

Effect of Nine-Square Counting Dance on Physical and Cognitive Function in Older Adults with Mild Cognitive Impairment: A Randomized Controlled Trial

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Abstract

The cognitive impairment was increasingly prevalent with advancing age and was associated with an elevated risk of falls, injury, functional decline, and cognitive impairment. This study aimed to investigate the impact of a four-week integrated intervention involving a nine-square dance and a counting program on physical function by the Timed Up and Go Test (TUGT), the five-times sit-to-stand test (FTSST), 10-meter walk test (10MWT), 6-minute walk test (6MWT), and cognitive functioning by the Mini-Mental State Examination (MMSE) in older adults diagnosed with mild cognitive impairment. A single-blinded randomized controlled trial was conducted in Thailand, involving 38 older adults from the community, each aged 60 years or older. In a random selection process, participants were designated to either the control group (which participated in the nine-square dance: CONT) or a nine-square counting dance (NSCD) intervention. The finding indicated that the NSCD group demonstrated a positive effect of the intervention on the overall cognitive test in MMSE (mean change of 4.67 points, $p < 0.001$). Moreover, statistically significant differences were observed between the groups across all physical function outcome measures ($p < 0.01$ or $p < 0.001$), except for the 10MWT. Therefore, the nine-square counting dance intervention was more effective in enhancing cognitive and physical performance among older adults exhibiting mild cognitive impairment when compared to the nine-square dance modality alone.

Keywords: Exercise, Dancing, Alzheimer's, Balance, Older People

Introduction

The cognitive impairment was increasingly prevalent with advancing age (> 60 years), has been notable, with projections mentioning that close to 50 million individuals faced this issue globally in 2022, and it is estimated that this figure will climb to at least 80 million by 2030 (Hao et al., 2025; Moon et al., 2024). Mild cognitive impairment (MCI) is considered a risk factor for dementia and may progress to mild dementia (Diniz et al., 2007). The Mini-Mental State Examination (MMSE) is typically scored out of 30 points, evaluating orientation, recall, language, and motor skills. Standard clinical cutoffs classify scores as normal (≥ 27), mild cognitive impairment (20–26), and dementia (< 20) (Gómez-Soria et al., 2021; Arevalo-Rodriguez et al., 2021; Galea & Woodward, 2005), has been acknowledged as a significant precursor to deficits in gait and balance, which subsequently resulted in diminished strength of the trunk and lower-limb musculature, alongside an elevated vulnerability to tripping hazards. These transitions were not limited to influencing the persons enduring them; they also brought about critical results for their relatives and those who assist them (Bahureksa et al.,

2017; Pieruccini-Faria et al., 2020). In these situations, it was increasing in falling rate, onset of complications, and disabilities (Bahureksa et al., 2017). On the other hand, the investigations highlight that the prevalence of falls and the introduction of disabilities may be addressed through the application of focused interventions. Consequently, the objective of this investigation was to augment cognitive functioning, balance stability, muscular strength, ambulation capability, and endurance, thereby enhancing mobility, decision-making processes, memory retention, and ultimately diminishing the likelihood of falls and their concomitant dangers in older adults diagnosed with mild cognitive impairments (Ambrose et al., 2015; Judge, 2017).

The aerobic exercises research, including step activities and dance 15 to 60 minutes per session with 1 to 3 times weekly, and spanning a duration of 4 to 24 weeks (Chow et al., 2022). Cognitive exercises, such as puzzle-solving, dual task and counting tasks, had also shown enhancing mental agility and memory (Fissler et al., 2017). Despite these advances, few studies have investigated the combined effects of nine-square dance with cognitive counting tasks on both physical and cognitive functions via a nine-square dance with easily counting (especially subtraction by fives) that could have been readily implemented for this population. This study selected subtraction by fives rather than more commonly used variants (e.g., subtraction by threes or sevens) due to its moderate difficulty. The beginner level was deemed suitable for patients with no prior experience and for the elderly. Consequently, backward subtraction of 5 was chosen for this study. Moreover, it helped stimulate working memory and concentration without imposing excessive cognitive load (Vaportzis et al., 2014). Thus, this study proposed integrating nine-square dance exercises with numerical tasks for older adults with mild cognitive impairment on physical by Timed Up and Go Test (TUGT) (Barry et al., 2014), five times sit-to-stand test (FTSST) (Poncumhak et al., 2016), 10-meter walk test (10MWT) (Potter et al., 2011), 6-minute walk test (6MWT) (Thaweewannakij et al., 2013) and cognitive functioning by the Mini-Mental State Examination (MMSE) (Manjavong et al., 2021). We hypothesized that older adults participating in the nine-square counting dance program would demonstrate greater improvements in cognitive function, balance, gait performance, muscle strength, and endurance than those participating in the nine-square dance program alone.

Materials and Methods

Participants

A single-blind randomized controlled trial, with an assessor blinded, was carried out among community-dwelling older adults aged 60 years and older from various rural communities in Thailand in 2025. Participants were required to be able to communicate in Thai (Manjavong et al., 2021), be considered able to walk independently or with walking aids for safety, and have MMSE scores between 20 and 26 (Gómez-Soria et al., 2021; Arevalo-Rodriguez et al., 2021; Galea & Woodward, 2005). Individuals demonstrating any indicators or manifestations that could potentially impair their ambulation or their ability to engage in the study, including but not limited to unstable health conditions, neurological impairments with subsequent consequences, or individuals who regularly participate in physical exercise at a frequency of no less than three days per week, were systematically excluded from the research (Turgut & Naz, 2023). The sample size was calculated with a standard two-sample t-test formula with 80% of a power, 0.70 of effect size from a pilot study using the MMSE outcome, and a significance level of 0.05. At least 19 participants per group were required to adequately represent the most variables of interest. All eligible participants provided written informed consent. The study was approved

by the Mae Fah Luang University Ethics Committee on Human Research (COA 146/2025) and registered with the Thai Clinical Trials Registry (TCTR20260209004).

Research protocols

On the initial day, eligible participants underwent interviews and baseline assessments to gather demographic information. Consequently, they were allocated to either the control group (which participated in the nine-square dance: CONT) or the experimental cohort (Nine-square counting dance: NSCD) via simple randomization by drawing lots to achieve allocation concealment. This study employed separate evaluators and a randomization label to conceal the evaluators' identities from the participant group. Moreover, the evaluators were not the same individuals who led the exercise sessions. Outcome measurements were conducted at baseline and subsequently reassessed after a duration of four weeks (Fig. 1). The details regarding the training programs and the outcome measures are described below.

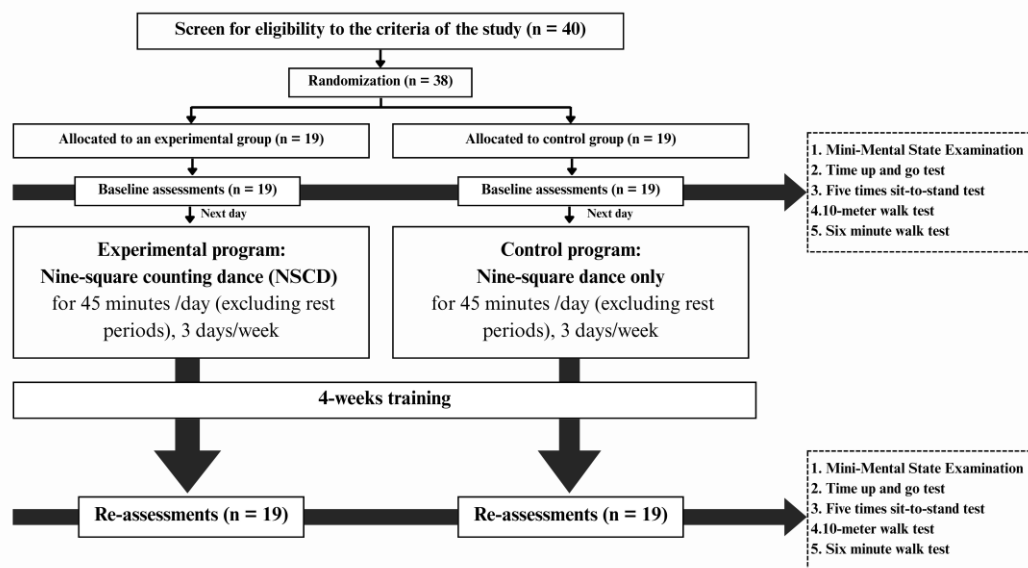


Figure 1 Participation flowchart

Nine-square training programs

Participants engaged in the activities assigned to their respective groups. All participants were instructed to perform a dance routine (Atipas et al., 2019), accompanied by music featuring various rhythms ranging from mild to moderate, by music with a tempo ranging from 120 to 160 beats per minute (bpm) that were lively and stimulating to enhance engagement (Mathews et al., 2001). The dance routine included two components: Kao-ta (step) and Kao-ten (dance) (Fig. 2). The movements were repeated in both directions for 20 cycles per position. Participants completed this routine for each session, lasting 45 minutes, including 10 minutes of warm-up and cool-down and 35 minutes of training, 3 days/week over 4 weeks (Fig. 1). All participants were instructed to dance barefoot, with no socks or slippers permitted.

- *Experimental group (NSCD)*: The participants were directed to perform the nine-square dance with simple subtraction counting (50, 45, 40, 35...) during the exercise sessions (Geary et al., 1993; Wei et al., 2024).
- *Control group (CONT)*: The participants were instructed to perform the nine-square dance on a hard, flat, and smooth surface without simple subtraction counting.

Outcome measures

Participants were assessed for their functional mobility necessary for being independent, including the TUGT, FTSST, 10MWT, 6MWT, and cognitive function using MMSE in a random sequence. The raters had excellent inter-rater reliability (intraclass correlation coefficients [ICCs] = 0.90 – 0.99). The details of each assessment are as follows.

- *Timed Up and Go Test (TUGT)*: this test serves as a highly reliable metric (ICC= 0.97), wherein the results signify the proficiency of dynamic balance regulation, mobility, and the potential risk of falls within the older adults. They were instructed to stand, then walk in 3 meters and around a traffic cone, and return to a seated position as quickly and safely as possible. The test was recorded for the time used in (seconds) (Barry et al., 2014; Shumway-Cook et al., 2000).

- *Five times sit-to-stand test (FTSST)*: This test is highly valid for muscle strength assessment (Poncumhak et al., 2016). They Participants were instructed to continuously perform in five times of sit to stand as quickly and safely as possible without using their arms. The start was recorded when the instruction "go" was given until the participant's back contacted the chair backrest after completing the fifth repetition. The test was recorded, the time used in (seconds) (Lord et al., 2002; Mato et al., 2022; Poncumhak et al., 2016).

- *10-meter walk test (10MWT)*: This test had ICC 0.97; all participants were directed to walk a 10-meter walk at their maximum speed (Amatachaya et al., 2020; Potter et al., 2011). The duration time was recorded at 4-middle walkway. Consequently, the data were modified into gait velocity in meters per second (m/s) (Cesari et al., 2005; Potter et al., 2011).

- *6-minute walk test*: A highly reliable (ICC = 0.95) and commonly used to assess functional endurance among community older adults (Chan & Pin, 2019; Steffen et al., 2002; Thaweewannakij et al., 2013). The test involved walking the maximum possible distance on a rectangular track over six minutes. Throughout the test, participants received periodic time updates and verbal encouragement to sustain their walking pace. The total distance traveled during the six minutes was recorded at the end of the test (Chan & Pin, 2019; Steffen et al., 2002; Thaweewannakij et al., 2013).

- *Mini-Mental State Examination (MMSE)*: It is the major tool for measuring mental faculties, especially in individuals dealing with mild cognitive impairments or analogous brain conditions. The test consists of 11 parts with a maximum possible score of 30 points. The instrument has been utilized within geriatric populations to ascertain baseline cognitive capabilities. It demonstrates substantial reliability, as evidenced by an intraclass correlation coefficient (ICC) that ranges from 0.93, in addition to exhibiting robust construct validity. MMSE was recorded in scores that had cutoffs like normal (≥ 27), mild cognitive impairment (20–26), and dementia (< 20) (Tanglakmankhong et al., 2022; Van Patten et al., 2019; Gómez-Soria et al., 2021).

6MWT and MMSE were conducted in a single trial; the 10MWT, TUGT, and FTSST were performed in three trials, with the average results used for data analysis. Throughout the assessments, an observer accompanied participants to ensure safety and measurement accuracy. Participants were given a practice session to acquaint themselves with the footwear. They were also allowed to rest as needed during the study and the tests.

Statistical analysis

Data were analyzed using SPSS version 31. Descriptive statistics were used to explain the demographic data of the participants and the findings of the study. The dependent sample t-test was used to analyze the different findings between baseline and 4-week measurement of each outcome (within-group comparisons). The one-way

analysis of covariance (ANCOVA) with the use of baseline data as a covariate and the group as a fixed factor was used to compare the 4-week data between the groups. The significance level was set at p -value < 0.05 .

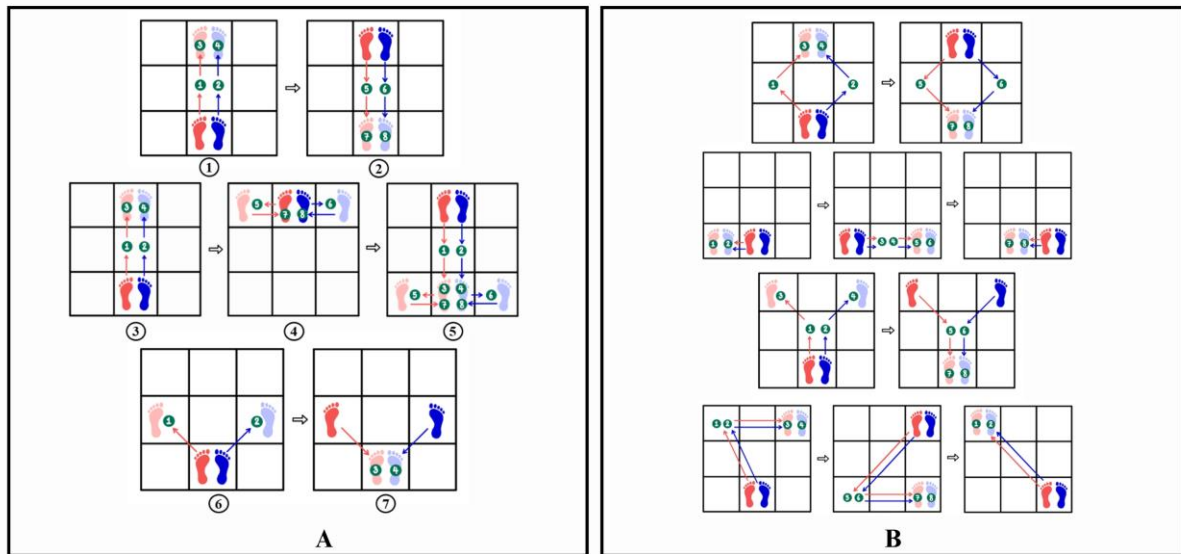


Figure 2 Detail of the nine-square dance

(A) Kao-ta (9-square step exercise) Stand in the bottom left square 1) Move right foot to bottom right square 2) then left foot 3) Move right foot to top right square 4) then left foot 5) Move left foot to top left square 6) then right foot 7) Move left foot back to bottom left square 8) then right foot 9) After one cycle, switch to the bottom right square and repeat clockwise.

(B) Kao-ten (9-square dance exercise) Stand with your left foot in the bottom left square and right foot in the bottom right square 1) Move left foot diagonally to top right square 2) Swing right leg over left and place it in top left square 3) Return left foot to bottom left square 4) Move right foot back to bottom right square 5) Repeat movements in the opposite direction.

Results

Participant characteristics

A total of 38 participants, with an average age of 63 years and a normal BMI, were enrolled and allocated to the control group ($n=19$) and the experimental group ($n=19$). No significant differences were observed between the groups in baseline demographic or health-related variables and normal distribution data (all $p > 0.05$). Approximately 21% of participants were male, and all participants in both groups had at least one underlying health condition. Additionally, there were no significant differences in baseline regarding fall history or weekly training frequency. These comparable initial values suggest a balanced starting point for subsequent group comparisons throughout the study (Table 1).

Table 1 Baseline demographics of the participants (n = 38)

Variables	Total (n=38)	Control group (n= 19)	Experimental group (n = 19)	p -value ^b
Age: year ^a	63.00 ± 3.65	63.00 ± 4.04	64.00 ± 3.29	0.249
Gender: male, n (%)	8 (21.05)	5 (26.32)	3 (15.79)	0.440
BMI: kg/m ²	24.64 ± 3.94	24.71 ± 3.66	24.56 ± 4.29	0.911
Underlying diseases: yes, n (%)	20 (100.00)	10 (100.00)	10 (100.00)	0.712
Fall history: times	0.71 ± 1.14	0.58 ± 1.02	0.84 ± 1.26	0.483
Total MMSE score	21.45 ± 2.27	21.37 ± 1.67	21.53 ± 2.79	0.834

Note: ^a The data are presented using mean ± standard deviation, ^b p -values from the independent samples t-test,

^{*} The superscripts indicated significant differences with the p-value < 0.05. Abbreviations: *n* number, *BMI* Body mass index, *MMSE* Mini-Mental State Examination.

Cognitive function outcomes

There were significant differences between the experimental and control groups of the four-week intervention. For the total score of MMSE for the control group exhibited only a marginal and statistically non-significant increase (a decrease of 0.79 score, $p > 0.05$), the score for the experimental cohort demonstrated a markedly significant enhancement ($p < 0.001$). Post-intervention comparative analysis revealed a significant difference in the experimental group ($p < 0.001$), demonstrating the positive effect of the intervention on overall cognitive test (Table 2). A comprehensive assessment of the MMSE subscales revealed that notable advancements were recorded within the experimental group, especially in the domains of temporal and spatial orientation, attention and calculation, as well as memory function (recall) (all $p < 0.001$). Conversely, the control cohort exhibited minimal fluctuations in these domains, with some areas even reflecting a decline. Furthermore, the experimental cohort attained a significant upsurge in performance in the “language” category ($p < 0.001$), whereas no significant alterations were detected in the control group (Table 3).

Physical outcomes

After 4 weeks, the experimental group showed significant improvement in several assessments when compared to the control group (Table 3). In the TUGT, the control group showed minimal change, whereas the experimental group significantly reduced their test time ($p < 0.001$, Table 2). Similarly, in the FTSST, the experimental group performed markedly better after four weeks compared to baseline and outperformed the control group ($p < 0.001$). The 6MWT also revealed a significant increase in distance covered in the experimental group ($p < 0.001$), with no notable changes in the control group (Table 2). Conversely, in the 10MWT, a significant decrease in walking speed was observed only in the control group ($p < 0.05$), although there were no significant differences between groups ($p = 0.74$) (Table 3).

Table 2 Comparison of baseline and 4-week measures (n=38)

Variables	Participants (n= 38)			
	Control group (n=19)		Experimental group (n=19)	
	Mean ± SD (95% CI)		Mean ± SD (95% CI)	
Timed up and go test (s)				
Baseline	9.30 ± 1.26	(8.70, 9.91)	9.26 ± 1.19	(8.68, 9.84)
4-weeks assessments	9.87 ± 1.76	(9.02, 10.73)	7.93 ± 1.77	(7.47, 8.39)
Mean difference	-0.36 ± 0.53	(-0.62, -0.11)	1.33 ± 0.74	(0.97, 1.69)
p -value ^a	0.008 ^{**}		< 0.001 ^{***}	
Five time sit-to-stand (s)				
Baseline	8.68 ± 1.71	(7.86, 9.51)	9.00 ± 1.56	(8.26, 9.76)
4-weeks assessments	9.05 ± 1.56	(8.29, 9.80)	8.01 ± 1.26	(7.41, 8.62)
Mean difference	-0.36 ± 0.39	(-0.55, -0.17)	0.99 ± 1.09	(0.47, 1.52)
p -value ^a	<0.001 ^{***}		< 0.001 ^{***}	
10 Meter Walk test (m/s)				
Baseline	1.42 ± 0.18	(1.33, 1.50)	1.42 ± 0.20	(1.33, 1.52)
4-weeks assessments	1.29 ± 0.14	(1.23, 1.37)	1.32 ± 0.25	(1.20, 1.44)
Mean difference	0.12 ± 0.10	(0.07, 0.17)	0.10 ± 0.31	(-0.04, 0.25)
p -value ^a	< 0.001 ^{**}		0.169	
6-minutes-walk tests (m)				
Baseline	349.46 ± 48.16 (326.25, 372.68)		351.26 ± 48.32 (327.97, 374.55)	
4-weeks assessments	351.21 ± 46.40 (328.84, 373.57)		395.18 ± 69.52 (361.68, 428.69)	
Mean difference	-1.74 ± 6.97 (-5.10, 1.62)		-43.93 ± 39.70 (-63.05, -24.80)	
p -value ^a	0.290		< 0.001 ^{***}	
Total MMSE score				
Baseline	21.37 ± 1.67		21.53 ± 2.79	
4-weeks assessments	22.16 ± 1.42		28.32 ± 1.88	
Mean difference ^a	0.79 ± 1.65 (1.58, -0.01)		6.79 ± 2.57 (8.02, 5.55)	
p -value ^a	> 0.050		< 0.001 ^{***}	

Note: ^a Baseline and 4-week outcomes were compared using a dependent samples t-test. Statistical significance *p-value < 0.05, **p-value < 0.01, ***p-value < 0.001. Abbreviation: The data were presented using s second, 10MWT 10-meter walk test, 6MWT 6-minute walk test n number m/s meter per second MMSE Mini-Mental State Examination

Table 3 Between-group differences in 4-week outcomes, baseline-adjusted (n=38)

Variables	Participants (n= 19)		Pairwise Comparisons		
	Control group (n=19)	Experimental group (n=19)	Mean difference	F	p-value ^a
TUGT (s)	9.65 ± 1.44 (9.35 – 9.94)	7.95 ± 1.44 (7.66 – 8.24)	1.69 ± 0.20 (1.29 – 2.11)	20.44 ^b	< 0.001
FTSST (s)	9.167 ± 0.17 (8.83 – 9.50)	7.893 ± 0.17 (7.557 – 8.229)	1.274 ± 0.235 (0.80 – 1.75)	29.46 ^b	< 0.001
10MWT (m/s)	1.30 ± 0.04 (1.21 – 1.39)	1.32 ± 0.04 (1.23 – 1.41)	1.32 ± 0.04 (1.23 – 1.41)	0.11	0.739
6MWT (m)	352.17 ± 6.58 (338.82 – 365.52)	394.22 ± 6.58 (380.87 – 407.57)	-42.05 ± 9.30 (-60.93, - 23.17)	20.44 ^b	< 0.001
Total MMSE score	22.90 ± 0.31 (22.28 – 23.52)	27.57 ± 0.31 (26.95 – 28.19)	-4.67 ± 0.47 (-5.62, -3.72)	99.38 ^b	< 0.001

Note: The data were presented using mean ± SD (95% confidence intervals). ^a To evaluate the 4-week assessments between groups, a one-way analysis of covariance (ANCOVA), which sets the baseline of covariate and the group as a fixed factor, and Bonferroni-adjusted pairwise comparisons of the estimated marginal means (EMMs) for the group.

^b Large effect size as partial eta squared values more than 0.14.

Abbreviation: The data were presented using *TUGT*, Timed Up and Go Test, *FTSST*, Five Times Sit-to-Stand Test *seconds* *10MWT* 10-meter walk test *6MWT* 6-minute walk test, *n* number, *m/s* meter per second, *MMSE* Mini-Mental State Examination

Discussion

This study compared the effects of 4 weeks of a combined nine-square dance and counting program on walking, balance control, agility, muscle strength, cognitive function in older adults with mild cognitive impairments. After four weeks, the experimental group showed significant improvements in physical functions, including faster timed up and go and sit-to-stand tests, greater distance in the 6-minute walk, and stable or slightly decreased walking speed by 10MWT, compared to minimal changes in the control group. Cognitively, the experimental group exhibited markedly substantial improvements in the aggregate scores of the MMSE, particularly in the domains of orientation, attention, memory, and language; conversely, the scores of the control group exhibited minimal alterations or a decline.

The notable improvements observed after engaging in the NSCD training can be attributed to the use of the counting and coordinated dance activities, which likely enhanced cognitive function in the experimental group by stimulating neural pathways involved in attention, memory, and executive functions, thereby contributing to improved cognitive outcomes (Table 2, Table 3). According to the previous study that involved a 6-week cognitive training program for MCI participants, showing significant improvements in MMSE scores in both groups, with the intervention group demonstrating higher scores. Additionally, the intervention group exhibited notable enhancements in activity diary and Bartel index scores ($p < 0.001$), along with significantly reduced serum levels of neuron-specific enolase in the brain, indicating decreased brain tissue damage. Overall, the cognitive training effectively alleviated brain tissue damage in older adults with MCI (Tian et al., 2022; Verghese et al., 2021). Consequently, the observed shift in MMSE scores among these participants provides empirical support for this mechanism, emphasizing the vital role of active cognitive engagement in preserving and enhancing cognitive health in older adults. While Vaportzis et al. (2014) investigated 28 younger and 28 older adults,

dual-tasking circle tracing with serial subtraction showed that older adults were slower across all conditions and had greater dual-task costs, especially with easy subtraction, while accuracy did not differ by age. Higher task difficulty slowed both groups, and participants traded speed for accuracy (or vice versa). Moreover, older adults may rely more on proprioceptive feedback for upper-limb movement (Vaportzis et al., 2014). In addition, the results of this study were consistent with other study which investigated the effects of cognitive-motor dual-task (CMDT) training on cognitive function, neuron electrophysiology, and frontal lobe hemodynamics in patients with post-stroke cognitive impairment (PSCI) (Sun et al., 2022). The results indicated that CMDT training led to significant improvements in cognitive assessments, specifically the MMSE, compared to a control group that received cognitive task training. However, even though this study examined different participant groups, the impairments were similar, indicating that movement training combined with brain function increased brain activity to work more than normal, which resulted in the experimental group showing development in MMSE (Sun et al., 2022). It was the same findings align with this study in demonstrating that cognitive training (CT) leads to improvements in cognitive assessments such as MMSE. Both studies found that higher baseline scores predict higher post-training scores with less room for improvement, and that age negatively impacts learning speed. Additionally, the current study's results showing significant increases in MMSE and MoCA scores after intervention support the effectiveness of cognitive training, consistent with the previous findings that adaptive, attention-focused training benefits cognitive function, especially in older adults with lower baseline abilities (Li et al., 2025). Furthermore, this study found that the experimental group had a MMSE change score of 6.79 points, which clearly reflects the clinical change. Because the minimal clinically important difference (MCID) for MMSE in patients with MCI or mild Alzheimer's disease typically ranges from 1.2 to 2.6 points (Andrews et al., 2019)

The effects of the NSCD on TUGT and FTSST in this study demonstrated that participants engaged in this structured activity showed significant improvements compared to a control group (Table 3, Table 4). Several factors contributed to outcomes. Firstly, the NSCD integrated physical movements that prioritize strength and balance (Dejvajara et al., 2022; Udom et al., 2022; Verghese et al., 2021), which were imperative for enhancing mobility and preventing falls (Dejvajara et al., 2022). Continuous engagement in these physical activities fortifies lower-body muscle strength and balance, which supports individuals in standing up from a seat and walking with improved comfort. In addition, the mental facet of the dance, which necessitated counting while carrying out the movements, operated as a dual-task that stimulated cognitive involvement and improved cognitive-motor synergy. The integration of dual tasks boosted mental processing and motor skills, facilitating quicker and more coordinated completion of the TUGT for participants. Moreover, participation in the NSCD elevated self-efficacy and mitigated the fear of falling, psychological factors that profoundly affected movement quality; heightened confidence resulted in more assertive and less tentative movements, thus enhancing test outcomes. Lastly, the integration of function and intellectual challenges triggered neuroplasticity, thereby bolstering the neural pathways linked to motor skill acquisition and coordination (Kempermann et al., 2010; Müller et al., 2017). This adjustment in neural processes was notably helpful for older adults, who commonly experienced declines in both their physical and cognitive skills (Dolega et al., 2024; Indrakumar & Silva, 2024). Taken together, these mechanisms demonstrate that the NSCD not only augments physical strength and postural balance but also enhances cognitive-motor integration, self-confidence, and neuroplasticity, ultimately driving superior performance across dynamic assessments like the TUGT (Tables 2 and 3). Another conceivable

explanation for the enhancement observed in the control group pertains to the nine-square dance exercise, which entails coordinated postures executed in multiple orientations (Fig. 2) (Atipas et al., 2019). Previous research indicates that nine-square dancing significantly enhances balance, postural control, agility, and coordination across diverse populations, albeit specific methodologies and outcomes were not comprehensively reported (Orr et al., 2006; Shigematsu et al., 2008; Udom et al., 2022). Shigematsu et al. (2008) discovered that square dancing improves balance and activates synergistic and agonistic leg musculature, corroborating earlier studies that suggest square-stepping exercises fortify the legs, thereby enhancing balance through sustained muscular engagement and force generation (Dejvajara et al., 2022; Orr et al., 2006). The movements examined in these studies, akin to the nine-square dance, encompassed slight knee and ankle extensions that enhanced neural functionality, reduced response latency, and improved sensory interpretation through effective engagement of postural muscles (Orr et al., 2006; Shigematsu et al., 2008; Udom et al., 2022). Consequently, participants experienced notable enhancements in balance and leg muscle strength relative to baseline, as evidenced by the modifications in TUGT and FTSST ($p < 0.05$; Table 2), with scores of the MCID values of the TUGT and FTSST were 3.00 sec and 3.50 sec, respectively (Intaruk et al., 2024). However, the magnitude of improvement in the control group was likely constrained compared to the experimental group, whose intervention specifically targeted cognitive functions, leading to more substantial gains (Table 3).

Moreover, the NSCD may have caused minimal improvements in cardiorespiratory fitness and attention during exercising among older adults with MCI, consistent with findings that dance and Tai Chi enhance cardiovascular fitness to improve endurance (Arfanda et al., 2022; Yan et al., 2022). In this study, dancing to music with variable rhythms at mild to moderate intensity (music with a tempo ranging from 120 to 160 beats per minute (bpm)) led to significant gains in 6MWT. Participants in the NSCD group showed greater improvements in functional and cardiovascular outcomes than those in the control group ($p < 0.001$), with the high demand of the NSCD group yielding significant enhancements in 6MWT. NSCD shows a clinically meaningful change of 43.93 m (Table 2). With the MCID for 6MWD at 17.8 m in moderately frail Asian older adults with fear of falling, this informs goal setting for this group (Kwok et al., 2013). Furthermore, a statistically significant change in walking speed was found in the control group after participating in the 4-week program (Table 2); no statistically significant difference in 10MWT was found between the control and experimental groups (Table 3). This may be because the grid dancing and number counting exercises are confined within a framework, which differs from the forward movement involved in walking (Atipas et al., 2019). This is consistent with numerous previous studies that have not found any changes, and with findings regarding changes in walking speed in older adults (Rodríguez et al. 2022).

Conclusion and Suggestions

A 4-week nine-square counting dance intervention provides a synergized approach to reversing or managing declines in cognitive function and mobility among older adults with mild cognitive impairment. However, this study had some limitations, including the absence of a follow-up period, which restricts understanding of the long-term effects of NSCD. Future research should involve extended training durations and ongoing data collection to assess retention of benefits. Additionally, it is important to include individuals with other impairments

and more severe cognitive impairment to thoroughly evaluate the efficacy and broader applicability of NSCD in these populations.

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Author Contributions

Donlaya Promkeaw: Conceptualization, Supervision, Investigation, Data collection, Data analysis and interpretation, and Manuscript editing and writing.

Janne Mia Schmidt, Chartnakrop Laksanakunlabutr, Natthaporn Muangsuk¹, Sithanan Promsri: Conceptualization, Data collection, Data analysis and Final manuscript approval.

Ampha Pumpho, Titi Phanjaroen: Conceptualization, Project administration, Final manuscript approval and Manuscript editing and writing.

Theerasak Boonwang: Conceptualization, Data collection, Supervision, Manuscript editing and writing and Corresponding author.

Conflict of Interests

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

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Declaration of Generative AI and AI-assisted Technologies

We would like to declare that generative AI (ChatGPT-3.5) and was used solely for assistance in checking and refining the English language in this manuscript, including minor translations. The authors entirely generated the content, ideas, and findings presented in the manuscript without AI assistance. After language editing, the authors reviewed and validated the final version to ensure its accuracy and integrity.

References

- Amatachaya, S., Kwanmongkolthong, M., Thongjumroon, A., Boonpew, N., Amatachaya, P., Saensook, W., Thaweewannakij, T., & Hunsawong, T. (2020). Influence of timing protocols and distance covered on the outcomes of the 10-meter walk test. *Physiotherapy Theory and Practice*, 36(12), 1348–1353. <https://doi.org/10.1080/09593985.2019.1570577>
- Ambrose, A. F., Cruz, L., & Paul, G. (2015). Falls and Fractures: A systematic approach to screening and prevention. *Maturitas*, 82(1), 85–93. <https://doi.org/10.1016/j.maturitas.2015.06.035>
- Andrews, J. S., Desai, U., Kirson, N. Y., Zichlin, M. L., Ball, D. E., & Matthews, B. R. (2019). Disease severity and minimal clinically important differences in clinical outcome assessments for Alzheimer's disease clinical trials. *Alzheimer's & dementia (New York, N. Y.)*, 5, 354–363. <https://doi.org/10.1016/j.trci.2019.06.005>
- Arevalo-Rodriguez, I., Smailagic, N., Roqué-Figuls, M., Ciapponi, A., Sanchez-Perez, E., Giannakou, A., Pedraza, O. L., Bonfill Cosp, X., & Cullum, S. (2021). Mini-Mental State Examination (MMSE) for the early detection of dementia in people with mild cognitive impairment (MCI). *The Cochrane Database of Systematic Reviews*, 7(7), CD010783. <https://doi.org/10.1002/14651858.CD010783.pub3>
- Arfanda, P., Wiriawan, O., Setijono, H., Kusnanik, N., Muhammad, H., Puspodari, P., Ayubi, N., Aprilo, I., & Mb, A. (2022). The effect of low-impact aerobic dance exercise video on cardiovascular endurance, flexibility, and concentration in females with sedentary lifestyle. *Physical Education Theory and Methodology*, 22, 303–308. <https://doi.org/10.17309/tmfv.2022.3.01>
- Atipas, S., Chongkolwatana, C., Suwannutsiri, T., Thongyai, K., Henggrathock, S., & Akarasereenont, P. (2019). Effect of Kao-Ta (9-Square Step Exercise) and Kao-Ten (9-Square Dance Exercise) on balance rehabilitation in patients with balance disorders. *Siriraj Medical Journal*, 71, 1–7. <https://doi.org/10.33192/Smj.2019.01>
- Bahureksa, L., Najafi, B., Saleh, A., Sabbagh, M., Coon, D., Mohler, M. J., & Schwenk, M. (2017). The impact of mild cognitive impairment on gait and balance: A systematic review and meta-analysis of studies using instrumented assessment. *Gerontology*, 63(1), 67–83. <https://doi.org/10.1159/000445831>
- Barry, E., Galvin, R., Keogh, C., Horgan, F., & Fahey, T. (2014). Is the Timed Up and Go test a useful predictor of risk of falls in community dwelling older adults: A systematic review and meta-analysis. *BMC Geriatrics*, 14, 14. <https://doi.org/10.1186/1471-2318-14-14>
- Cesari, M., Kritchevsky, S. B., Penninx, B. W. H. J., Nicklas, B. J., Simonsick, E. M., Newman, A. B., Tylavsky, F. A., Brach, J. S., Satterfield, S., Bauer, D. C., Visser, M., Rubin, S. M., Harris, T. B., & Pahor, M. (2005). Prognostic value of usual gait speed in well-functioning older people—results from the health, aging and body composition study. *Journal of the American Geriatrics Society*, 53(10), 1675–1680. <https://doi.org/10.1111/j.1532-5415.2005.53501.x>
- Chan, W. L. S., & Pin, T. W. (2019). Reliability, validity and minimal detectable change of 2-minute walk test, 6-minute walk test and 10-meter walk test in frail older adults with dementia. *Experimental Gerontology*, 115, 9–18. <https://doi.org/10.1016/j.exger.2018.11.001>

- Chow, B.-C., Jiao, J., Man, D., & Lippke, S. (2022). Study protocol for “the effects of multimodal training of cognitive and/or physical functions on cognition and physical fitness of older adults: A cluster randomized controlled trial.” *BMC Geriatrics*, 22(1), 398. <https://doi.org/10.1186/s12877-022-03031-5>
- Dejvajara, D., Aungkasuraphan, R., Palee, P., Piankusol, C., Sirikul, W., & Siviroj, P. (2022). Effects of home-based nine-square step exercises for fall prevention in Thai community-dwelling older adults during a covid-19 lockdown: A pilot randomized controlled study. *International Journal of Environmental Research and Public Health*, 19(17), 10514. <https://doi.org/10.3390/ijerph191710514>
- Diniz, B. S. O., Yassuda, M. S., Nunes, P. V., Radanovic, M., & Forlenza, O. V. (2007). Mini-mental State Examination performance in mild cognitive impairment subtypes. *International Psychogeriatrics*, 19(4), 647–656. <https://doi.org/10.1017/S104161020700542X>
- Dolega, J., Lukasz, S. P., Mol, P., Maciejczyk, T., Sienko, A., Labus, M., Zabawa, B., Hudzinska, P., Krzykowski, K., & Sadowski, J. (2024). Neuroplasticity. How regular physical activity influences the brain’s structure and function. *Quality in Sport*, 34, 56026–56026. <https://doi.org/10.12775/QS.2024.34.56026>
- Potter, K., Fulk, G. D., Salem, Y., & Sullivan, J. (2011). Outcome measures in neurological physical therapy practice: part I. Making sound decisions. *Journal of neurologic physical therapy: JNPT*, 35(2), 57–64. <https://doi.org/10.1097/NPT.0b013e318219a51a>
- Fissler, P., Küster, O. C., Loy, L. S., Laptinskaya, D., Rosenfelder, M. J., von Arnim, C. A. F., & Kolassa, I.-T. (2017). Jigsaw Puzzles As Cognitive Enrichment (PACE) – the effect of solving jigsaw puzzles on global visuospatial cognition in adults 50 years of age and older: Study protocol for a randomized controlled trial. *Trials*, 18(1), 415. <https://doi.org/10.1186/s13063-017-2151-9>
- Galea, M., & Woodward, M. (2005). Mini-Mental State Examination (MMSE). *The Australian Journal of Physiotherapy*, 51(3), 198. [https://doi.org/10.1016/s0004-9514\(05\)70034-9](https://doi.org/10.1016/s0004-9514(05)70034-9)
- Geary, D. C., Frensch, P. A., & Wiley, J. G. (1993). Simple and complex mental subtraction: Strategy choice and speed-of-processing differences in younger and older adults. *Psychology and Aging*, 8(2), 242–256. <https://doi.org/10.1037//0882-7974.8.2.242>
- Gómez-Soria, I., Peralta-Marrupe, P., Calatayud-Sanz, E., & Latorre, E. (2021). Efficacy of cognitive intervention programs in amnesic mild cognitive impairment: A systematic review. *Archives of Gerontology and Geriatrics*, 94, 1–10. <https://doi.org/10.1016/j.archger.2020.104332>
- Indrakumar, J., & Silva, S. (2024). Physical activity in the older adults: a review of the benefits and recommendations for promoting healthy aging through exercise. *Journal of the Indian Academy of Geriatrics*, 20(4), 207–213. https://doi.org/10.4103/jiag.jiag_49_24
- Intaruk, R., Phadungkit, S., Kanpai, A., Pawanta, K., Srihapol, N., Saengsuwan, J., Amatachaya, S., & Thaweewannakij, T. (2024). Test-retest reliability and minimal detectable change of four functional tests in community-dwelling older adults with high risk of falls. *Turkish journal of physical medicine and rehabilitation*, 70(2), 164–170. <https://doi.org/10.5606/tftrd.2024.12725>
- Hao, M., & Chen, J. (2025). Trend analysis and future predictions of global burden of alzheimer’s disease and other dementias: a study based on the global burden of disease database from 1990 to 2021. *BMC medicine*, 23(1), 378. <https://doi.org/10.1186/s12916-025-04169-w>

- Judge, J. (2017). Can physical activity prevent falls in older adults with poor physical performance? *Journal of the American Geriatrics Society*, 65(11), 2457–2458. <https://doi.org/10.1111/jgs.15071>
- Kempermann, G., Fabel, K., Ehninger, D., Babu, H., Leal-Galicia, P., Garthe, A., & Wolf, S. A. (2010). Why and how physical activity promotes experience-induced brain plasticity. *Frontiers in Neuroscience*, 4, 189. <https://doi.org/10.3389/fnins.2010.00189>
- Kwok, B. C., Pua, Y. H., Mamun, K., & Wong, W. P. (2013). The minimal clinically important difference of six-minute walk in Asian older adults. *BMC geriatrics*, 13, 23. <https://doi.org/10.1186/1471-2318-13-23>
- Li, C., Li, M., & Shang, Y. (2025). Cognitive training with adaptive algorithm improves cognitive ability in older people with MCI. *Aging Clinical and Experimental Research*, 37(20), 1–8. <https://doi.org/10.1007/s40520-024-02913-5>
- Lord, S. R., Murray, S. M., Chapman, K., Munro, B., & Tiedemann, A. (2002). Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, 57(8), M539–M543. <https://doi.org/10.1093/gerona/57.8.m539>
- Manjavong, M., Limpawattana, P., & Sawanyawisuth, K. (2021). Performance of the Rowland Universal dementia assessment scale in screening mild cognitive impairment at an outpatient setting. *Dementia and Geriatric Cognitive Disorders EXTRA*, 11(2), 181–188. <https://doi.org/10.1159/000517821>
- Mathews, R. M., Clair, A. A., & Kosloski, K. (2001). Keeping the beat: Use of rhythmic music during exercise activities for the elderly with dementia. *American Journal of Alzheimer's Disease and Other Dementias*, 16(6), 377–380. <https://doi.org/10.1177/153331750101600608>
- Mato, L., Chankavee, N., Amatachaya, S., & Thaweewannakij, T. (2022). Knee extensor muscle strength to measure the ability of five times sit to stand independently in patients with incomplete spinal cord injury. *The Malaysian Journal of Medical Sciences: MJMS*, 29(5), 74–82. <https://doi.org/10.21315/mjms.2022.29.5.8>
- Moon, A., Jang, S., Kim, J.-H., & Jang, S. (2024). Risk of falls or fall-related injuries associated with potentially inappropriate medication use among older adults with dementia. *BMC Geriatrics*, 24(1), 699. <https://doi.org/10.1186/s12877-024-05300-x>
- Müller, P., Rehfeld, K., Schmicker, M., Hökelmann, A., Dordevic, M., Lessmann, V., Brigadski, T., Kaufmann, J., & Müller, N. G. (2017). Evolution of Neuroplasticity in Response to Physical Activity in Old Age: The Case for Dancing. *Frontiers in Aging Neuroscience*, 9(56), 1–8. <https://doi.org/10.3389/fnagi.2017.00056>
- Orr, R., de Vos, N. J., Singh, N. A., Ross, D. A., Stavrinou, T. M., & Fiatarone-Singh, M. A. (2006). Power training improves balance in healthy older adults. *The Journals of Gerontology: Series A*, 61(1), 78–85. <https://doi.org/10.1093/gerona/61.1.78>
- Pieruccini-Faria, F., Sarquis-Adamson, Y., Anton-Rodrigo, I., Noguerón-García, A., Bray, N. W., Camicioli, R., Muir-Hunter, S. W., Speechley, M., McIlroy, B., & Montero-Odasso, M. (2020). Mapping associations between gait decline and fall risk in mild cognitive impairment. *Journal of the American Geriatrics Society*, 68(3), 576–584. <https://doi.org/10.1111/jgs.16265>

- Poncumhak, P., Suwannakul, B., & Srithawong, A. (2016). Validity of five times sit to stand test for the evaluation of risk of fall in community-dwelling older adults. *Journal of Associated Medical Sciences*, 49(2), Article 2.
- Rodríguez, B., & Paris-Garcia, F. (2022). Influence of Dance Programmes on Gait Parameters and Physical Parameters of the Lower Body in Older People: A Systematic Review. *International journal of environmental research and public health*, 19(3), 1547. <https://doi.org/10.3390/ijerph19031547>
- Shigematsu, R., Okura, T., Sakai, T., & Rantanen, T. (2008). Square-stepping exercise versus strength and balance training for fall risk factors. *Aging Clinical and Experimental Research*, 20(1), Article 1. <https://doi.org/10.1007/BF03324743>
- Shumway-Cook, A., Brauer, S., & Woollacott, M. (2000). Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. *Physical Therapy*, 80(9), 896–903.
- Steffen, T. M., Hacker, T. A., & Mollinger, L. (2002). Age- and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and gait speeds. *Physical Therapy*, 82(2), 128–137. <https://doi.org/10.1093/ptj/82.2.128>
- Sun, R., Li, X., Zhu, Z., Li, T., Zhao, M., Mo, L., Li, W., Xi, X., Huang, P., & Gong, W. (2022). Effects of dual-task training in patients with post-stroke cognitive impairment: A randomized controlled trial. *Frontiers in Neurology*, 13, 1027104. <https://doi.org/10.3389/fneur.2022.1027104>
- Tanglakmankhong, K., Hampstead, B. M., Ploutz-Snyder, R. J., & Potempa, K. (2022). Cognitive screening assessment in Thai older adults: A prospective study of the reliability and validity of the Abbreviated Mental Test. *Journal of Health Research*, 36(1), 99–109. <https://doi.org/10.1108/jhr-02-2020-0049>
- Thaweewannakij, T., Wilaichit, S., Chuchot, R., Yuenyong, Y., Saengsuwan, J., Siritaratiwat, W., & Amatachaya, S. (2013). Reference values of physical performance in Thai elderly people who are functioning well and dwelling in the community. *Physical Therapy*, 93(10), 1312–1320. <https://doi.org/10.2522/ptj.20120411>
- Tian, R., Jiang, Y., Zhang, Y., Yan, X., Zhou, Y., & Chen, D. (2022). Cognitive training program improves cognitive ability and daily living ability in elderly patients with mild cognitive impairment. *Aging Clinical and Experimental Research*, 34(5), 997–1005. <https://doi.org/10.1007/s40520-021-02015-6>
- Turgut, B. A., & Naz, I. (2023). Physical activity in neurological disorders: A narrative review. *European Journal of Therapeutics*, 29(1), 97–102. <https://doi.org/10.58600/eurjther-344>
- Udom, C., Kerdnet, S., Wohmae, S., Pitakkumpon, A., Wadeng, A., & Chandee, N. (2022). The Effect of the nine-square step dance on the postural stability of overweight female undergraduate students: A Randomized Trial. *Trends in Sciences*, 19(14), 4713. <https://doi.org/10.48048/tis.2022.4713>
- Van Patten, R., Britton, K., & Tremont, G. (2019). Comparing the Mini-Mental State Examination and the modified Mini-Mental State Examination in the detection of mild cognitive impairment in older adults. *International Psychogeriatrics*, 31(5), 693–701. <https://doi.org/10.1017/S1041610218001023>
- Vaportzis, E., Georgiou-Karistianis, N., Stout, J. C. (2014). Age and task difficulty differences in dual tasking using circle tracing and serial subtraction tasks. *Aging Clin Exp Res*, 26(2), 201–211. <https://doi.org/10.1007/s40520-013-0151-5>

- Verghese, J., Mahoney, J. R., Ayers, E., Ambrose, A., Wang, C., & Holtzer, R. (2021). Computerised cognitive remediation to enhance mobility in older adults: A single-blind, single-centre, randomised trial. *The Lancet. Healthy Longevity*, 2(9), e571–e579. [https://doi.org/10.1016/s2666-7568\(21\)00173-2](https://doi.org/10.1016/s2666-7568(21)00173-2)
- Wei, Z., Zhao, X., & Liu, Y. (2024). A meta-analysis of the consequences of cognitive training on the cognitive function of aged mild cognitive impairment patients. *Psychogeriatrics: the official journal of the Japanese Psychogeriatric Society*, 24(6), 1371–1388. <https://doi.org/10.1111/psyg.13177>
- Yan, Z.-W., Yang, Z., Yang, J.-H., Song, C.-L., Zhao, Z., & Gao, Y. (2022). Comparison between Tai Chi and square dance on the antihypertensive effect and cardiovascular disease risk factors in patients with essential hypertension: A 12-week randomized controlled trial. *The Journal of Sports Medicine and Physical Fitness*, 62(11), Article 11. <https://doi.org/10.23736/S0022-4707.22.13424-9>