

Effects of a Tri-Exercise program on physical fitness and quality of life for older adults in Thailand: A single-group pre-post quasi-experimental study

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Abstract

Purpose: Among older adults, falls are a major public health concern associated with reduced physical fitness, impaired balance, and decreased quality of life. This study aimed to evaluate the effects of a Tri-Exercise program, integrating Thai Hermit Exercise, Yoga, and Dao De Xinxu, on physical fitness and quality of life for older adults. **Methods:** A quasi-experimental study was conducted among 31 older adults in Kamphaeng Phet Province, Thailand. Participants engaged in a 12-week Tri-Exercise program, performed three times weekly. Outcomes included balance (One Leg Balance test), upper and lower body flexibility (Back Scratch Test and Chair Sit-and-Reach Test), blood pressure, heart rate, knee joint mobility, and quality of life (EQ-5D-5L). Data were analyzed using paired t-tests. **Results:** Significant improvements were observed in most measured outcomes ($p < 0.001$). Balance, flexibility, and knee flexion increased, while blood pressure and heart rate decreased; knee extension showed no significant change. Quality of life scores also improved significantly following the intervention. **Discussion:** The observed improvements in balance, flexibility, cardiovascular parameters, and quality of life are consistent with previous research on mind-body and stretching-based exercises in older adults, and may reflect the combined effects of controlled movement, proprioceptive training, and coordinated breathing inherent in the integrated program. However, this study utilized a single-group design without a control group, so these changes cannot be categorically attributed to the intervention. Further, the findings should be interpreted with caution given the small sample size and short intervention period. **Conclusions:** The Tri-Exercise program was associated with improvements in physical fitness and quality of life for older adults. As this was a single-group study without a control group, controlled studies are needed to confirm whether these changes are attributable to the intervention.

Keywords: Traditional Exercises; Tri-Exercise; Physical Fitness; Quality of Life

Introduction

The aging population is a global phenomenon, with the number of older adults increasing significantly each year. In Thailand, the proportion of older adults is projected to reach 28% of the total population by 2030 (Tantirat et al., 2020). This demographic shift is associated with increasing health challenges, including chronic diseases, reduced physical fitness, and a heightened risk of falls and fall-related injuries (Briggs et al., 2016; Organization, 2018). Falls are of particular concern, as they represent one of the leading causes of injury, disability, and mortality among older adults worldwide. In Thailand, falls among older adults constitute a major public health problem, often resulting in serious injuries, loss of independence, and decreased quality of life. Key contributing factors include muscular weakness, impaired balance, and reduced flexibility (Chang et al., 2004), which collectively increase vulnerability to falls and functional decline.

Beyond their immediate physical consequences, falls among older adults impose a substantial burden on individuals, families, and healthcare systems. Fall-related injuries frequently result in prolonged hospitalization, reduced independence in activities of daily living, and a persistent fear of falling that can further restrict mobility and social participation, creating a self-reinforcing cycle of physical decline (Whipple et al., 2018). In the Thai context, where the population is aging rapidly and community-based long-term care resources remain limited relative to demand, the prevention of falls and the preservation of functional capacity in older adults represent an urgent public health priority rather than a matter of individual well-being alone. Despite this urgency, many community elderly programs in Thailand continue to rely on generic exercise recommendations that are not grounded in the country's own traditional movement practices, leaving a gap between available cultural resources and evidence-based fall-prevention strategies (Aung et al., 2021).

To address these challenges, effective exercise-based interventions are essential for improving physical function and reducing fall risk in older adults. Traditional exercise practices, including Thai Hermit Exercise (Rue-Si Dat Ton), Yoga, and Chinese Dao De Xinxi, have been widely used for promoting health and well-being. Rue-Si Dat Ton is a traditional Thai exercise characterized by gentle stretching movements and breathing techniques designed to improve flexibility, circulation, and body awareness (Khanthong et al., 2022). Yoga, originating from India, incorporates physical postures, controlled breathing, and relaxation techniques that enhance muscular strength, flexibility, and mental well-being (Birdee et al., 2009; Thanasilungkoon et al., 2023). Dao De Xinxi, a form of Chinese mind-body exercise, emphasizes slow, coordinated movements combined with breathing and mental focus to improve balance, coordination, and internal energy flow (Chyu et al., 2010; Intarakamhang & Chintanaprawasee, 2011). Although each of these exercise modalities has demonstrated individual benefits, there is limited evidence regarding their combined effects. Integrating these practices into a single program, referred to as “Tri-Exercise,” may provide synergistic benefits by simultaneously targeting multiple physiological and functional domains, including balance control, muscular flexibility, joint mobility, and psychological well-being.

This integrative approach may offer a more comprehensive and culturally adaptable intervention for older adults (Micheo et al., 2012; Patel et al., 2016). From a practical standpoint, traditional exercise modalities such as Rue-Si Dat Ton, Yoga, and Dao De Xinxi offer several advantages for community-based implementation among older adults. These practices generally require minimal equipment, can be adapted to different levels of physical ability, and are often already familiar or culturally acceptable to older adults, which may support long-term adherence compared with unfamiliar or equipment-intensive exercise programs (Yang et al., 2024). Integrating these three modalities into a single structured program, as proposed in the present study, therefore represents not only a scientific opportunity to examine potential synergistic effects across multiple physiological domains, but also a practical opportunity to develop a low-cost, culturally grounded intervention that could be readily implemented within existing elderly clubs, temples, and community health centers in Thailand (Khanthong et al., 2022). Previous studies have demonstrated that individual traditional exercise programs, such as Yoga and Qigong, can improve balance, reduce stress, and decrease the risk of falls among older adults (Li & Goldsmith, 2012; Patel et al., 2016). Additionally, mind-body exercises such as Tai Chi have been shown to enhance physical function and quality of life in older adults (Chyu et al., 2010; Intarakamhang & Chintanaprawasee, 2011). However, most existing studies have focused on single-modality interventions. There is limited evidence regarding the combined or integrative effects of multiple traditional exercise practices within a unified program.

Therefore, this study aims to investigate the effects of an integrated “Tri-Exercise” program, combining Thai Hermit Exercise (Rue-Si Dat Ton), Yoga, and Dao De Xinxi, on key health outcomes in older adults. Specifically, the study evaluates changes in balance, muscle flexibility, vital signs (blood pressure and heart rate), knee joint mobility, and health-related quality of life following a 12-week intervention. By examining these outcomes, this study seeks to provide evidence for a culturally integrated and comprehensive exercise approach that may contribute to fall prevention and overall well-being in older adults.

This study is significant for several reasons. First, it addresses a major public health issue by focusing on fall prevention and overall health improvement in older adults, which are crucial factors in aging populations. Second, it introduces a novel approach by integrating three traditional exercise modalities, including Thai Hermit Exercise, Yoga, and Dao De Xinxi, which have not previously been evaluated as a combined program. Finally, the findings from this research could inform strategies aimed at enhancing physical and psychological well-being, supporting public health initiatives that foster healthy aging and improve the quality of life for older adults. Taken together, this study addresses an important public health problem using an approach that has not previously been tested in an integrated form, and its findings are intended to inform both future research design (e.g., larger controlled trials of combined traditional exercise programs) and practical implementation by community health workers, elderly school instructors, and public health policymakers seeking low-cost, culturally appropriate strategies for fall prevention and healthy aging in the Thai population as well as other aging societies in Southeast Asia.

Material & methods

Design

This study employs a quasi-experimental design with a pre-test and post-test to assess the effects of the Tri-Exercise program on physical fitness and quality of life for older adults. The study was conducted over a period of 12 weeks, with assessments conducted at baseline and after the intervention. Ethical guidelines were strictly followed throughout the research.

The study protocol was approved by the Ethics Committee of the Institute for Human Research (Approval Code No.: 25/2566), Kamphaeng Phet Hospital, Thailand. All participants provided written informed consent prior to participation, and the study adhered to the ethical standards outlined by the World Medical Association Declaration of Helsinki.

Participants

The study sample consisted of 31 older adults aged 60 years and older, enrolled at the Nakhon Chum Elderly School in Kamphaeng Phet Province, Thailand. Participants were selected through purposive sampling based on the following inclusion criteria:

1. Aged 60 years and older
2. Able to perform basic physical activities
3. Free from severe cardiovascular, musculoskeletal, or neurological conditions that would contraindicate exercise
4. Provided written informed consent to participate in the study

Innovative integration of traditional exercises

The warm-up phase (10 minutes) included light stretching and gentle movements to prepare the musculoskeletal system and reduce the risk of injury.

The main exercise phase (40 minutes) consisted of an integrated sequence of three traditional exercise modalities. Thai Hermit Exercise (Rue-Si Dat Ton) was performed for approximately 15 minutes, focusing on gentle stretching, postural alignment, and controlled breathing to enhance flexibility and circulation. Yoga was conducted for approximately 15 minutes, incorporating selected poses aimed at improving muscular strength, flexibility, and relaxation. Dao De Xinxu was performed for approximately 10 minutes, emphasizing slow, coordinated movements combined with breathing and mental focus to improve balance, coordination, and body awareness. The cool-down phase (10 minutes) involved relaxation exercises and breathing techniques to promote recovery and reduce muscle tension.

Exercise intensity was maintained at a low to moderate level that was appropriate for older adults and was monitored by trained instructors throughout the program. The progression of the program was achieved by gradually increasing the duration of posture holding, movement coordination, and balance challenges over the 12-week intervention period. All sessions were supervised by qualified practitioners to ensure safety and correct performance of movements.

Measurements

1) Balance and flexibility were assessed using standardized field tests from the Senior Fitness Test battery. Balance was measured using the One Leg Balance (OLB) test, in which participants stood on one leg and the time until loss of balance was recorded in seconds, up to a maximum of 45 seconds, with the better of two trials retained. Upper-body flexibility was assessed using the Back Scratch Test, and lower-body flexibility was assessed using the Chair Sit-and-Reach Test, both recorded in centimeters (Jones et al., 1998). For the Back Scratch Test, participants reached one hand over the shoulder and the other hand up the back, and the distance of overlap or gap between the middle fingers was recorded in centimeters (negative values indicate a gap; positive values indicate overlap); the better of two trials was recorded. For the Chair Sit-and-Reach Test, participants sat at the edge of a chair with one leg extended and reached toward the toes, and the distance between the fingertips and the toes was recorded in centimeters (negative values indicate the fingertips did not reach the toes); the better of two trials was recorded. For interpretation of change scores, the minimal detectable change (MDC) reported for community-dwelling older adults is approximately 24.1 s for single-leg stance time using a 60-second protocol, 4.6 cm for the Back Scratch Test, and 6.0 cm for the Chair Sit-and-Reach Test (90% CI); observed pre-post changes in the present study exceeded these thresholds for all three measures, reinforcing that the improvements reflect true change rather than measurement error. Because the OLB test in this study used a 45-second ceiling rather than the 60-second protocol from which the balance MDC was derived, this comparison should be interpreted with caution pending population- and protocol-specific MDC data.

2) Vital signs, including systolic and diastolic blood pressure and resting heart rate, were measured using a digital sphygmomanometer and heart rate monitor. Measurements were taken in a seated position after a minimum of 5 minutes of rest to ensure accuracy and consistency.

3) Knee joint mobility was assessed using a standard goniometer to measure the range of motion in flexion and extension. Each measurement was performed by a trained assessor to ensure consistency, and the average of two measurements was used for analysis (De la Corte-Rodriguez et al., 2024). Universal-goniometer knee flexion measurements have reported an MDC of approximately 6 - 9°, signifying that the mean 21.07° improvement observed here exceeded measurement error.

4) Health-related quality of life was evaluated using the EQ-5D-5L questionnaire, a standardized instrument with established validity and reliability for assessing quality of life across five dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression (The EuroQol Group, 1990). Published anchor-based minimally important difference (MID) estimates for the EQ-5D-5L index score in older or clinical populations generally range from about 0.03 to 0.06, and 6.5 to 8.2 points for the VAS; the mean changes observed in this study (0.09 index points, 9.03 VAS points) exceeded these thresholds, suggesting the improvement in quality of life was clinically as well as statistically meaningful.

Data collection procedure

Data were collected at two time points: baseline (pre-intervention) and after 12 weeks of the Tri-Exercise program (post-intervention). Each participant underwent the following assessments:

- Baseline Assessment, conducted during the first week prior to the start of the exercise program
- Post-intervention Assessment, conducted during the final week of the intervention period

Data analysis. Statistical analyses were performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including mean and standard deviation (SD), were used to summarize participant characteristics and outcome measures.

Prior to inferential analysis, data were assessed for normality using the Shapiro–Wilk test. Paired t-tests were used to compare pre- and post-intervention values for all outcome variables, as the data were normally distributed.

In addition to p-values, effect sizes (Cohen's d) were calculated to determine the magnitude of changes following the intervention. The level of statistical significance was set at $p < 0.05$. All statistical tests were two-tailed.

Results

The study aimed to evaluate the effects of the Tri-Exercise program on balance, muscle flexibility, vital signs, knee joint mobility, and quality of life among older adults. Data were collected from 31 participants before and after the 12-week intervention (**Fig. 1**). The following sections summarize the key findings.

Table 1. Physical characteristics of the participants (n= 31)

Characteristic	Mean (SD)
Age (yr)	65.65 (4.42)
Height (cm)	155.45 (4.01)
Weight (kg)	61.03 (10.37)
Body mass index (kg/m ²)	25.21 (4.14)

Values are presented as mean± standard deviation.

The sample included 31 older adults (all female) with a mean age of 65.65 years (SD = 4.42). The majority belonged to the age group of 60-64 years (48.39%), followed by 70-74 years (29.03%), and 65-69 years (22.58%). The average weight was 61.03±10.37 kg, the average height was 155.45±4.01 cm, and the average BMI was 25.21±4.14 kg/cm² (**Table 1**). The highest percentage of participants had completed high school education (22.58%), followed by elementary education, junior high school, and bachelor's degree (19.35% each). Regarding chronic diseases, 54.80% reported having them.

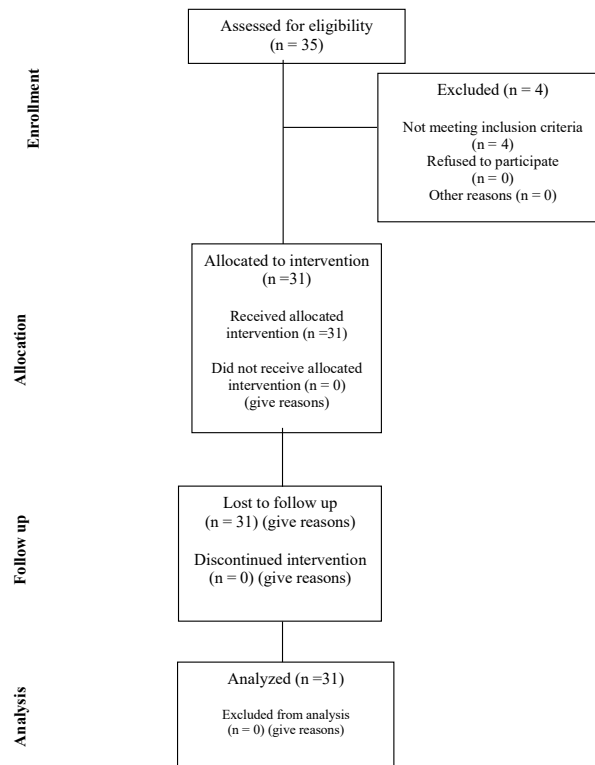


Fig. 1. Flow diagram of participant recruitment, enrollment, follow-up, and analysis

The effects of the Tri-Exercise program on physical and health-related outcomes were evaluated in 31 older adults following a 12-week intervention. The descriptive characteristics of participants (**Table 1**) and health-related outcomes were evaluated in 31 older adults following a 12-week intervention (**Table 2**).

Significant improvement in balance was observed, with One Leg Balance (OLB) test times increasing from 25.23 ± 11.15 s at baseline to 47.94 ± 12.68 s post-intervention ($t(30) = -11.32$, $p < 0.001$; 95% CI for the mean change, 18.61 to 26.81 s). Flexibility also improved significantly: upper-body flexibility (Back Scratch Test) improved from -11.29 ± 11.30 cm to -4.24 ± 10.47 cm ($t(30) = -7.18$, $p < 0.001$; 95% CI, 5.04 to 9.05 cm), and lower-body flexibility (Chair Sit-and-Reach Test) improved from 5.97 ± 8.61 cm to 13.35 ± 7.07 cm ($t(30) = -6.85$, $p < 0.001$; 95% CI, 5.18 to 9.58 cm).

Systolic blood pressure decreased from 132.70 ± 8.52 mmHg to 118.81 ± 10.47 mmHg ($t(30) = 10.90$, $p < 0.001$; 95% CI, 11.29 to 16.49 mmHg), and diastolic blood pressure decreased from 74.68 ± 8.50 mmHg to 62.41 ± 6.15 mmHg ($t(30) = 10.81$, $p < 0.001$; 95% CI, 9.95 to 14.59 mmHg). Resting heart rate also declined significantly from 82.51 ± 10.66 bpm to 72.03 ± 8.74 bpm ($t(30) = 10.17$, $p < 0.001$; 95% CI, 8.38 to 12.58 bpm).

Knee joint mobility improved significantly for flexion, increasing from $104.61 \pm 13.03^\circ$ to $125.68 \pm 9.63^\circ$ ($t(30) = -11.34$, $p < 0.001$; 95% CI, 17.28 to 24.86°). Knee extension showed no measurable change from baseline to post-intervention (0° to 0° ; not applicable), as participants had full knee extension range at baseline with no room for further improvement.

Quality of life improved significantly, with EQ-5D-5L index scores increasing from 0.90 ± 0.08 to 0.99 ± 0.02 ($t(30) = -6.23$, $p < 0.001$; 95% CI, 0.060 to 0.120), and EQ-5D-5L visual analogue scale (VAS) scores increasing from 79.68 ± 8.46 to 88.71 ± 8.40 ($t(30) = -11.09$, $p < 0.001$; 95% CI, 7.37 to 10.69).

Table 2. Comparisons of pre-intervention and post-intervention

Outcome Measure	Pre (Mean $\pm$ SD)	Post (Mean $\pm$ SD)	Mean Change (95% CI)	t	P	Cohen's d*
One Leg Balance (s)	25.23 $\pm$ 11.15	47.94 $\pm$ 12.68	22.71 (18.61 to 26.81)	-11.32	<0.001	2.03
Back Scratch, upper-body flexibility (cm)	-11.29 $\pm$ 11.30	-4.24 $\pm$ 10.47	7.05 (5.04 to 9.05)	-7.18	<0.001	1.29
Chair Sit-and-Reach, lower-body flexibility (cm)	5.97 $\pm$ 8.61	13.35 $\pm$ 7.07	7.38 (5.18 to 9.58)	-6.85	<0.001	1.23
Systolic BP (mmHg)	132.70 $\pm$ 8.52	118.81 $\pm$ 10.47	-13.89 (-16.49 to -11.29)	10.90	<0.001	1.96
Diastolic BP (mmHg)	74.68 $\pm$ 8.50	62.41 $\pm$ 6.15	-12.27 (-14.59 to -9.95)	10.81	<0.001	1.94
Heart Rate (bpm)	82.51 $\pm$ 10.66	72.03 $\pm$ 8.74	-10.48 (-12.58 to -8.38)	10.17	<0.001	1.83
Knee Flexion ($^\circ$)	104.61 $\pm$ 13.03	125.68 $\pm$ 9.63	21.07 (17.28 to 24.86)	-11.34	<0.001	2.04
Knee Extension ($^\circ$)	0 $\pm$ 0	0 $\pm$ 0	0 (not applicable)	NA	NA	NA
EQ-5D-5L Index	0.90 $\pm$ 0.08	0.99 $\pm$ 0.02	0.09 (0.060 to 0.120)	-6.23	<0.001	1.12
EQ-5D-5L VAS	79.68 $\pm$ 8.46	88.71 $\pm$ 8.40	9.03 (7.37 to 10.69)	-11.09	<0.001	1.99

* Indicates statistically significant difference (paired t-test). BP indicates blood pressure; VAS, visual analogue scale. The 95% confidence interval for the mean within-group change and Cohen's dz were derived from the reported t value, mean difference, and sample size ($SE = \text{mean difference} / t$; $dz = t / \sqrt{n}$; $df = 30$, $t_{crit} = 2.042$). Knee extension showed no measurable pre-post difference because participants had full extension range of motion at baseline, leaving no room for improvement; NA indicates not applicable.

Discussion

The present study found significant pre-post changes in multiple health-related outcomes among older adults who participated in the Tri-Exercise program, including balance, flexibility, cardiovascular parameters, knee flexion, and quality of life; knee extension showed no measurable change. These findings suggest that the integration of traditional exercise modalities warrants further investigation as a comprehensive approach to enhancing physical function and reducing fall risk in older adults, though causal conclusions cannot be drawn from this single-group design.

The significant improvement in balance observed in this study is consistent with previous research on mind body exercises such as Tai Chi and Yoga, which have been shown to enhance postural stability and reduce fall risk in older adults (Chen et al., 2023; Chyu et al., 2010; Geiger et al., 2025; Li & Goldsmith, 2012; Patel et al., 2016). The large effect size observed for balance (Cohen's d = 2.03) underscores the magnitude of the

observed within-group change. This change may be related to the combined effects of controlled movements, proprioceptive training, and coordinated breathing patterns inherent in the integrated exercise regimen, though this cannot be confirmed without a control group.

Flexibility also improved significantly following the intervention, which is in agreement with prior studies demonstrating that stretching-based exercises can enhance musculoskeletal function and mobility in older adults (Birdee et al., 2009; Thanasilungkoon et al., 2023). The observed improvement may be explained by increased muscle elasticity and joint range of motion resulting from regular practice (De la Corte-Rodriguez et al., 2024; Micheo et al., 2012; Pfeifer et al., 2022).

The reductions in systolic and diastolic blood pressure, as well as resting heart rate, may reflect improved cardiovascular efficiency, though this cannot be attributed solely to the intervention without a control group. These findings are consistent with previous studies reporting that moderate-intensity physical activity can improve autonomic regulation and cardiovascular health in older adults (Cramer et al., 2018; Hagberg et al., 2000; Li & Goldsmith, 2012; Patel et al., 2016). Although the effect sizes for these parameters were moderate to large, the clinical relevance should be interpreted cautiously.

The improvements in knee flexion observed in this study may contribute to enhanced functional movement and reduced risk of falls, although knee extension showed no measurable change, likely because participants already had full extension range of motion at baseline. Increased flexion range of motion is essential for adults to perform daily activities safely and efficiently (Messier et al., 2000; Rejeski et al., 2002). This finding is consistent with studies that have reported improved joint mobility and reduced pain with regular practice of traditional exercises like Yoga and Tai Chi (Song et al., 2014).

The significant enhancement in health-related quality of life, as measured by the EQ-5D-5L, suggests that the changes observed alongside the Tri-Exercise program were not limited to physical health measures. Improvements across multiple dimensions are consistent with a positive association with both physical and psychological

well-being, though this study cannot confirm that the program caused these changes (Michalsen et al., 2005).

This study has several limitations. First, the quasi-experimental design without a control group limits the ability to establish causal relationships. Second, the relatively small sample size may reduce the generalizability of the findings. Third, the short duration of the intervention limits the assessment of long-term effects. All participants were female. Therefore, the findings may not be generalizable to older men. Future studies should consider randomized controlled designs with larger sample sizes and longer follow-up periods. Despite these limitations, the findings of this study provide preliminary evidence supporting the effectiveness of the Tri-Exercise program as a holistic intervention for improving physical fitness and quality of life among older adults.

Conclusions

In conclusion, significant pre-post improvements were observed in balance, flexibility, cardiovascular parameters, knee flexion, and health-related quality of life among older adults who participated in the Tri-Exercise program. These findings suggest that integrating traditional exercise modalities may serve as a practical approach to promoting physical function and reducing fall risk among older adults, and that the program warrants evaluation in a controlled trial. However, the findings should be interpreted with caution given the quasi-experimental design and limited sample size. Further studies, using adequately powered randomized controlled trials with larger populations and longer follow-up periods, are recommended to confirm the effectiveness and long-term benefits of this intervention.

From a theoretical perspective, these findings contribute to the growing body of evidence on multi-modal, mind body exercise interventions by demonstrating that combining three distinct traditional practices, comprising Thai Hermit Exercise, Yoga, and Dao De Xinxu, within a single structured program is feasible and is associated with measurable improvements across multiple physiological domains simultaneously, including balance, flexibility, cardiovascular indicators, and joint mobility. This pattern of broad, multi-domain change is consistent with the proposed synergistic mechanism underlying the Tri-Exercise program, in which complementary elements of stretching, postural control, and coordinated breathing act on overlapping physiological systems, and it extends prior single-modality research by suggesting integrated approaches (Bai et al., 2021).

From a practical standpoint, the Tri-Exercise program offers a low-cost, low-technology, and culturally familiar model that could be adopted by community health workers, elderly school instructors, and local public health units in Thailand with minimal additional resources. Because the constituent exercises are already recognized within Thai, Indian, and Chinese traditional practice, the program may face fewer barriers to acceptance and sustained participation than unfamiliar or equipment-dependent exercise regimens, which is a critical consideration for long term fall prevention initiatives in aging communities. Policymakers and community health planners may therefore consider Tri-Exercise, or similarly integrated traditional exercise models, as a scalable component of elderly wellness programs, particularly in settings where access to structured rehabilitation or clinical exercise services is limited.

Looking forward, several directions warrant attention. Randomized controlled trials with an appropriate comparison group are needed to determine whether the observed changes are attributable specifically to the Tri-Exercise program rather than to the non-specific effects of increased social engagement or physical activity in general. Future studies should also examine dose-response relationships (e.g., session frequency and duration), long-term adherence and maintenance of gains after program completion, and effects in more diverse populations, including male older adults and individuals with pre-existing musculoskeletal or cardiovascular conditions. Cost-effectiveness analyses comparing Tri-Exercise with conventional fall-prevention exercise programs would further strengthen the case for wider implementation (Olij et al., 2018). Taken together, this study provides preliminary but encouraging evidence that the integration of traditional exercise modalities can be both scientifically meaningful and practically feasible, offering a foundation for future controlled research and for community-level strategies to support healthy, independent aging in Thailand and other nations with comparable settings.

CRedit authorship contribution statement

Ronnachai Poowanna: Writing review & editing, Writing original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Charoen Seekhiew:** Writing - original draft, Methodology, Investigation, Data curation, Conceptualization. **Chinnaphat Chaloeamram:** Data curation, Writing review & editing. **Panicha Pongnaratorn:** Data curation, Writing review & editing. **Naruwat Pakdee:** Writing review & editing, Writing original draft, Visualization, Supervision.

Submission statement

This study is original and not under consideration elsewhere.

Ethical approval statement

The research protocols were approved by the Ethics Committee of the Institute for Human Research (Approval Code No.: 25/2566), Kamphaeng Phet Hospital, Thailand.

Conflicts of interest

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

Limitations

This study has several limitations that should be considered when interpreting the findings. The quasi-experimental, single-group design without a control group limits the ability to attribute the observed changes causally to the Tri-Exercise program rather than to other factors such as increased social contact, attention, or natural fluctuation over time. The relatively small sample size ($n = 31$) and the exclusively female composition of the sample further limit the statistical power and generalizability of the findings, particularly to older men and to populations with pre-existing cardiovascular or musculoskeletal conditions who were not represented in this study. The 12-week intervention period, while sufficient to detect short-term change, does not allow conclusions regarding the long-term maintenance of the observed benefits after the program ends. Finally, outcome assessors were not blinded to the pre-post design, which may introduce a degree of measurement bias.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Claude (Anthropic) in order to assist with formatting, the manuscript according to the journal's style requirements and improving the clarity of the English language. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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