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Long-term Tai Chi Training Is Associated With Better Dual-task Postural Control and Cognition in Aging Adults

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Abstract

Objective—Many activities within our daily lives require us to stand upright while concurrently performing a cognitive task (ie, dual tasking). The "costs" of dual tasking can present as a detriment to either task, or even both. Evidence supports that tai chi (TC), a mind-body exercise, improves both postural control and cognition. The purpose of this study was to (1) determine whether long-term TC training reduces dual-task costs to standing postural control, and (2) determine whether it characterizes the relationship between these costs and cognition in aging adults with and without long-term TC training.

Methods—Twenty-six TC experts (age 63 ± 8 y, TC experience 24 ± 11 y) and 60 controls (TC naive: age 64 ± 8 y) were studied. Center-of-pressure sway speed and elliptical area were recorded during quiet and dual-task standing. In addition, postural sway speed and range were analyzed in the anterior-posterior and medial-lateral direction. Dual-task cost was calculated as the percent

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AUTHOR DISCLOSURE STATEMENT
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change in center-of-pressure outcomes from quiet to dual-task conditions. Cognition was assessed with the digit span (verbal memory), trail making test (working memory and task switching ability), category naming (semantic verbal fluency), and F-A-S test (phonemic verbal fluency).

Results—TC experts had significantly lower dual-task costs to postural control in elliptical area (16.1 vs 110.4%, 95% confidence interval [CI], −94.27 to −0.07) compared with TC-naïves. TC experts also performed better on the digit span (23.5 vs 19.2; 95% CI, 0.68 to 3.59), trail making test A (28.5 vs 32.6 s; 95% CI, −3.83 to −0.21), and category naming (46.2 vs 41.3, 95%, CI 0.80 to 4.09), compared with TC naïves. There was not a clear significant association between better cognitive functioning and lower dual-task costs for either groups. These group differences and associations were independent of age, body mass index, education, and physical activity level.

Conclusions—These observations suggest cognitive-motor benefits from TC and the need for future controlled trials.

INTRODUCTION

Numerous activities of daily living require individuals to "dual task" (ie, to stand and maintain their balance while concurrently performing an unrelated cognitive task). Such dual tasking often comes at a "cost" to postural control, cognitive task performance, or both.[1,2] Previous studies have linked higher dual-task costs to aging,[1,3] cognitive deficits,[4,5] and falls risk.[6,7] Moreover, dual-tasking ability is associated with the executive function network and has been shown to have correlates to cortical structure and activation.[8,9] Together, these findings highlight the importance of functional connections between what are generally viewed as top-down (ie, cognition) versus. bottom-up (ie, postural control) processes, and support the therapeutic potential for multifaceted mind-body interventions.[10,11]

Tai chi (TC) is a mind-body exercise originating from traditional Chinese martial arts. TC combines slow movements with heightened body awareness, focused attention, imagery, and training of breathing.[12,13] TC has been shown to improve functions often deteriorated by age such as gait and balance,[14–16] flexibility,[17–18] cardiovascular health,[18–19] and cognition.[20] One recent study reported that in comparison with older adults without TC expertise, experienced TC practitioners demonstrated superior postural stability under both quiet and dual-task conditions.[21] Another study reported that long-term TC training was associated with improved gait dynamics, especially during dual-task challenges.[22] However, the potential of long-term TC training to attenuate the impact of dual task-mediated distractions on postural control during standing has received little attention.

Numerous studies have separately shown that TC practice has the potential to improve cognitive functioning in aging adults, specifically of the executive function network.[20,23,24] Prior research supports the idea that long-term TC training (ie, duration of approximately 14 y) may induce regional structure in the brain (ie, thicker cortical thickness within the prefrontal cortex and increased brain volume),[25] whereas a 6-week short-term multimodal intervention including TC, enhanced network connectivity relevant to cognitive-motor interactions during resting states.[26] Therefore, TC training may improve dual-task ability through benefits partly induced by plastic changes in cortical structure, particularly in the executive function regions, as well as connectivity.[25–28]

The aim of the current study was to determine cross-sectionally the effects of long-term TC training on (1) the dual-task costs to standing postural control induced by performance of a serial subtraction cognitive task, and (2) the relationship between the dual-task cost to standing postural control and cognitive function in aging adults with and without long-term TC training. We hypothesized that (1) long-term TC practitioners would exhibit lower dual-task costs to standing postural control, as compared with naïve healthy aging adults (ie, TC naïve group, those with no prior TC training), and (2) regardless of group, those with lower dual-task costs would exhibit greater cognitive functioning.

METHODS

Subjects

Healthy community dwelling adults with and without TC training (26 TC expert and 60 TC naïve, respectively) were recruited. Inclusion criteria were being 50 to 79 years of age and living or working within the greater local area. For the TC naïve group, exclusion criteria were as follows: (1) chronic medical condition including cardiovascular disease (myocardial infarction, angina, atrial fibrillation, or presence of a pacemaker); stroke, respiratory disease requiring daily use of an inhaler, diabetes mellitus; (2) active cancer (diagnosis <5 y ago and requiring ongoing chemotherapy or use of cytotoxic agents), stage III prostate cancer, dermatological cancer with reoccurrence; (3) neurological conditions (eg, seizure disorder, Parkinson's disease, peripheral neuropathy); (4) significant neuromuscular or musculoskeletal conditions requiring chronic use of pain medication; (5) acute medical condition requiring hospitalization within the past 6 months; (6) self-reported (current) alcohol/drug abuse or smoker; (7) uncontrolled hypertension (resting SBP > 160 or DBP > 100 mm Hg); (8) abnormal heart rate (resting HR > 100 BPM; <50 BPM); (9) abnormal ECG (eg, supraventricular tachyarrhythmia, atrial fibrillation, significant ST wave abnormality, second- and third-degree heart block); (10) current use of cardio- or vasoactive drugs and medications that can affect autonomic function including β-agonists and antagonists, drugs with anticholinergic properties (eg, tricyclic antidepressants or antipsychotics), and cholinesterase inhibitors; (11) self-reported inability to walk continuously for 15 minutes unassisted; (12) regular TC practice within the past 5 years; and (13) regular participation in physical exercise on average 4 or more times per week. Exclusion criteria were similar for the TC expert group, except they were not excluded based on the amount of weekly physical exercise, prior TC experience or the use of β-blockers to control diagnosed hypertension. All subjects signed an informed consent approved by the institutional review boards of institutions conducting this study.

Protocol

Dual-task Assessment.—Standing postural sway was recorded as the center-of-pressure (COP) displacement using a force plate (Kistler Instruments Corp, Amherst, NY, USA) during tests of quiet and dual-task standing. Subjects stood for 60 seconds with arms by their side and feet shoulder-width apart. For quiet standing, subjects were asked to stand as still as possible and to visually fixate on an "X" drawn on a wall approximately 3 meters away at eye-level. For dual tasking, subjects were instructed to stand with eyes open while subtracting 3s starting from a random 3-digit number between 200 and 999. Two trials were completed for each condition with at least 1-minute rest between trials. During the first trial, the position of each big toe was marked with tape to ensure consistent foot placement throughout the study.

Cognitive Battery

Subjects completed a test battery to assess cognitive status. The battery included the following cognitive domains and tests: short-term verbal memory was assessed with the digit span test,[29] perceptual speed and executive function (ie, working memory and task switching ability) was assessed using the trail making test(TMT) A and B,[30,31] respectively, semantic verbal fluency was assessed using the category naming test (ie, naming animals and supermarket items), and phonemic verbal fluency was assessed using the F-A-S test.[29] Subjects also completed the Mini-Mental State Exam (MMSE).[32] Subjects were given ample rest between each test.

Physical Activity

Subjects completed the physical activity status scale to determine their general level of physical activity during the previous week. The scale consisted of an 11-point scale (ie, 0–10) which combined physical activity duration (minutes) and intensity level (ie, heavy, modest or none).[33,34]

Data Analysis

Dual-task Performance.—Postural control parameters were (1) COP sway speed, calculated as COP path length divided by the trial duration (ie, 60 s) (mm/s), and (2) elliptical area, calculated as the area of a confidence ellipse enclosing 95% of the COP signal (mm^2). In addition, postural sway speed and range were analyzed separately for the medial-lateral (ML) and anterior-posterior (AP) directions. Postural control outcomes were recorded during both quiet and dual-task standing, objective metrics to determine dual-task costs, and averaged across two trials per condition. The first 5 seconds of postural control data were removed to eliminate the influence of early postural adjustments. Dual-task costs to postural control were calculated separately for each postural control outcome (ie, COP sway speed, elliptical area, ML and AP sway speed, and ML and AP range) as the percentage change from quiet to dual-task condition.[36,36]

Serial subtraction performance was also calculated as the percentage of correct responses; that is the number of correct subtraction responses divided by the total number of attempted subtractions, multiplied by 100. Performance was averaged across the 2 trials.

Cognition

The digit span test was scored as the longest number of digits the subjects could correctly recall, both forward and backward, after hearing a sequence of numbers. The number of correct digits in the forward trial and backward trial were added together to comprise the digit span "total."[29] The TMT-A was recorded as the time in seconds required for the subject to connect a series of numbers. TMT-B was recorded as the time in seconds required for the subject to connect a series of circles in an alternating sequence of numbers and letters.[30] TMT-B was adjusted by subtracting the TMT-A time from the TMT-B time. This derived score has been shown to be a better measurement of executive function.[31] The category total was calculated as the additive of the number of animals the subject could name in 60 seconds and the number of supermarket items named in 60 seconds. F-A-S total was calculated the additive of the number of "F", "A", and "S" words the subject could name within 60 seconds.[29]

Statistical Analysis

Student's *t* tests were used to compare group characteristics, postural sway parameters during quiet and dual-task conditions, the dual-task cost to standing posture, serial subtraction performance and performance on the cognitive test battery. Of note, the assumptions underlying these analyses were tested for unequal variances. Therefore, either the Welch's or Student's *t* tests were used.

One-way analysis of covariance (ANCOVAS) were used to test the hypotheses that TC experts would exhibit lower dual-task cost to standing posture as compared with the TC naïve group. Dependent variables were dual-task cost to standing posture outcomes (ie, COP sway speed, elliptical area, ML and AP sway speed, and ML and AP range). The independent variable was group (TC expert, TC naïve). Models were adjusted for age, body mass index (BMI), education level, and physical activity. These analyses were secondary and exploratory in nature and not meant to be confirmatory, therefore, the significance level was set to $P = .05$.

Multiple linear regression analyses were used to test the hypotheses that regardless of group, those with greater cognitive functioning, as measured by the cognitive battery, would exhibit lower dual-task costs. The dependent variables were dual-task cost to standing posture outcomes (ie, COP sway speed, elliptical area and ML and AP sway speed and range). The independent variables were the individual cognitive test scores (digit span, TMT-A, TMT-B, TMT-B adjusted, category total, and F-A-S test). Separate models were conducted for each group and performed for each dual task cost outcome. Models were adjusted for confounding variables (ie, age, BMI, education level, and physical activity level). Significance levels were set to $P = .05$. All analyses were performed using JMP PRO 11 software (SAS Institute, Cary, NC, USA).

RESULTS

Subjects

The TC expert subjects were well-matched to the age and sex distribution of the TC naïve group. Groups did not differ in global cognitive status as measured by the MMSE. Compared with the TC naïve group, TC experts had lower BMI, and a higher physical activity level. There was a statistically nonsignificant trend in education level, such that within the TC naïve group, the percentage of subjects with a high school diploma or less was higher, as compared with the TC expert group. The TC expert group reported an average of 24 years of TC training experience (Table 1).

The Association Between Long-term Tai Chi Training and Dual-task Performance

Group Differences in Serial Task Performance.—As compared with the TC naïve group, the TC expert group exhibited better performance on the serial subtraction task (Welch's *t* test: $t_{79.5} = 2.5$, $P = .01$, 95% CI, −6.36 to −0.76) (Table 1). However, in adjusted models accounting for age, BMI, education, and physical activity, the magnitude of observed between-group differences in performance was reduced and no longer statistically significant.

Among all participants, and within groups, performance on the serial subtraction task was not associated with the dual-task cost to any parameter of standing postural control (across groups: $R^2 < 0.04$, $P > .07$; TC expert: $R^2 < 0.15$, $P > .06$; TC naïve: $R^2 < 0.02$, $P > .27$). However, there was a statistically nonsignificant trend, such that among all participants and within the TC expert group, those who performed better on the serial subtraction task recorded lower dual-task cost to ML range.

Group Differences in Quiet and Dual-task Postural Control.—Unadjusted models determined that there were no differences in postural control parameters during quiet standing. During dual-task postural control, the TC expert group displayed lower elliptical area and ML range as compared with the TC naïve group ($P = .01$ and $P = .05$, respectively) (Table 2). However, after adjusting for age, BMI, education and physical activity level, the group differences in elliptical area was no longer significant, whereas ML range decreased to a statistically nonsignificant trend.

Group Differences in Dual-task Cost to Postural Control.—Unadjusted models suggest that the TC expert group exhibited lower dual-task costs to standing postural control as compared with the TC naïve group. Specifically, the TC expert group had lower dual-task cost to all measures of sway speed (Welch's *t* test; COP: $t_{83,6} = 2.50$, $P = .01$; ML: $t_{82.4} = 2.25$, $P = .03$; AP: $t_{83,8} = 2.31$, $P = .02$) and magnitude (Welch's *t* test; elliptical area: $t_{73.0} = 2.7$, $P = .009$, ML: $t_{82.2} = 2.47$, $P = .02$), as compared with the TC naive group. After adjusting for age, BMI, education, and physical activity level, between group differences remained for elliptical area ($P = .05$), whereas sway speed (COP, AP) and the magnitude of ML range decrease to a statistically nonsignificant trend (Table 3).

The Association Between Long-term Tai Chi Training and Cognition.—The TC expert group presented with better performance on the digit span (Student's *t* test; $P = .003$), TMT-A ($P = .001$), category total ($P = .01$) and F-A-S total ($P = .03$), as compared with the TC naïve group. Group differences in TMT-B results in a statistically nonsignificant trend. Group differences in digit span ($F_{1,77} = 8.52$, $P = .005$),TMT-A ($F_{1,81} = 4.92$, $P = .03$), and category total ($F_{1,81} = 8.74$, $P = .004$) remained significant after adjusting for age, BMI, education and physical activity (Table 3).

The Association Between Dual-task Performance and Cognition

The Relationship Between Serial Subtraction Performance and Cognition.—Among all subjects, those that performed better on the serial subtraction during standing performed better on the TMT-A test ($R^2 = 0.31$, $P = .006$, 95% CI [−0.54 to −0.09]) (ie, shorter amount of time to complete the task). There were statistically nonsignificant trends such that those that performed better on the serial subtraction during standing tended to perform better on the digit span and the TMT-B. This association was independent of age, BMI, education and physical activity. There were no other statistically significant or nonsignificant trending associations between dual-task serial subtraction performance and cognitive functioning.

The Relationship Between Dual-task Costs to Postural Control and Cognition.—Linear regression analyses determined that the relationship between dual-task costs to standing postural control and cognition was dependent upon TC group. Within the TC expert group only, those with better performance on the category test exhibited higher dual-task cost to AP range ($R^2 = 0.28$, $P = .03$, 95% CI [0.36 to 7.25]), independent of age, BMI, education, and physical activity. There were statistically nonsignificant trends such that those that performed better on the Category test, displayed higher dual-task costs to elliptical area and those with better performance on the F-A-S test, displayed higher dual-task costs to ML sway speed.

Within the TC naïve group, only statistically nonsignificant trending associations were present. Those with better performance on the category test tended to exhibit lower dual-task costs to ML sway speed and magnitude (elliptical area, ML). In addition, those with better performance on the F-A-S test tended to exhibit lower dual-task costs to sway speed (COP, ML, and AP) and ML range. Models were adjusted for age, BMI, education, and physical activity.

No other statistically significant associations or nonsignificant tends between dual-task costs to postural control and cognitive outcomes were observed.

The Association Between Education, TC Training, Dual-task Performance, and Cognition

Due to the observed attenuation of differences in cognitive-motor performance when years of education were considered, we performed secondary analyses to further explore how the effects of TC training on dual-task cost and cognition differed based on educational status (LOWER vs HIGHER). Subjects were stratified by educational status to where those with less than/equal to 16 years of education were considered the LOWER education group (n = 35), whereas those with greater than or equal to 17 years of education were considered the HIGHER education group (n = 47). Each education group was then separated into subgroups based on TC training (ie, LOWER education group [TC expert = 7, TC naïve = 28]; HIGHER education group [TC expert = 19; TC naïve = 28]). Four TC naïve subjects had missing education data and therefore was not included in the analyses.

Group Differences in Dual-task Cost to Postural Control Based on Education and TC Training.—The effects of TC training on dual-task cost to postural control were moderately influenced by educational status. Specifically, within the LOWER education group, there were no differences in dual-task cost to sway speed (Wilcoxon: COP, ML, AP) or magnitude (elliptical area, ML range, AP range) between the TC experts and TC naïves. However, there was a statistically nonsignificant trend in dual-task cost to ML sway speed and range, such that within the LOWER education group, TC experts had lower ML sway speed and range compared with the TC naïve group (25.4% vs 75.1% and 19.4% vs 61.3%, respectively). Lack of significance may be due to small sample size. Within the HIGHER education group, there were no differences or statistically nonsignificant trending differences in dual-task cost to postural control between the TC experts and TC naïves.

Group Differences in Postural Control Within Quiet and Dual-task Conditions Based on Education and TC Training.—The effects of TC training on quiet standing were not influenced by educational status. However, the effects of TC training on dual-task standing were marginally influenced by educational status. Within both the LOWER and HIGHER education groups, statistically nonsignificant trends were presented, such that TC experts displayed lower ML range compared with the TC naïve group (12.5 vs 23.1 mm^2 and 16.6 vs 22.2 mm^2, respectively). Within the HIGH education group only, statistically nonsignificant trending group differences were present for elliptical area such that TC experts had lower elliptical area as compared with TC naïves (223.4 vs 289.1 mm^2).

The Relationship Between Education, TC Training, and Cognition.—The effects of TC training on cognitive functioning were influenced by educational status. Specifically, within the LOWER education group, TC experts performed better on the TMT-A ($P = .04$), F-A-S ($P = .004$), and category ($P = .03$) tests compared with the TC naïve group. Conversely, within the HIGHER education group, TC experts performed better on the digit span ($P = .02$) and TMT-A ($P = .04$) test compared with TC naïve group. There were no other differences in cognitive test performance within the LOWER or HIGHER education groups.

DISCUSSION

This observational study suggested that long-term TC training was associated with lower dual-task costs to standing postural control. Our results also indicated that TC experts tend to perform better across a range of cognitive tests; these findings were robust to inclusion of confounders. Within the TC expert group, those with *higher* dual-task costs (across multiple measures of postural control) had *higher* cognitive function. However, within the TC naïve group, those with *lower* dual-task costs (across multiple measures of postural control) had *higher* cognitive function. These between-group differences suggested that dual-task performance is partially dependent on cognitive function, particularly in non-TC practitioners, and that the underlying mechanisms involved in TC may reduce this dependency. Collectively, these findings indicated that those who practiced long-term TC (in this study, the mean was approximately 24 y) tended to exhibit better cognitive-motor performance compared with those without TC training.

TC training is associated with reduced falls in aging adults, which has been attributed in part to improved postural control.[15,37,38] As falls typically occur during ADLs and IADLs that often include dual tasking, it is plausible that the lower fall rates following TC training result from improved postural control specifically during dual-task activities. Our results are the first to reveal that, as compared with those without TC training experience, long-term TC practitioners demonstrated lower dual-task costs to postural sway speed (ie, COP and ML) and magnitude (ie, elliptical area and ML range) in response to the execution of a serial subtraction task. These results were consistent with reports that TC interventions improved gait under quiet and dual-task conditions[22,39] and performance in clinical measures of balance, mobility, and physical function.[15,17,18,37,39] Of note, although we observed that employing a dual-task challenge during quiet standing impacted postural control and discriminated differences between TC experts and TC naïve adults, caution is required in interpreting this as a mechanism related to fall prevention. Parameters of quiet standing in community-dwelling aging adults are not consistently associated with fall risk.[40] Future studies should continue to explore the impact of short- and long-term TC training on more provocative dual-task challenges (eg, during stair descent),[21] and the association of these indices of cognitive-motor interactions on fall risk.

Mounting evidence indicated that a range of interventions (eg, exercise, blood pressure and stress management, diet) can slow age-related cognitive decline. In the current study, those with long-term TC training had better cognitive functioning, specifically in verbal memory, working memory, and semantic verbal fluency. This observation is supported by previous studies that link shorter-term TC interventions to improved executive functioning related to working memory, attention, planning, and organizing.[27,41] These known positive effects on cognition appeared to be related to observable differences in brain structure and function.[25,27,28,41] For example, in a MRI study conducted by Wei et al,[28] a group of healthy adults (mean age 52 ± 6 y) with long-term TC training had greater cortical thickness in the frontal lobe (ie, the precentral gyrus, middle frontal sulcus, the insula sulcus) and smaller areas within the temporal and occipital lobes. Furthermore, studies by Yin et al[27] suggested that only 6 weeks of TC training combined with group counseling enhanced memory, as well as the resting-state functional connectivity between the prefrontal cortex and medial temporal lobe areas vital for verbal and semantic memory. Therefore, future work is needed to determine the effects of TC training on additional markers of brain function (eg, cerebral blood flow and oxygen regulation), particularly within the executive-function network of the frontal lobe, which has been shown to be linked to both dual-task capacity and balance control.

Previously, the postural control system was perceived as being largely autonomous. We have now come to realize that there is a functional integration between the mind (ie, cognitive functioning) and the body (eg, postural control, gait).[4,42] Our results indicated that within the TC naïve group, those with lower dual-task cost to standing sway speed (COP, ML, and AP) and magnitude (ie, elliptical area and ML range), tended to perform *better* on the category and F-A-S tests. Unexpectedly, our results further indicated that within the TC expert group, those that recorded lower dual-task cost to standing ML sway speed and magnitude (ie, elliptical area, AP range), tended to perform *worse* on the category and F-A-S test. Verbal fluency (ie, category and F-A-S) are known clinical tests to measure executive functioning. Numerous studies have already determined that impairments within the executive function network manifests as impairments in motor function such as postural control and gait, also termed executive dysfunction.[43–45] Directional differences between groups may be due to the effects of TC training implementing a different compensatory strategy compared with the TC naïve group. For example, in TC experts with lower executive functioning, differences may be attributed to the allocation of cognitive resources toward control of the postural system rather than the serial subtraction cognitive task.

Nonetheless, previous research findings of executive dysfunction provide the rationale for the link between standing postural control sway speed and magnitude, and category and F-A-S test performance within both groups.

Formal education is a known confounder of dual-task cost and cognition. A secondary analysis was conducted to determine whether TC practice had a uniform and consistent effect across postural sway parameters and cognitive performance, independent of educational status (ie, LOWER vs HIGHER). The effects of TC training on postural sway parameters appeared to be marginally influenced by educational status as dual-task cost parameter tended to be similar. However, there were trends suggested that TC training had consistent positive effects on postural control in the ML plane irrespective of educational status. These findings are supported by previous TC research which showed improved ML body sway after 12-week of TC training and highlighted the ML plane as being more responsive to TC improvements in dual tasking and the system's ability to cope with such task.[46]

Our secondary analyses also determined that the effects of TC training on cognitive functioning were influenced by educational status. TC practice improved perceptual speed (ie, TMT-A) irrespective of educational status. However, educational status appeared to influence the effect of TC training on other domains of cognitive functioning. Specifically, in persons with lower levels of education, TC was associated with better semantic and verbal fluency (ie, F-A-S and Category naming tests), whereas in persons with higher levels of education, TC was associated with better attentiveness and short-term verbal memory (ie, digit span). These differences in cognitive domains, as well as postural sway, based on educational status within this cohort may have mechanistic underpinnings related to neuroplastic changes due to enriched environments (eg, frequent novel life experiences)[47,48] and cognitive reserve.[49–51] In turn, these neuroplastic changes may increase cognitive reserve which improves cognitive-motor function.[52,53] Therefore, TC training may impose different cognitive-motor improvements based on educational status. Perhaps, such knowledge can be used to support the need for individualized cognitive-motor training programs within rehabilitation settings. At a minimum, education should be carefully considered as a potential confounder or effect modifier in future studies.

This cross-sectional secondary analysis investigated the effects of long-term TC training on dual-tasking ability and cognition; therefore, the results should not be considered causal. Comorbidities, medication, and form of tai chi style were not explored in the current study and their role should be more systematically evaluated in future studies. In addition, post hoc corrections for multiple comparisons were not used due to the exploratory nature of this study. Nonetheless, the reported results support the hypothesis that long-term TC training benefits dual-task postural control and cognition, along with related mental processes. Future randomized controlled trials are thus warranted to examine the effects of longer-term TC intervention (eg, for several years) and whether there is a dose response (ie, a minimum amount of years to see an improvement) on dual-task performance, postural control and cognition in older adults without prior TC training experience.

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Table 1.

Group Characteristics Among Those With and Without Long-term TC Training

	TC Expert n = 26	TC Naïve n = 60	*P* Value
Age (y)	63 (8)	64 (8)	.36
Sex (women, %)	54	67	.33
Body Mass Index (kg/m^2)	23 (2)	26 (5)	<.001[b]
Education (≤HS Diploma, %)	0	14	.05
Mini Mental State Exam	29 (1)	29 (1)	.99
Physical Activity Level[a]	6 (2)	4 (2)	.01[b]
TC Practice (y)	24 (11)	-	-
Serial Subtraction Performance (%)	96 (4)	92 (9)	.01[b]
Range	87.5–100	61.9–100	

Note: Data = means (SD).

[a]Based on the physical activity status scale: 6 = run approximately 6 to 10 miles/week or walk 7–13 miles/week or spend 1–3 hours/week in comparable physical activity; 4 = run approximately 1 mile/week or walk approximately 1.3 miles/week OR spend approximately 30 minutes/week in comparable physical activity.

[b]Significant *P* value < .05 as determine by Student's *t* test and Fisher's exact test.

Abbreviations: TC, tai chi; HS, high school; SD, standard deviation.

Table 2.

Quiet and Dual-task Postural Control Parameters in TC Expert and TC Naïve.

	TC Expert	TC Naïve	*P* Value
Quiet Standing			
COP Sway Speed (mm/s)	8.9 (3.3)	8.3 (2.4)	.41
ML	3.9 (2.2)	3.7 (1.7)	.69
AP	7.1 (2.3)	6.6 (1.9)	.33
Elliptical Area (mm^2)[a]	109.7 (56.8)	131.0 (73.2)	.16
ML Range (mm)	14.3 (12.7)	15.5 (9.8)	.65
AP Range (mm)	24.6 (9.4)	24.5 (7.7)	.98
Dual-task Standing			
COP Sway Speed (mm/s)	11.0 (4.6)	12.5 (7.1)	.27
ML	4.8 (2.3)	5.8 (4.2)	.15
AP	8.8 (3.7)	9.7 (5.1)	.40
Elliptical Area (mm^2)[a]	127.9 (106.3)	225.4 (231.1)	.01[b]
ML Range (mm)	15.5 (12.0)	22.9 (21.6)	.05[b]
AP Range (mm)	28.1 (16.6)	31.5 (15.7)	.38

Note: Data = means (SD).

[a]High variability for this sway parameter resulted in the removal of outliers 2SD +/− the mean for this analysis only: Quiet - (1) TC expert, (4) TC naïve; Dual task – (1) TC expert, (2) TC-naïve.

[b]*P* value < .05 as determine by Student’s *t* test.

Abbreviations: TC, tai chi; COP, center of pressure; ML, medial-lateral; AP, anterior-posterior.

Table 3.

Dual-task Cost and Cognition Unadjusted and Adjusted for Covariates in TC-expert and TC-naïve

	UNADJUSTED				ADJUSTED			
	TC Expert	**TC Naïve**	***P* Value**	**95% CI**	**TC Expert**	**TC Naïve**	***P* Value**	**95% CI**
Dual-task Cost (%)								
COP Sway Speed	23.7 (24.8)	47.2 (62.4)	.01[a]	4.82 to 42.24	44.5 ± 15.3	69.0 ± 10.5	.08	−26.19 to 1.70
ML	27.8 (35.0)	53.6 (70.8)	.03[a]	3.01 to 48.48	41.8 ± 18.0	69.9 ± 12.3	.09	−30.52 to 2.37
AP	23.8 (25.1)	45.4 (61.5)	.02[a]	3.05 to 40.22	47.2 ± 14.9	68.9 ± 10.2	.18	−24.47 to 2.78
Elliptical Area	12.1 (50.3)	88.9 (206.5)	.009[a]	20.11 to 133.41	16.1 ± 51.6	110.4 ± 35.3	.05[a]	−94.27 to −0.07
ML Range	13.4 (47.3)	51.2 (94.5)	.02[a]	7.30 to 68.28	15.7 ± 24.6	56.6 ± 16.9	.07	−42.94 to 2.02
AP Range	13.8 (43.5)	32.2 (66.2)	.13	−5.64 to 42.51	21.7 ± 17.4	44.8 ± 11.9	.15	−27.50 to 4.33
Cognition								
Digit Span	22 (4.2)	18 (6)	.003[a]	−5.87 to −1.26	23.5 ± 1.6	19.2 ± 1.08	.005[a]	0.68 to 3.59
TMT-B Adj (s)	27 (19)	30 (19)	.52	−6.20 to 11.98	30.2 ± 5.7	33.9 ± 4.0	.47	−6.89 to 3.22
TMT-A	24 (6)	30 (8)	.001[a]	2.31 to 8.81	28.5 ± 2.0	32.6 ± 1.4	.03[a]	−3.83 to −0.21
TMT-B	51 (21)	60 (21)	.09	−1.45 to 18.4	59.7 ± 6.2	67.2 ± 4.3	.17	−9.19 to 1.68
Category Total	46 (6)	42 (7)	.01[a]	−7.12 to −0.87	46.2 ± 1.8	41.3 ± 1.2	.004[a]	0.80 to 4.09
F-A-S Total	47 (9)	41 (11)	.03[a]	−9.95 to −0.66	42.0 ± 2.9	38.4 ± 2.0	.17	10.54 to 61.17

Note: Data = means (SD); CI, confidence intervals 95% (lower, upper) for dual-task cost (%) and cognition; adjusted data, least square means ± SE; *P* value as determined by 1-way ANCOVA.

[a]Significant *P* value < .05 as determine by Student's *t* test and Fisher's exact test, Welch's or Student's *t* test; dual-task cost and cognition adjusted by age, BMI, education level, and physical activity level, $P < .05$.

Abbreviations: TC, tai chi; COP, center of pressure; ML, medial-lateral; AP, anterior-posterior; TMT, trial-making test.