long jump performance compared to the control group. Regarding flexibility, there was no significant increase observed in the TC group. In contrast, the control group showed a significant decrease in flexibility ($p < 0.05$). No statistically significant differences were found between both groups for other physical performance outcomes.

## Discussion

This study aimed to examine the impact of a 12-week TC training program on alpha band power and physical performance, and explore the potential relationship between alpha band and physical fitness in college students. The results showed that the Tai Chi group had significant improvements in long-jump performance compared to the control group, and the alpha-band power in the Tai Chi group increased while it decreased in the control group, which is an intriguing area of study that merges neuroscience with exercise physiology.

Previous research has indicated the beneficial effects of TC on various aspects of physical performance in individuals with specific health conditions, this study revealed significant improvements in long jump performance and alpha band power following the 12-week TC training among young adults. A systematic review indicated that TC has positive effects on leg strength and flexibility in this population, however, it also found no significant effect of TC on BMI and grip strength[32]. Nevertheless, other studies have shown promising results, suggesting that TC may indeed offer benefits beyond elderly or diseased populations, extending to healthy college students[33]. Furthermore, some studies showed TC practitioners improved inter-hemispheric metabolism and neural integration, enhancing the network connection between the frontal cortex and central motor cortex, thus improving brain function[34], and elderly TC practitioners exhibited enhanced activity in the left frontal middle gyrus during resting states[35]. In this study, TC significantly improved physical fitness[36], and increased

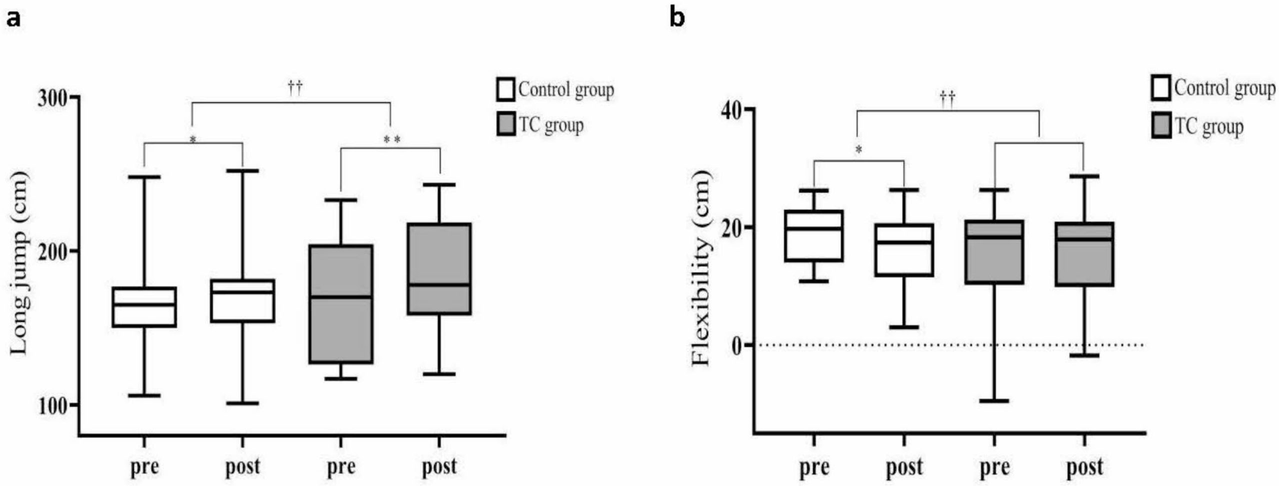


**Fig. 2**. Changes of body fitness after 12 weeks of TC intervention. (**a**) Changes of long jump after 12 weeks of TC intervention. (**b**) Changes of flexibility after 12 weeks of TC intervention. $p^*$ or $p^\dagger$ indicates a p-value less than 0.05, while $p^{**}$ or $p^{\dagger\dagger}$ indicates a p-value less than 0.01. The asterisk (*) denotes the mean before-after comparison within the group, while the dagger (†) represents the mean comparison between the before-after difference within the TC group and the before-after difference within the control group.

alpha band power in rs-EEG, aligning with previous studies showing associations between low alpha band power and negative symptoms[37].

Alpha band are commonly observed when the brain is in a relaxed and awake state, often associated with a calm and focused mental state[30]. Research has suggested that there may be a correlation between alpha brain waves and certain aspects of physical fitness. One proposed theory is that alpha band play a role in enhancing motor coordination, reaction time, and overall movement efficiency[30]. When an individual engages in physical activity, particularly activities that require precise coordination and skill, alpha band may become more prominent. And alpha band have been linked to states of mindfulness and mental concentration[19]. During exercise, particularly in activities like yoga or TC that emphasize mindfulness and body awareness, alpha band may increase as individuals focus their attention on their movements, breathing, and sensations within the body[20]. Furthermore, alpha band have been associated with the relaxation response, which is the body's natural counterbalance to stress. Regular exercise has been shown to reduce stress and anxiety levels, and it is possible that alpha band play a role in mediating this effect. Moreover, there is evidence to suggest that alpha band may contribute to the experience of "flow" or being in the zone during exercise. Flow is a state of optimal performance characterized by deep focus, heightened awareness, and a sense of effortless action. Alpha band have been observed in individuals experiencing flow states during various activities[38].

Indeed, the findings of this study contribute to the growing body of evidence suggesting that TC practice not only enhances physical performance but also improves alpha band performance. Prior research has highlighted individual differences in alpha band power of rs-EEG, which reflects cortical inhibition and cognitive control[17]. To the best of knowledge, this study represents the first randomized controlled trial (RCT) to investigate the effects of TC intervention on the physical and alpha band power of college students in mainland China. The findings revealed several noteworthy outcomes. Firstly, while the control group exhibited a decline in alpha power in rs-EEG, indicating potential negative effects on neural activity. The TC group showed improvements in long jump performance and increased alpha power in rs-EEG. A systematic review comparing TC to traditional physical activities in healthy adults found that TC is more effective than pure physical exercise in maintaining overall cognitive skills, and TC practitioners performed better in fitness tests[39].

The present study is not without limitations. First, although we initially thought the 12-week observation period might be short, previous research on similar exercise interventions has indicated that significant changes can take place within this time. However, a drawback of this study is that we only measured the outcomes immediately after the 12-week training. Future studies should extend the post-intervention observation period to determine how long these changes last. Secondly, while modern amplifiers with high internal resistances can record at higher scalp impedance without using conductive gel, it is conventional practice to keep electrode impedance below 5 kΩ. Although efforts were made to maintain low electrode impedance levels, variations in impedance could still have influenced the quality of the EEG data collected. Finally, the study did not explore the relationship between TC practice and brain structure, functional connectivity, and brain activity using advanced neuroimaging techniques. Future studies should consider integrating advanced neuroimaging methods to investigate the impact of TC exercise on different brain regions and neural networks underlying physical performance. Another limitation of this study is the relatively basic assessment of the musculoskeletal system. Future research could adopt more objective methods like myoton, tensiomyography, or elastography. These methods can more accurately measure the mechanical properties of the musculoskeletal system and establish correlations with morphological changes.

## Conclusion

TC's combination of gentle, flowing movements, deep breathing, and meditative focus can lead to an increase in alpha band, promoting a state of relaxation and mental clarity. Simultaneously, TC provides a comprehensive workout that improves physical fitness, including strength and flexibility. That is suggesting its potential as a valuable strategy for promoting overall physical health among college students.

## Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request. Data requests should include a brief description of the intended use and any relevant research credentials. All data sharing will comply with applicable ethical guidelines and institutional policies.

Received: 23 August 2024; Accepted: 13 February 2025
Published online: 18 February 2025

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## Acknowledgements
We fully appreciate all of the students who participated in our study.


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M.W.: Conceptualization, Methodology, Data curation, Visualization, Investigation, Writing- Original draft preparation. K.K.: Conceptualization, Methodology, Data curation, Investigation, Writing- Original draft preparation, Writing- Reviewing and Editing, Project administration, Funding acquisition. W.E.: Writing- Reviewing and Editing. S.W.: Conceptualization, Methodology, Writing- Reviewing and Editing, P.S.: Data curation, Visualization, Investigation.


## Funding
The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: the Research Center in Back, Neck, Other Joint Pain, and Human Performance (BNOJPH), Khon Kaen University, Thailand. The funder had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.


## Competing interests
The authors declare no competing interests.

## Additional information
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